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THE

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~~PAPERS AND PROCEEDINGS~~

OF THE

UNITED STATES

NAVAL INSTITUTE.

VOLUME I.

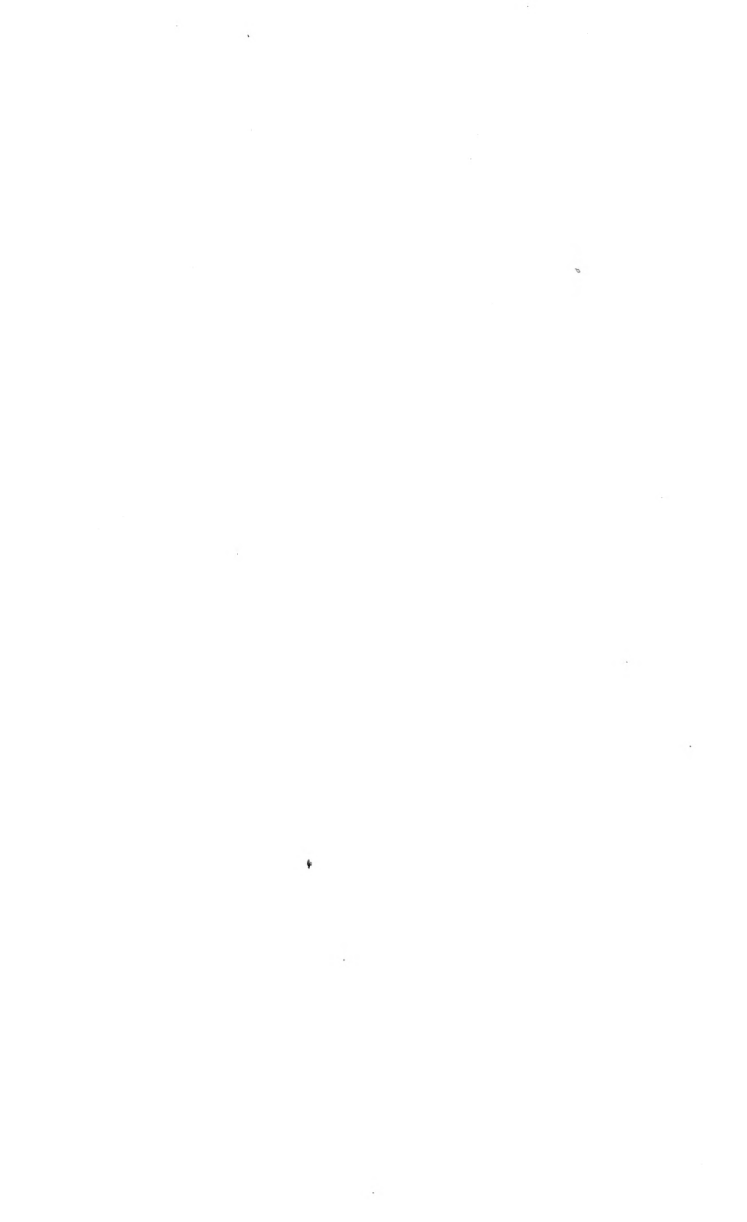
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# THE UNITED STATES NAVAL INSTITUTE.

*Organized October 9, 1873, at the U. S. Naval Academy.*

CONSTITUTION ADOPTED DECEMBER 11, 1873.

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# CONSTITUTION.



## TITLE

ARTICLE I.—This Society shall be known as “The United States Naval Institute.”

## OBJECT.

ART. II.—Its object shall be the advancement of professional and scientific knowledge in the Navy.

## ORGANIZATION AND OFFICERS.

ART. III.—1. The officers, and the permanent and temporary committees of the Society, shall include :

A Patron.

A President.

A Vice-President.

A Council of Regents.

An Executive Committee.

Special Committees.

A Secretary.

Corresponding Secretaries.

A Recorder and Treasurer.

2. The Honorable Secretary of the Navy shall be recognized *ex officio* as the Patron of the Society.

3. The Admiral of the Navy shall be *ex officio* its President.

4. The Commanding Officer of the Station at which the Society holds its regular meetings shall be *ex officio* its Vice-President.

5. A Council, with the Vice-Admiral as President, which shall include as *ex officio* members the Commandants of all Naval Shore Stations al

Chiefs of Bureaus, and the Commanding General of the Marine Corps, shall constitute the Council of Regents.

6. An Elective Committee of five, to be selected by ballot in session of the Society, and to hold office for one year, shall be chosen to act as an Executive Committee.

7. Special Committees may at any time be appointed by a majority vote of the Society, to consider questions not properly under the cognizance of the Executive Committee.

8. The position of Secretary shall be considered a permanent office.

9. There shall be a Corresponding Secretary in each Squadron, who shall be chosen to hold office for one year by the members of the Society on the Station.

10. One member of the Executive Committee will act as Recorder to the Committee and as Treasurer of the Society.

#### MEMBERSHIP.

ART. IV.—1. All Officers of the Navy, Marine Corps, and of the Academic Staff of the Naval Academy, shall be entitled to become members without ballot, on payment of the entrance fee.

2. Honorary members may be elected, by a two-thirds vote of the members present, at any regular meeting; and all persons eligible in the opinion of the Executive Committee to honorary membership may attend meetings of the Society on invitation of that Committee.

3. The annual assessment shall be \$5.00, payable on becoming a member, and on the first day of each succeeding January. Special assessments may be authorized by a two-thirds vote.

4. Membership shall only be forfeited in cases where the recommendation of a Committee, supported by a two-thirds vote of the Society, shall so determine.

#### NOMINATIONS AND ELECTIONS.

ART. V.—1. There shall be a meeting of the Society, on the second Thursday in January of each year, to choose the Elective Officers.

2. Members not in attendance may vote by proxy at such elections, as well as upon questions relating to the Constitution and By-Laws; but vote by proxy will only be allowed in the two cases herein specified. Honorary members will not be allowed to vote on any question.

3. A majority of votes recorded shall determine choice.

4. Members elected to the position of Officers of the Society will assume their duties as soon as notified.

5. Vacancies may be temporarily filled by the Executive Committee, but regular nominations and elections shall follow as soon as practicable.

6. All voting for Officers shall be by ballot in session of the Society.

7. The members of the Executive Committee shall be voted for collectively, and a majority of all the votes cast shall be necessary to a choice in each case.

8. The Recorder of the Executive Committee and Treasurer of the Society will be chosen from the Executive Committee.

#### DUTIES OF OFFICERS.

ART. VI.—1. The Society will at all times anticipate the same kindly interest from the Patron which is now received.

2. It sincerely trusts that the President, Vice-President, and Council of Regents will bring to its notice and lay before it all pertinent matters connected with the service, and that they will note the duties of the Society in connection therewith. It is also expected that they will suggest such changes in the organization of the Society as they may think beneficial; that they will suggest subjects for discussion, etc.

3. The President, or in his absence the Vice-President, or in the absence of both a member of the Executive Committee, will preside in Executive Session.

4. The transaction of all financial, executive, or administrative business, in which latter shall be included censorship of papers offered for presentation to the Society, shall be in the hands of the Executive Committee. The Committee will determine for itself its routine of business and form of record.

5. The Secretary shall attend to all correspondence with members on matters of routine. He shall keep a Register of the Members, a Copy of the Constitution and By-Laws, in which he shall note all changes, a Journal of the Proceedings, and a Letter-Book. These books shall at all times be in readiness for inspection. Papers offered by members unable to be present, if accepted by the Executive Committee, shall be read by the Secretary.

6. He shall give due notice of all meetings, and shall have control of the stenographer, copyists, etc., employed to prepare records of proceedings.

7. He shall keep a file-book, in which reports of Committees, etc., shall be entered.

8. Corresponding Secretaries shall keep the Institute, through its

Secretary, advised of all matters of interest, and shall attend to the collection and transmission to the Treasurer of the dues of members.

9. The Treasurer, under the direction of the Executive Committee, shall be the disbursing officer. He shall keep a receipt and expenditure book, and an account current with each member.

10. He will submit his books for examination whenever asked for.

11. The Society may, by a two-thirds vote of all members present, declare any office vacant for neglect or improper performance of duty.

### MEETINGS.

ART. VII.—1. There shall be a meeting of the Society on the second Thursday of each month for the discussion of professional and scientific subjects.

2. Special meetings may be called by the Secretary, at the request of one or more of the general officers, or of standing or special Councils or Committees.

3. A stenographer shall be employed to keep the record of all proceedings of regular meetings.

4. Whenever papers read before the Society, and the discussion growing out of them, shall accumulate in quantities sufficient to make one hundred octavo pages printed matter, they shall be prepared for issue in pamphlet form, and one copy of the same be sent by the Treasurer to each member and one to each *ex-officio* member.

Papers on intricate technical subjects may be published as a part of the proceedings of the Society without being publicly read, if, in the opinion of the Executive Committee, the subject to which they relate be not of a character to be appreciated on merely casual investigation.

### AMENDMENTS.

ART. VIII.—No addition or amendments to the Constitution and By-Laws shall be made without the assent of two-thirds the members voting. Notice of proposed changes or additions shall be given by the Secretary at least one month before action is taken upon them.

## BY-LAWS.

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ARTICLE I.—The rules of the United States House of Representatives shall, in so far as applicable, govern the parliamentary proceedings of the Society.

ART. II.—1. At both regular and stated meetings the routine of business shall be as follows :

2. At executive meetings the President, or in his absence the Vice-President, or in the absence of both a member of the Executive Committee, will call the meeting to order and occupy the chair during the session ; in the absence of these, the Society will appoint a chairman.

3. At meetings for presentation of papers and discussion, the Society will be called to order as above provided, and a chairman will be appointed by the presiding officer ; such chairman shall be chosen, when practicable; from the Council of Regents, reference being had to the subject about to be discussed, and an expert in the specialty to which it relates selected. In the absence of such Regent, suitable selection to act as chairman shall be made upon the same principle from the members present.

4. At regular meetings, after the presentation of the paper of the evening, or on the termination of the arguments made by members appointed to or voluntarily appearing to enter into formal discussion, the chairman will make such review of the paper as he may deem proper. Informal discussion will then be in order, each speaker being allowed not exceeding ten minutes in the aggregate, unless by special permission of the Society. The author of the paper will in conclusion be allowed such time in making a résumé of the discussion as he may deem necessary. The discussion ended, the Chairman will close the proceedings with such remarks as he may be pleased to offer.

5. At the close of the concluding remarks of the Chairman, the Society will go into Executive Session, as hereinbefore provided for the transaction of business, as follows :

1. Stated business, if there shall be any to be considered.
2. Unfinished business taken up.
3. Reports of officers or Committees.
4. Applications for membership reported.
5. Correspondence read.
6. Miscellaneous business transacted.
7. New business introduced.
8. Adjournment.



THE RECORD  
OF THE  
UNITED STATES NAVAL INSTITUTE.

Vol. I. 1874. No. 1

U. S. NAVAL ACADEMY, ANNAPOLIS,

NOVEMBER 13, 1873.

Commodore C. R. P. ROGERS, U. S. N., in the Chair.

THE MANNING OF OUR NAVY AND MERCANTILE  
MARINE.

BY CAPTAIN S. B. LUCE, U.S.N.

[In a few introductory remarks, Captain Luce said that as the generality of the naval officers read nearly the same kind of professional literature, much that he had to say might sound very familiar to those present. He disclaimed all intention to lay before them anything startling or original; on the contrary, he should go over well-beaten ground, and only call their particular attention to a subject so very common as seemingly to have escaped general observation.]

The breaking out of the Crimean War revealed two interesting facts till then not generally known: the splendid organization and discipline of the French navy, and the low state of the English seamen. Following promptly the opening of hostilities, the French squadron put to sea in the highest state of efficiency, and large bodies of troops and all the various munitions of war were transported to their destination with an alacrity and order which filled with dismay their ever-watchful neighbors across the Channel, while numbers of the finest line-of-battle ships of the English fleet swung

NOTE.—The first paper actually read before the Institute was one by Commodore Foxhall A. Parker, U.S.N., at its first meeting, on October 9, 1873. Rear-Admiral John L. Worden, U.S.N., in the Chair, "On the Battle of Lepanto," which, however, has been withdrawn by Commodore Parker, with the consent of the Executive Committee for publication in another form.

to their anchors in helpless inactivity waiting for men. The English, relying on their ancient prestige, had been content to continue customs which the advanced state of naval science had long before rendered ineffective; while the complete reorganization of the French navy, commenced by de Joinville and wisely continued by the late Emperor, brought the French fleet up to the state of perfection in which the war found it.

The lesson which a comparison of the two fleets forced upon England was humiliating to her pride—not, indeed, that she had any serious cause of apprehension, even had they not been allies; but there was a thoroughness and perfection about the French, extending even to the minor details, the majority of Englishmen were not prepared, and none were glad, to see. If the lesson was humiliating, however, it was wholesome. The question of the manning the navy was brought before the country in a manner not to be evaded; and the speeches delivered in Parliament at that day show with what anxiety the subject was regarded. The result was the appointment of a committee, which was instructed to examine into and report upon the whole subject of manning the navy. The investigation seems to have been very thorough, and the report was certainly elaborate. Among other recommendations, it was stated emphatically “*that the gradual organization of a permanent navy must principally depend upon a supply of trained boys*”; and that “at least five large vessels should be stationed at the different ports, forming, as it were, so many marine schools.” This part of the plan was adopted at once; five of the old line-of-battle ships were commissioned as training-ships, and the new system fully inaugurated. It was not long before the truth dawned upon the public mind that this kind of technical education for lads answered admirably well for the navy; the number of training-ships has been from time to time increased, and now, instead of five, they have twelve large training-ships and eight tenders (mostly sailing-brigs), besides four ships for gunnery practice, and nine ships and one tender for coast-guard drill for the naval reserve—making thirty-four vessels devoted to the purpose of naval training. This, I think, sufficiently accounts for the splendid body of native-born seamen which now mans the British fleet.

What answered so well for the national navy it was reasonably supposed would be advantageous to the commercial navy; so various marine societies and charitable institutions borrowed from the Government old men-of-war, which were converted into nautical schools—some for destitute boys picked up in the highways and byways of the large cities; some for reformatories; some for lads belonging to the “poor but honest” class, and who were destined to follow the sea for a living; and some for a

higher class, who were intended to be fitted as officers of the mercantile service—in all, thirteen vessels, making, with the naval training-ships, a grand total of forty-seven national ships employed for educational purposes, or about as many as we generally maintain in active service to perform the duty of the whole navy.

Further than this, it may be here stated that in the Canadian Dominion and Newfoundland it is estimated that there are about eighty-seven thousand seamen and fishermen, whom it is now proposed to drill in naval gunnery.

Mr. President and gentlemen of the Association, I beg you to think, for one moment, of having half only of this number of trained naval gunners, allowing the estimate to be excessive, at our very doors, and contrast with it the fact stated in one of the reports of Mr. Secretary Welles, during the war of the rebellion, and while we were straining every nerve to get seamen, that we had in the navy nearly nineteen thousand landsmen. On this statement alone we might rest our case.

In adopting the policy of raising her own seamen, England only followed what had long been the practice in France. That great minister, Colbert, instituted in his day a system which has withstood, with more or less variation, all the political vicissitudes of France for two hundred years; and it was only when his policy was neglected that the navy suffered. Thus, at the time of the Revolution, and under the first Napoleon, the navy had, through long neglect, gone down too far, in every way, to be readily raised to its proper standard. Various excuses were given for their losses at sea. The English ships, they said, had heavier scantling, and their very thick sides resisted the penetration of shot which the lightly-built ships of France could not withstand. But every reader of naval history knows that their losses were due to a want of proper training not only of their men, but their officers. Sir Charles Napier is quoted as saying: "It is a mistake to imagine that our successful actions were gained either by our having tougher ships or heavier artillery." "We were generally opposed to larger ships and heavier metal." "It was our experience at sea," he continues, "our rapid fire, and the superiority of our aim, that gave us victory." This opinion is further confirmed by a German writer, who, in an impartial review of the history of the English and French navies, notes with emphasis the smaller number of casualties in the English navy as compared with that of France. "This contrast, so favorable to England," he remarks, "has been constantly maintained, and can only be attributable to her superior artillery. Her seamen not only aimed with greater precision and fired more steadily than those of the French,

but they had the reputation of loading with far greater rapidity. It was remarked in 1805 that the English could fire a round with ball every minute, whereas it took the French gunners three minutes to perform the same operation." It is with pardonable pride that we may here pause for a moment to note that if the English gunnery at that day was good, the gunnery of our infant navy was even better. As the French had said before, so the English, in their turn, repeated, "What heavy scantling!" and so we answered, "It was not the tough sides, but the good gunnery that gave us the victory." And the same will prove true to-day. Victory will ever be with the best gunnery, let the sides be never so tough. In that day, however, both our navies were recruited much in the same way; but whereas England has completely remodelled her ancient system by bringing it up to the requirements of modern times, we have steadfastly adhered to the practice which prevailed in the early part of the century.

The French navy had been gradually deteriorating till the early part of the reign of Louis Philippe, when, owing to certain troubles in the East, Admiral Lelande was placed in command of a small squadron and despatched to the Levant. From that time the French navy took its rise, and culminated under the late Empire. In one of the most charming works in all naval literature, the Prince de Joinville tells us the whole story. It was in the school of the French Mediterranean squadron, indeed, that the Prince studied and graduated, and where he imbibed those just ideas of naval administration which enabled him subsequently, as Admiral of France, to adopt those measures by which the French navy attained its excellence. Admiral Lelande, on being called to a seat in the Chamber of Deputies, was succeeded in the command of the squadron by Vice-Admiral Baron Hugon, who "exercised" the squadron of evolutions till 1842. I beg leave to call particular attention, by way of parenthesis, to the language of the historian. It is that Hugon *exercised* the squadron of evolutions: "*Il est remplacé dans son commandement par le Vice-amiral Baron Hugon, qui exerce cette escadre dans le Méditerranée jusqu'en 1842.*" That squadron was in truth—and the fact is worthy of our careful consideration—the real naval school of France, and is so to this day; just as the English Channel squadron is the real naval school of England, a species of school—and here is another fact for consideration—which this country has never known.

De Joinville, then, having graduated in that naval school commonly known as the French Squadron of Evolutions, was eminently qualified for the task of reorganizing the French navy. He succeeded, it is said of

him, in doing what no one else had been able to do—he rendered the navy popular. On all naval subjects his words are the words of wisdom. Hear him: “The question of fitting out a fleet is not a mere question of finance. Money can always be raised by the state, and money will produce any number of craft; but money will not make sailors; gold will not make a disciplined crew nor an experienced staff of officers; and of what use are ships without the living soul to command and the ready hands to obey? To collect, form, and train these should be the first solicitude of a great maritime power, as it is the most important part of its tasks. Every other requirement will then follow as a matter of course.” In 1833 the corps of *matelots-canonniers* (seamen-gunners) was established, and at the same time a number of improvements adopted; but, owing to certain defects in the system, it was found that trained men did not remain in the service. Various modifications were adopted, till the reign of the late Emperor. “Among the first great efforts,” we are told, “visible at the commencement of his reign was a determination to augment the number of ships to an extent never previously thought of, and at the same time to enhance the efficiency of the seamen. Under the new regulation, it was stipulated that every sailor must enter the service for a period of ten years, and that, with the practical knowledge inculcated on board the training-ship, there should be combined a course of theoretical instruction on shore, stimulated by periodical examinations. The French marine-artillerist may, therefore, be held to be well grounded in at least the rudimentary principles of the science of projectiles. In this way, a body of five hundred picked gunners is annually turned out.” These fill the positions of gun-captains and the several grades of petty-officers throughout the fleet. England had already adopted this plan of training her men to gunnery. The name of the old gunnery-ship, the *Excellent*, has long been familiar to us. Here was a special training-course established for the instruction of gun-captains and the higher grades of petty-officers; and from the best of the latter were selected the warrant-officers. It was from the English, probably, that the French took the idea of the seaman-gunner, and fully adopted her practice, possibly improving on it, and the English, in their turn, adopted from the French the “*École des mousses*.” The dates here given, and the precise order of precedence may not be absolutely correct, but quite near enough to show how England and France have, through long years, been struggling to excel each other in naval power, first one outstripping the other in some particular, then the other. Their rivalry keeps both navies on the very crest of the wave of progress.

Let us turn from this rapid glance over the modern history of the two

navies we are (after our own) most familiar with, and ask what we have been doing for our sailors since 1812. If, in the language of de Joinville, it be any part of our duty to "collect and train seamen" for the organization of a permanent navy, is it too much to say that that duty has been sadly neglected? It is not to be denied that for the navy in general we have done much within the past few years. In looking back, it seems of comparatively recent date that what were called our new steam-frigates were deemed models of modern naval architecture; our guns ranked highest in naval ordnance; the educational facilities afforded our young naval officers, it is quite safe to say, are not equalled in any country in the world; and the problem which the European navies failed to solve—the devising of a new system of naval tactics which should meet the requirements of a modern fleet—has been solved in our navy with an ease and a completeness; and is in itself, withal, so happily conceived, and so simple, as to command our admiration for the work and its author alike. And yet, with these legitimate causes of gratulation, we have been for years persistently neglecting one of the most important elements of an efficient navy. Engaged in a naval war, by whom are our fine ships to be manned? The model naval officer, with his high culture and careful training—whom is he to lead in the day of battle? And after all the patient study of the arts and sciences, and the racking of brains, and exhausting the inventive faculties of the country, that we may have the very best gun, mounted on the most perfect carriage, and loaded with the most effective powder and most destructive shell, who is to reap the rich harvest, and in one supreme moment utilize these rare contributions of brains, time, and money? Is it not the one who points the gun and pulls the lock-string? And does it seem wise to go to so much trouble and expense to prepare a great engine of war and not at the same time to prepare for its being properly used? Does it seem the part of wisdom to neglect one member of a body, the want of which may neutralize the perfection of the remainder? *Does it not seem rather the reverse of wisdom?* Nor do we need the marine-artillerist merely—the Italians have those. Many of us may be able to bear witness to the thoroughness of their great-gun drill; but "*Il ne sont pas gabiers,*" the captain of the *Ré Galantuomo* said, when asked if his men exercised aloft. They were not topmen, indeed, nor sailors in any sense; and with such crews it would be safe to prophesy a repetition of the disaster of Lissa. We need for our ships the thorough seaman, with his characteristic devotion to the flag of his country, his contempt of danger, his love of adventure, combined with the carefully-trained naval gunner. And, the prejudices of

many of our officers to the contrary, we may look to our seamen of the future for yet higher qualities, but such as are sure to come by that very course of education which is to give us the best type of a modern man-of-warman.

"Education," it has been observed, "has reference to the whole man, the body, the mind, and the heart; its object, and, when rightly conducted, its effect, is to make him a complete creature after his kind. To his frame it gives vigor, activity, and beauty; to his senses, correctness and acuteness; to his intellect, power and thoughtfulness; to his heart, *virtue*. If you would mark the perfect man, you must not look for him in the circus, the university, or the church exclusively, but you must look for one who has '*mens sana in corpore sano*'—a healthful mind in a healthful body. To make all men such is the object of education." \*

Is any one prepared to say that these principles apply to one kind of education merely and not to another; that they apply to the university and not to the public-school; to the sons of affluence and not to the children of toil; that the sailor may not be educated to be a "complete creature after his kind"? The proposition is not to be entertained. But the views in regard to the particular methods of education have been considerably modified within the past twenty years. In 1851 took place in the city of London the great exhibition, where, in the Crystal Palace, 100,000 persons were assembled to witness the competitive industries of the civilized world; then and there it was demonstrated to that immense throng that England, in the profusion of the raw material, in the native genius of her artisans, and in the mechanical power which she exhibited, possessed a superiority which made competition with her, at that exhibition, by the other powers of Europe, hopeless.

"But it taught another lesson: that what was wanting by others either in the raw material or in bone and muscle might be more than supplied by *educated skill*, and that technical education, if inaugurated for these industries upon a liberal plan, and steadily pursued, would give to France, Germany, and Switzerland a power which would more than compensate for natural disadvantages. These countries were not slow in establishing such schools, reaching from technical training for lads and apprentices, in the various branches of industry, by a well-graded system, up to a polytechnic university; and no expense was spared to give to these institutions all the appliances which could provide educated skill to labor and industry.

"The next exhibition was held in Paris in 1855. A marked change

was already observable in the competitive industries of Germany and France, as compared with England. The result of this exhibition increased the zeal for technical education in those countries. They were assured by these early results that they were, indeed, upon the right track; for the successful examples in machinery and iron manufacture in which England had hitherto possessed an hereditary pre-eminence demonstrated that educated skill might successfully compete with genius and other natural advantages.

“When the next exhibition was held in London in 1862, England was left far in the rear by the skilled labor of the Continent: and mortification to the national pride was felt throughout the realm. Germany, France, and Switzerland bore away the palms in those departments of mechanical skill in which hitherto England had been without a peer. This mortification was further intensified at the last exhibition in 1867; and English artisans and English manufacturers demanded an enquiry into the causes which led to this great discomfiture, and into the ways and means of rectifying it.

“It was found that in every metropolis, large town, or centre of industry in France, Germany, or Switzerland, schools for educating professional men and masters, for training foremen and skilled workmen, and for teaching apprentices, had been established, and that these technical schools had caused the rapid supremacy of continental over British industry. The testimony of such scientific gentlemen as Professors Tyndall and Franckland was that what England needed was a better provision for industrial education; a higher scientific education for those likely to be master-manufacturers, so that when discoveries are made they may be rendered available by the skilled intelligence of those who command capital, and can at the same time appreciate the merits of such discoveries.”

An English chair-maker, who went to the last Paris exhibition as one of a committee of eighty-six representative skilled English workmen, to look into the teaching of this great exhibition, thus expresses his opinion: “Seeing some lads at work with the men in the carvers’ shop, I went to the bench of one about fourteen. He was carving a chair-back of a mediæval form from a working drawing. I expressed my surprise that one so young should have been found capable of carving so well, and was informed that boys at school are specially prepared for the trades they fancy, so that a boy about to be apprenticed to learn carving is instructed in ornamental drawing, modelling, and designing.” He adds, as the result of his observation, that the “mere mechanical workman stands



not the slightest chance with the workman of cultivated taste." Like opinions were expressed by each of the eighty-six committee-men representing the intelligent but self-educated workmen of England, in each department of industry; and they were all profoundly impressed with the conviction that the English nation was in great peril in regard to manufacturing pre-eminence.\*

Now if this technical education is found necessary for chair-makers, and similar trades on shore, how much more essential is it for the difficult trade of mariner; and when we add to the trade of mariner that of a skilful marine-artillerist, our deduction must be similar to that of the "self-educated eighty-six": *Our uneducated seamen will stand no chance against the trained gunners of England and France.*

The enlightened views which, in Europe, recognized the necessity of technical education, soon made their way to this country and found expression in the act of Congress of July 2, 1862, commonly known as the agricultural-college bill. By the provisions of this act a munificent grant of public land was authorized for the "endowment, support, and maintenance of at least one college in each State claiming the benefit of the act, where the leading object shall be, to teach such branches of learning as are related to agriculture and the mechanic arts, . . . without excluding other scientific and classical studies, and including military tactics" (a clause I shall take occasion to refer to presently), "in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life."

This act has given an impulse to technical education in this country which has already been productive of much good. Following it up we find that last year the ancient commonwealth of Massachusetts passed an act to authorize its cities and towns to establish industrial schools, the language of the act being, "The city council of any city may establish and maintain one or more industrial schools, . . . and the school-board shall employ teachers, prescribe the arts, trades, and occupations to be taught in such schools," etc. Thus we see two important acts making ample provision for technical education, and I ask if the trade of mariner is to be totally excluded from the one, the science of navigation from the other? In the name of our seamen I for one solemnly protest. But, fortunately for the cause of the sailor, the great State of New York has not left the matter in doubt. With her vast

\* *Gymnastic and Technical Education.* By Francis H. Smith, A. M., Lexington, Va. 1871.

commercial interests she saw the necessity of the times, and, by an act passed last year, made special provision for a nautical school.\*

Thus, as we have seen, England learned through her Crystal Palace that she must do for her trades-people on shore what she had already been doing for her seamen, while we have learned that what has been done for our industrial classes and the army must be done for our seamen and the navy. We need not look to the example of foreign navies, then, to learn how to legislate for our seamen; the very spirit of the age cries out to educate them.

In 1837 an act was passed authorizing the enlistment of boys from fourteen to seventeen years of age to serve in the navy until twenty-one, and soon after we had as many as two thousand apprentice boys. The effort proved a failure and died out, to be renewed once more in 1863, only to fail again. There were good reasons, needless now to enumerate, for both failures; but this want of success in no way disturbs the principle lying at the bottom. The very best of schemes, as we know, may be rendered abortive by the introduction of a very slight disintegrating element.

Besides the attempt with the *Sabine*, the last few years have seen the introduction of the "continuous-service certificate," which carries with it certain advantages, the honorable discharge and the good-conduct medal; all established with a view to encouraging men to remain in the naval service. But if any one will take the trouble to examine the class of men to whom these inducements are held out, it will seem an open question whether or not they are worth such inducements. Statistics show that our national ships are only partially manned by American seamen. If it was indignantly declared in Congress to be a disgrace to the country to have our ships flying a national flag made of foreign bunting, what will be said of the fact that the greater part of the men who man our naval guns are foreigners? It must be admitted, too, that many of those claiming to be, and who perhaps are, Americans, are utterly useless for any good purpose on board ship. It is a positive misfortune to us that many of these men *are* induced to remain in the service; indeed, it would be quite advantageous to offer inducements to some to remain on shore. And yet I will yield to no one in my high appreciation of a true American seaman. When found, as he still may be, in our service, though in a deplorably small minority, he is one to be proud of and to respect; prompt and fearless, fertile in resources.

\* Since this was written, the New York Nautical School has been opened on board the schooner-ship *St. Mary's*, and is now—January, 1875—in successful operation.

patient, even cheerful under adversity, of wonderful endurance, intelligent, and self-reliant, and withal of unflinching, uncompromising fidelity to his flag. Take him all in all, I maintain that your "true Yankee sailor" has not his equal in the world. May I ask your indulgence, Mr. President, if I here trespass upon your patience so far as to pay a passing tribute to the sailor of my early days? I speak of the higher type. It is with unfeigned pleasure that I recall the recollection of many worthy representatives of the class, and some I love to remember as my tutors. I recall them with their bronzed faces, their kind hearts beaming through their eyes, with a degree of feeling bordering on affection. The early lessons learned of them I think the most indelible impressions on my mind, and whatever fondness I had for the sea I trace to the quaint yarns of adventure, not unmingled with goodly precepts, which fell from their honest lips. They owned their full share of human weakness, if you will, but it is not mine to cast the first stone. I respected them then; I honor their memory now.

It is related on good authority that when the *Constitution* returned from Holland, after transporting the specie required to pay the last instalment of our national debt to that country, in 1812, the term of service of her crew had expired, and a few days after arrival were discharged. Commodore Hull immediately manned his ship by drawing on the fishermen of the New England coast, and the merchant-seamen of Salem, Newburyport, Boston, and vicinity. The response was prompt, and it is alleged that when the *Constitution* soon after captured the *Guerrière*, of her 450 seamen only 60 had ever served on board of a man-of-war. To such a proud record can the native American seaman point. But is he alone of all the world to rest idly on his laurels, while his brethren on shore and his old antagonist on the ocean advance on the full tide of progress? Shall we not all solemnly, earnestly, loudly protest?

If, then, the native American seaman is a valuable person, and if, as we all admit, the class is rapidly disappearing, is it not our plain duty to set ourselves earnestly to work to rear them? So obvious, indeed, is it, as to remind one of those self-evident propositions which, while difficult from their very simplicity to demonstrate, seem, in the attempt to do so, like an imputation on the understanding.

To establish a school of seamen for the navy alone, however, would be as unwise as illiberal and short-sighted. Any scheme for the benefit of our seamen must include all, both those of the national and those of the commercial marine.

The settled, well-established policy of our Government is to maintain but a comparatively small standing army and a small navy, relying upon the patriotism of our people to swell either indefinitely as may be needed; but such reserves must in some way be specially provided for. This has already been done for the army most effectually. The agricultural-college bill, already referred to, provides for the maintenance of colleges where instruction in military tactics is made obligatory; and another statute, the act of July 23, 1866, fixing our military peace-establishment, provides the means, by authorizing the detailing of army officers for duty, at any regularly established college, as instructors, as the act specially declares, for the purpose of "promoting a knowledge of military science among the young men of the United States," by these two means creating a body of trained men, ready to spring to arms at the first tap of the drum. It is plainly to be seen that while the military element of the country is well represented in our legislative halls, not a single representative voice is heard in behalf of the navy.

I am not prepared to say that this is to be deplored; but we, too, must have a reserve, and as it has not been given to us we must ask for it. Whence, then, is that reserve to come if not from our mercantile marine?

We have been discussing seamen in general, alluding more particularly at times to *naval* seamen. Let us contemplate for a moment the entire body on which we propose to draw in the event of a sudden expansion of the navy—an expansion, gentlemen, that may be called for now any day.

If we go back to our early history, we will find in the stirring pages of the *Federalist* much that will indicate the cast of thought in that day, and serve for our instruction now. In that dark hour which preceded the dawn of the young Republic, the luminous minds of Hamilton, Madison, and Jay seemed, like the scintillations of the aurora, to lighten up the gloom. The vigorous pen of Hamilton lined out with wonderful boldness and truth the rapid growth and development of our country. His prophetic eye, piercing into dim futurity, saw the thousand tributaries of a vast commerce pouring its streams of richness into the bosom of one common country, invigorating the uncertain growth of trade, and giving wealth and power to the nation. He warned the country that it was only by a union of all the States that the people of America could hope to defeat the machinations of those foreign countries who would appropriate to themselves our ocean-trade. Hear his words ring down to us through the long avenues of time, as true now as then, and as they

ever will be whenever our highest interests as a nation are threatened. "There are appearances," he observes, "to authorize a supposition that the adventurous spirit which distinguishes the commercial character of America has already excited uneasy sensations in several maritime powers of Europe. They seem to be apprehensive of our too great interference in that carrying-trade, which is the support of their navigation and the foundation of their naval strength. They foresee the dangers that may threaten their American dominions from the neighborhood of states which have all the dispositions and would possess all the means requisite to the creation of a powerful marine. Impressions of this kind will naturally indicate the policy of fostering divisions among us, and depriving us, as far as possible, of an active commerce in our own bottoms. In a state of disunion," he argues, "the combinations of foreign maritime nations might exist and operate with success. It would be in their power to embarrass our navigation in such a manner as to effectually destroy it, and confine us to a passive commerce. We should thus be compelled to content ourselves with the first price of our commodities, and to see the profits of our trade snatched from us to enrich our enemies and persecutors. That unequalled spirit of enterprise which signalizes the genius of the American merchant and navigator, and which is in itself an inexhaustible mine of national wealth, would be stifled and lost." Alas! that it should be said, what Hamilton was apprehensive our enemies and rivals would do in the event of disunion, we have, as a united and powerful nation, accomplished ourselves. We have, indeed, "clipped the wings" of our own commerce, and our carrying-trade has been passing into foreign bottoms. In a wide sense, gentlemen, our patriotism, and in a more especial way our professional instincts, alike forbid our regarding this subject with indifference; indeed, our peculiar relations to the mercantile marine render us particularly sensitive to any change affecting it. Hamilton himself, in discussing the prospects of our commerce, observed that "the necessity of naval protection to external or maritime commerce, and the conduciveness of that species of commerce to the prosperity of a navy, are points too manifest to require a particular elucidation; they, by a kind of reaction mutually beneficial, promote each other."

But in trade and commerce, and in human affairs generally, there is an eternal law of compensation which, like the tides of the ocean, tend to preserve the general level. The rise in the price of coal and labor in England, together with the immense production of iron in this country, and the gradual, but sure, appreciation of our national currency, with the consequent fall in prices, all tend to an equalization of trade between the

two countries. It is already estimated that at least one hundred thousand tons of shipping of various kinds have been put up, or are going up, in this country during the present year. If the wings of our commerce were clipped, either through our own fault or from causes beyond our control, they are certainly growing again; and our tonnage, which in 1860 nearly equalled that of England, it is safe to predict will, at no very distant day, surpass it. With the revival of our shipping interests, then, is the auspicious time for turning our attention to the *personnel* of our merchant-marine. Let us turn once more to our great commercial rival, and see what she is doing in this respect. In her various ports are stationed, as already mentioned, thirteen vessels of war loaned to various societies for the sole purposes of nautical education for the benefit of her merchant-service. Of these I shall call particular attention to but two: The *Conway* frigate, under the control of the Mercantile Marine Association of Liverpool, and the *Worcester* frigate, known as the Thames Marine Officers' Training-ship. These are of a higher order of nautical school than the others, and are intended for the education of those desiring to become officers of the merchant-service. While the others are free schools, the charges for tuition in these are forty pounds a year, and the course of instruction, which includes French, trigonometry, nautical astronomy, etc., is such as to qualify the graduate of highest standing for admission into the Royal Navy. The two associations include among their members some of the most distinguished noblemen, naval officers, and commoners of the realm. At the annual examinations it is a representative of royalty itself, a first lord of the admiralty or other high dignitary, who distributes the prizes; while noted admirals, members of Parliament, and merchant-princes attend. Need it be added that amid the brilliant assemblage the presence of woman, like the "sweet influences of Pleiades," lends a charm and beauty to the scene? The character of the company attending these examinations, and the nature of the prizes, sufficiently attest the paramount importance attached to these schools. The highest prize given on these occasions is "her Majesty's gold medal." And for what is it awarded? Not for scholarship, not for the attainments which generally win preferment at schools; but it is assigned to the boy who gives promise of making the finest sailor. Could anything be more significant of the objects and aims of these schools, and the high value set upon them by the country?

It may not be uninteresting to hear the order establishing this reward of merit: "Her Majesty's wish, in the establishment of this prize, is to encourage the boys to acquire and maintain the qualities which will make

the finest sailor. These consist" (and mark how the precepts of Fox find an echo in the words) "of cheerful submission to superiors, self-respect and independence of character, kindness and protection to the weak, readiness to forgive offence, desire to conciliate the differences of others, and, above all, fearless devotion to duty, and unflinching truthfulness." Her Majesty's second prize consists of a binocular glass and thirty-five pounds (the latter to provide an outfit), and is given to the boy who passes highest in the competitive examination, provided he passes his examination at Portsmouth in the examination immediately succeeding such competition, "the desire of her Majesty being to facilitate the entry into the Royal Navy of the boy who is fortunate enough, in honorable competition, to obtain this cadetship." Such are the two principal schools of the British mercantile marine. And, as if this were not enough, we find in a recent number of the *United Service Journal* Mr. Brassy, M.P.—in whom is the rare combination of the statesman, legislator, and sailor—using the following language: "I would urge the endeavor to raise the status of the officers of the mercantile marine as an object of high administrative policy, and essentially philanthropic in its tendency." In sad and painful contrast to these schools stands alone the New York reformatory school-ship *Mercury*, established and maintained by the Commissioners of Public Charities of New York, and scarcely known outside the port.\* If we look for the cause of this wide difference, it will be found in some degree in the difference of our navigation laws: England puts a high premium upon professional ability; we do not.

I do not know if on an occasion of this kind it be permissible to regard the subject under consideration from a moral and religious point, and yet, being all followers of one whom we love to call our Divine Master, and discussing a question affecting so large a portion of our fellow-countrymen, and so deserving of our sympathies, should it not rather have been the first and most prominent point from which to regard it? Our newspapers are constantly telling of the brutality and outrages perpetrated on board our merchant-vessels. At one time American merchant-ships in the London docks were getting the highest rates of freight to the prejudice of English ships, a fact which elicited so much attention as to result in a parliamentary investigation. The evidence brought out was highly creditable to American ships and American seamen. But now, not only have we lost that pre-eminence, but we are fast losing our good name. Those engaged in our foreign commerce are

\* The *St. Mary's* and *Jamstown* school-ships have been opened since this paper was written.

to a certain extent our representatives abroad, bearing witness to far-off peoples to the genius of the country; but the American seaman is becoming a dissolute and depraved being. Mariners have been compared to missionaries sowing on pagan shores the goodly and fruitful seeds of civilization and Christianity. But the very name of sailor seems to have become a synonym for drunkenness and sin, and the thoughtful heathen despises a religion which tolerates such vice.

Regarding the subject, then, in what light soever we may, the aspect is the same. A large and indispensable class of our fellow-countrymen is suffered to fall into degradation and decay from sheer, heartless, and unwise neglect.

Mr. President, if the positions I have assumed are made clear, and are deemed tenable—and I frankly submit them to your judgment—then it is our plain duty as naval officers to examine for ourselves into the needs of our seamen, and, agreeing upon some sound and comprehensive scheme for the amelioration of their condition, to strive by all the means in our power for its adoption.

We are not without a bright example for our guidance. "It is worthy of remark," says Cooper, in giving the history of our early navy, "that Congress did nothing of any moment for the navy during the year 1812, although war was declared in June." He then proceeds to account for this neglect, adding, "And it literally became necessary for the accomplished officers who composed the germ of the service to demonstrate, from fact to fact, their ability to maintain the honor of the country, before that country would frankly confide to them the means. As we proceed," he adds, "this singular historical truth will become more apparent." Those gallant officers saw clearly that their first duty was to insist upon being supplied with the means; and when, owing to their earnest solicitations, the means were furnished, right bravely did they use them.

Mr. President and gentlemen of the association, you who so well represent the talent and industry and courage of the service, I put the question fairly and squarely to you, Shall we wait for the declaration of war to drive us to exertion, or shall we unite at once to discharge the duty which so long has stared us in the face? And who here can say how soon will rise the cloud of war already hanging darkly on the horizon? Up to a certain period negotiations with Russia suddenly terminated in the Crimean War, finding England unprepared. The Franco-German war, long foretold by the few, yet at last burst upon the masses of Europe like a thunderbolt, and, "pitiless disaster following fast."



pursued the demoralized and unprepared French till the bubble of the Empire burst, leaving scarce a trace behind. And what is our situation at this very moment? Cuba, "endowed," as once said of Italy, "with the fatal gift of beauty"; Cuba, the Rose of the Antilles, with her thorn ever pressing in our side; Cuba—to change the figure—lies bleeding at our doors, a prey to contention, and rent by "fierce civil strife." Are we to depend upon the disorganized state of Spain for immunity from war? Suppose for a moment her Government should desire a foreign war as a means of uniting her people and consolidating the supreme authority? Are we, for peace, to rely upon the happy accident of a local governor stumbling, with his snap judgment, in the right? Suppose he has already blundered in the wrong! But speculation is idle, and would lead us from the main purpose—the plain duty which lies before us.

Mr. President, I have finished. I esteem it a very high compliment, indeed, to have been invited to appear before you to-night. If by means of this association our officers are induced to consider carefully the various questions affecting our profession, and to give the service at large the benefit of their reflections, the navy will owe you a deep debt of gratitude.

We have many reasons to felicitate ourselves upon the real improvements which have been achieved in the navy during the last quarter of a century. But let us, when speaking of the navy, use with caution that word "progress," which so frequently falls from the lips of our public speakers. Mere change, as has often been observed, is not necessarily progress. As the heavenly bodies have to our eyes an apparent motion not really their own, so, in the grand march of time we may move and still make no real advance. Let us then look to the root of the whole matter, and seeking the true interests of our profession, and putting aside all petty jealousies and selfish ends, work with honest hearts for the general good.

At the conclusion of the address the President thanked the speaker, etc.

Commander BREESE. Have you any definite plan to propose for the improvement of our seamen?

Captain LUCE. The first thing for us to do is to get Congress to give us an allowance of at least one thousand boys over and above our present complement of seamen; the act, in granting them, to specify that they are to be trained for the purpose of being seamen and petty-officers in the navy; and at least three vessels should be commissioned in our

principal ports, for the purpose of carrying out the provisions of the act.

With regard to the mercantile marine, the speaker submitted for the consideration of the meeting the subjoined synopsis of a bill which he said should be presented to the next Congress, and its favorable consideration urged by all honorable means. After briefly explaining the objects of the several clauses, the meeting adjourned.

*Analysis of the bill to promote the efficiency of masters and mates in the merchant service, and to encourage the establishment of public marine schools, amendatory to an act entitled "An act to provide for the better security of life on board of vessels propelled in whole or in part by steam, and for other purposes," approved February 28, 1871.*

The increasing number of marine disasters; the demoralization, becoming so general on board our merchant-vessels; and the growing scarcity of American seamen, all indicate that we can no longer disregard with impunity the examples of other maritime countries, in providing technical education for those employed in the mercantile service.

Technical instruction, which has taken such deep root in the educational systems of Europe, is fully recognized in this country as one of the necessities of the times. It is simply asked now that the science of navigation may have a chair in our institutes of technology, and the trade of mariner find a place in our industrial schools.

Efforts in this direction have been made at various times for the past forty years; but, for the want of stimulating and sustaining laws, have, up to the present time, invariably failed. The revival of our shipping interests, now happily begun, is believed to be a favorable time for the introduction of a general system of nautical education, which, if properly encouraged, must prove one of the most important measures affecting our marine commerce which has been adopted since the foundation of the Government.

The legislatures of New York and Massachusetts have already passed acts by which marine-schools are, or may be, engrafted upon their respective common-school systems; but, as the successful maintenance of these schools must materially benefit the country at large, and as we should be guided by the light of past experience, the assistance of the National Legislature is now invoked.

The act of the Legislature of New York authorizes the Board of Edu-

cation of the city of New York "to provide and maintain a nautical school for the education and training of pupils in the science and practice of navigation," etc.

The act of Massachusetts provides that the city council of any city may establish and maintain one or more industrial schools, the school board being authorized "to employ teachers, and to prescribe the arts, trades, and occupations to be taught," etc.

It is believed, however, that it would be unadvisable to open nautical schools in the absence of a positive and active demand for the kind of education they are alone intended to supply. The object sought in the proposed bill, therefore, is to create that demand by establishing, by legislative enactment, a fixed standard of professional attainment on the part of the masters and mates of our merchant-service, and by requiring our merchant-vessels to take, as a part of their crews, duly qualified sailor-boys in numbers proportioned to their tonnage.

Aside from the high considerations cited, and from a purely mercantile as well as from a humane point of view, the public has a right to ask that this important safeguard be thrown around the lives and property of all those who derive their pleasure or profit from the sea.

The influence of our marine insurance companies, and of others pecuniarily interested, has already secured, under the act to "provide for the better security of the lives of passengers on board of vessels propelled in whole or in part by steam," many wise precautions against disaster on board steamers. Thus, the act provides for an inspector of hulls, whose duty it is to examine carefully the hulls and appurtenances of steam-vessels; an inspector of boilers, who inspects everything in his department. Among many other things, the inspectors certify to the presence on board the inspected ship of due provision against fire. She must have hose, boats, life-preservers, and other things in conformity with law, and a certificate to this effect is signed by the inspectors under oath. The captain, mate, and engineer must each appear before the board of inspectors, who "shall examine the applicant," and if, upon full consideration, they are satisfied that his character, habits of life, knowledge, and experience in his duties qualify him for the position, they grant him a certificate to that effect for one year.

Should a pilot desire a license, he presents himself before the board, and, on furnishing satisfactory evidence of character, ability, etc., obtains a license for one year; but there is no Government inspector of the master and officers of the sailing-ship. If called upon, they can produce no legal evidence of their worth, so that, for all the public know to the con-

rary, he who commands the staunch and well-found ship may himself be totally unfit for his position.

The bill under consideration is designed to supply this omission, as well as to give an impetus to all kinds of nautical education, whether on board school-ships in our principal harbors for lads just entering, or navigation-schools on shore for those who have already been to sea.

To command an ocean-steamer properly, one must first be a sailor, and a sailor can be made only on board a sailing-ship.

Section 1 of the bill provides for "certificates of competency," and for the examination of masters and mates, and prescribes the manner in which the board of examiners shall be appointed. The members of the board are selected in a manner to guard as much as possible from undue influences, the several bodies nominating them being directly interested that the conduct of the examination be impartial and thorough.

Sections 2, 3, 4, 5, 6, 7, 8, 9, 10, prescribe the rules under which the certificate of competency is to be granted, as well as for its suspension, cancellation, etc.

Section 11 provides for certificates of service, to be granted to those masters who have already been to sea in command of sailing-ships, who bear a good reputation as seamen and navigators, and enjoy the confidence of their owners. Such masters will not be required to undergo an examination.

Section 12 authorizes the Navy Department to lend such ships of war as are of no further use to the navy as cruisers, to be used as school-ships. These vessels are by far the best, cheapest, and in every way the most suitable for the purpose that can be procured.\*

Section 13 authorizes the employment of naval officers as superintendents of, and instructors in, nautical schools. Naval officers, by their early education and subsequent training in actual service, are the best class from which to draw instructors for nautical schools of all kinds.\*

The 23d section of the act approved July 28, 1866, authorizes the President to detail officers of the army to act as instructors in military science at any regularly-established college, "for the purpose of promoting a knowledge of military science among the young men of the United States," thus, in effect, creating a vast reserve from which to fill out our skeleton regiments in time of necessity, and, if need be, to expand our army indefinitely.

The section under consideration is framed with a view to giving the

\* These two sections have been embodied in the act of June 20, 1874, "establishing public marine schools."

navy an equivalent advantage—that is to say, by educating the *personnel* of our mercantile marine, and adding a *quasi*-naval training, we not only greatly elevate the character of that service, but convert it into a naval reserve: in time of peace a body of producers, whose capacity for contributing to the wealth of the country is thus materially increased, and in time of war forming an invaluable auxiliary for its defence.

Section 14 provides for the appointment of a registrar of seamen, to keep, in addition to other prescribed duties, an account of the seamen of the country, that we may have at all times some knowledge of the auxiliary sea force on which the country may rely in the event of war.

Section 15 establishes the proportionate number of boys merchant-ships are required to carry.

In order that the young sailors, when properly qualified, may not be left on our hands, a “drug in the market,” or their employment even rendered doubtful, there must be created a positive demand for them. Heretofore, for various groundless reasons, and from a shortsighted policy, many masters of our merchant-ships were opposed to taking boys to sea. This lack of wisdom on their part should no longer be permitted to stand in the way of our rearing American seamen.

This section only anticipates the action of Great Britain, where the question of amending their navigation act by similar provision is now under discussion.

Section 16 provides that boys shall be regularly indentured, to serve at least three years, or until twenty-one. It is obviously unwise to go to the pains and expense of educating a boy, and then set him adrift to follow the bent of his own inclinations.

The graduate of West Point cannot resign from the army till two years after graduation, on the theory that he must actually serve his country for at least that period as a return for his education. The same rule applies to the Naval Academy, and of course to apprentices to all the trades.

Section 17 provides that, to enable the Government and the country at large to be at all times apprised of the state of the navigation-schools, a naval officer should be regularly detailed to inspect and report on them. Such published reports, moreover, have the effect of stimulating the officers of such schools to their highest efforts.

Section 18 provides that, owing to the peculiar manner of conducting the affairs of vessels engaged in the fisheries, it is not deemed expedient to apply to them the several requirements of this act.



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Commodore C. R. P. RODGERS, U.S.N., in the Chair.

## THE CRUISE OF THE TIGRESS.

By LT.-COMMANDER H. C. WHITE, U.S.N.

THE present paper cannot, in any degree, present facts which are of value to science. The cruise of the *Tigress* was one purely of humanity, and the orders which directed it were not written with the intention of executing scientific research. The remarkable story of the ice-floe party—separated from their ship, the *Polaris*, whether by accident or negligence, and surviving on a piece of ice scarcely a hundred feet square, a drift of 1,800 miles, will bring to the minds of all who heard it recollections of the terrors and hardships of the Arctic Sea.

The investigation which brought forth the evidence of Tyson, the hero of the ice-floe, called for a suitable vessel, properly equipped and manned, to go at once in search of the survivors of the *Polaris* crew, and with that object solely in view, the *Tigress* sailed away on her mission of rescue. So far as her success was concerned on that mission, it must be remembered that Buddington and his thirteen associates were picked up before the search expedition sailed from New York, rescued partly by their own exertions and mainly because of the open season of the present year.

All works upon Arctic research point to the necessity of being at the entrance of Melville Bay by the 15th of August. About that date, but usually not later, is the time when the Polar and Spitzbergen currents have done the major part of their work and cleared the Arctic Sea of its masses of floating ice, leaving little as a barrier to progress save

the huge bergs which float down later in the season from the thousands of unexplored glaciers which line the coast of that "Land of Desolation." The season was already far advanced, too far almost to justify any hopes of success. Fears rather were entertained that the lateness of the season would necessitate remaining all winter in the ice region, with, perhaps, little chance for active operations which might crown our labors with success, had the Buddington party not already been rescued, as was duly anticipated before sailing.

Not until the 14th of July was the *Tigress* ready for sea, and on the evening of that day, at five o'clock, started on her mission cheered by thousands of people along the shores of the East River, and on board the floating palaces of the Sound. The details of the cruise up to the time of reaching the Greenland coast are mainly devoid of interest. The ordinary bad weather on the banks gave us the opportunity of judging of the qualities of the vessel. As a weatherly craft much dependence was placed upon her. But it was evident that under steam alone, under the most favorable circumstances, her speed would not exceed five knots per hour—a fact which caused much uneasiness for many reasons. It proved conclusively that the main dependence must be upon the sails of the vessel, which, fortunately, were new and of the best quality and workmanship. On the 3d of August we first saw the Greenland coast and its ice-covered mountains in the neighborhood of Cape Desolation, and the effect was most grand and beautiful, more particularly so because of the contrast between the land before us and that which we had just left, alive with all the beauties of vegetation. Greenland, devoid of all except the very lowest orders of vegetation, was like mountains of silver glistening in the sun's rays, while at the same time, as from a prism, were reflected all the colors of the rainbow; and this not from a single mountain, but from chain upon chain as far as the eye could reach. This was ten o'clock in the forenoon, and the sea was smooth and the breeze light; and so changeable is the weather in these latitudes, that at four o'clock in the afternoon the ship was lying to, unable to make any progress against the heavy sea which had suddenly arisen, created by a north gale which set in just before noon with hardly any warning. The presence of the Spitzbergen current was first perceived this day—quantities of sea-weed and drift-wood floating by us. Its average force, as far north as Upernivick, may be estimated at six fathoms per hour.

On the 6th of August, at 1.20 A.M., we anchored in the harbor of Lively, Island of Disco. We remained at Disco until 5 P.M. on the 8th, having replenished our stock of coal and receiving twenty-seven



Esquimaux dogs for sledge purposes, if obliged to remain the winter north. Our next port was Upernivick, or as translated means the place of the sun—a pertinent meaning, for from its sheltered position it enjoys the reputation of being a warm, sunny place during the short Arctic summer. From the time we arrived in the vicinity of Disco Island much ice was seen in the form of bergs, the glaciers about the Wygat Channel and Disco Bay (or more properly the Gulf of Disco) being a fruitful source of these masses of ice, and a grand procession of them may be seen at any time during the season of open water, on their stately march from the Wygat to the sea. Especially was the ship harassed in her passage to Upernivick from Disco by bergs. Fortunately at this time the daylight did not entirely leave us at any time, though as yet we had not seen the midnight sun. At 10 o'clock on the morning of Sunday, the 10th of August, the ship was brought to anchor in the harbor of Upernivick. A dense snow-storm lasted the entire day, making the country look all the more dreary for its new, fresh covering. From this time forward, snow storms, storms of sleet, and a sort of frozen fog were not unfrequent. The zone of rain for the present season was left behind us when we sailed from Upernivick. Our stay here of a day and a half was occupied in replenishing, as far as possible, our stock of coal, and in the purchase of a dozen more Esquimaux dogs, to complete the necessary number for four sledges.

At 5 in the evening of the 11th got under way for Tessuissak, the most northern civilized settlement on the globe. The run to this place, 34 miles distant, was made through one of the grandest of passages, between mountains from 1,000 to 3,000 feet high, with the water of the narrow channel studded with islands and bergs, the latter drifting rapidly to join those which had preceded them towards the open waters of Baffin Bay; and when finally the narrow passage had been cleared and the broad sea was open before us, the horizon was completely obscured by icebergs, and our course lay oftentimes through a labyrinth of them, so close aboard that our boats were in danger: an occasional bump on one bow or the other would start the people to their feet, but the ship had been built for the ice, and she had our most perfect confidence.

On the 11th of August, at 11.45 P.M., we arrived, without any accident of a serious nature from contact with the ice. Jansen, the Danish Governor of Tessuissak was soon on board, a man famous in the popular books of Kane and Hayes as an Arctic traveller. He informed us that there were no tidings relative to the fate of the *Polaris*, or that of

her crew. However, he gave us the cheering opinion that we were just in time to cross Melville Bay, and that the season would prove to be an open one, comparatively speaking. Remaining but an hour in the harbor of Tessuissak, and accepting the proffered services of Gov. Jansen to pilot us clear of the sunken rocks which border the bay on its northern side, we stood to sea, and, leaving civilization behind, headed for Melville Bay. The shores of this bay, as represented by the geographer, are indicated by a curve of the coast-line from Cape Shackleton to Cape York. But Melville Bay, to the Arctic navigator, comprehends much more. It is undoubtedly the most dreaded and dangerous locality of the Arctic Sea. The icebergs and floes which are found within it are the offspring of its shores, and if its bottom could be examined it would be found to be strewn with the timbers of scores of good ships, crushed in a moment in the merciless pack, with hardly any warning to those whose fortunes were with the ships. Since the days of 1616 when Baffin first penetrated the waters of this bay, a fleet of whale-ships has yearly run the gauntlet of this pack-ice, but oftentimes destruction has overtaken the whole fleet. The Governor of Upernivik told me that in one year alone, he had two hundred men thrown upon the bounty of the colony, whose ships had been crushed in this treacherous pack-ice. But whalers still go the same course year after year, and those who succeed in reaching the north water about Cape York are generally well repaid for their dangers and hardships. The whale-ships take a lead in the pack, with a good lookout aloft, and run as far as possible in this lead; when a barrier of a mile or so intercepts their progress, they endeavor to reach a lead ahead by crushing through the ice to the open water beyond. The general principles employed in the construction of an ice-crushing boat in our harbors are the ones used in the construction of the modern whale-ships of the Arctic Sea. They are supplied with great steam power, and can be handled in times of emergency to avoid dangers, when the detention of a few moments to a sailing-ship, for want of power, might cause her destruction. The whalers intend to enter the leads of the pack *inshore*, away from the influences of currents, early in May. But the inshore leads in August are quite different matters. When the bay ice is broken out the bergs commence to leave the glaciers, and an inshore lead would tend to positive detention, if not to destruction. It is not in the late season the pack-ice which has to be fought and overcome, but a pack of icebergs which cannot be so easily conquered, as well as the hummock-ice, or fragments of the bergs and glaciers floating out to sea, being rapidly and constantly

replaced by similar pieces during the open water season. It is evident, therefore, that in the late season the inshore leads should be avoided, and the less hazardous middle passages taken to cross Melville Bay.

The *Tigress* was particularly fortunate in making this passage. Shortly after midnight of the 12th, the ship was headed for Cape Shackleton, and in about thirty-six hours Cape York was sighted. We had now reached the point where the Buddington party might be seen at any moment, had they survived the winter, and not already been rescued. A landing at Cape York was not effected, owing to the heavy ice which skirted its shores for some four miles. Not a smooth, unbroken plain of ice, but filled with hummocks and small bergs from fifty to one hundred feet high—the whole a homogeneous mass, *almost* unsurpassable; and, if at all, only by the consumption of more than a week of most valuable time. We were sufficiently near the shore to see human beings, had there been any, and to observe smoke or other signals. Our progress from this point was uninterrupted by want of sufficient light at night, for on the 12th the midnight sun was observed. Remaining a few hours in the neighborhood of Cape York, scanning the shore with powerful glasses for signs of life, we stood on to the northward, observing carefully the whole coast, examining Holsteinholm Sound, Cape Athol, and into Hartstene Bay. In this latter the ice was very thick, and had the appearance of not having been broken out at all during the present season. For miles, as far as the eye could reach, the waters of the bay were covered with an unbroken plain of ice, without an apparent crack. In the open water, we found the new ice fast making, and the ship's side was much scarred by its sharp, thin edges and points.

Standing out of the bay by Saunders Island, towards the three islands known as the "Sister Bees," much heavy pack-ice was encountered, and at times it seemed as if the ship could not advance further. But to retreat was equally as hazardous. A passage must be forced; and many a rough shock did the vessel receive as, with all her force, she struck against the ice, stopped, backed, and renewing her efforts again and again, until, at last, the ice-stream had been cut through, and the open water off Blackwood Point was reached.

On the 14th, Northumberland Island was sighted, and hopes were raised that perhaps the statement of Meyers, of the Signal Corps—one of the ice-floe party—might be correct: that it was off this island the separation had taken place. It was, however, seriously doubted; for in his testimony, his geography of the country was sadly at fault, for he placed Cape Alexander to the southward of Northumberland Island. An exami-

nation of the chart in New York had convinced us that there was much reason to doubt if Northumberland Island was near the scene of the separation. However, the island was closely examined, and without the discovery of any kind of life to reward our efforts. Still northward went our vessel, towards Littleton Island, the place which all felt certain was near the locality where Tyson commenced his ice-drift. During the afternoon of this day, the wind was northerly, with a dense snow-storm; the whole atmosphere seemed filled with a driving, frozen fog, making it perfectly impossible to see scarcely the ship's length in any direction. To add to our discomfort, the bergs were so numerous about us that it was impossible to count or estimate their number. It was a trying position; every hour at this juncture was of the utmost importance to us. New ice was making rapidly; each hour of delay enhanced the chances of failure to ascertain anything of the fate of the *Polaris* or her crew; and our proximity to the bergs made our situation a most dangerous one. Toward evening, however, the storm abated, and shortly afterwards we sighted Capes Alexander and Ohlsen, between which is situated Hartstene Bay, and the locality where Dr. Hayes made his first winter-quarters, calling the place Port Foulke, directly to the west of which is the grand "Brother John Glacier" of Kane. Doubling Cape Ohlsen, Littleton Island and McGary's Island came in sight; and Tyson at once recognized the locality as the place of separation.

At 9 P.M. of the 14th of August the engines were stopped, in latitude 73° 30' north. It was just a month from the time of sailing from New York, and during that time we had not only reached the Greenland coast, but were 2,267 miles due north of that city. A boat was lowered, and, under the orders of Commander Greer, I left the ship to reconnoitre for signs of the missing vessel or her crew. The excitement was so intense that the boat's crew was composed of officers, who had volunteered for the long pull ahead of us. When not a hundred yards from the ship, I was hailed by the commanding officer, who informed me that he heard cheers coming from the shore; and, while waiting to hear the sounds from the boat, word came from the captain, "I see them! I see them!" and, pointing the boat in the direction which he indicated, pulled towards the mainland to the eastward of Littleton Island, distant from the ship about three miles. Threading our way through patches of open water, surrounded by floe-pieces and bergs, I saw people dressed in clothing which my glass told me was not that commonly worn by the natives; it was white, and evidently not of skins. We felt sure that at last we would be repaid for all our endeavors by finding *something* relating to the *P-*

*laris* and her crew. A mile nearer the shore, the complexion of the people proved that they were savages, and not whites. They made the usual friendly signs of the Greenland tribes, that of raising both hands slowly above the head, and dropping them quickly again to the side; to which salutation I replied, upon which they cheered vociferously. A few minutes later brought us to the shore. We landed in a little cove, to which the natives had preceded us, and, with extended hands, welcomed us to the shore—a custom which is far from common among them, and one which assured us that they had been among white men. Stepping ashore, we found two manila hawsers, which had every appearance of having been recently broken. Walking about a hundred yards up the rocky beach, we came to an abandoned house, which proved to be the deserted camp of the *Polaris's* crew. Getting, hurriedly, the main facts in relation to the ship and her people—how they had lived, how they had gone, and the whereabouts of the ship herself, and with the ship's bell and some few books, which had belonged to Captain Hall—we returned to the ship to give the news to those who were so anxiously awaiting it. Commander Greer went immediately to the camp, and, upon his return, directed me to go again on shore, and make an official and careful investigation of the place, and, if possible, to find the wreck. Landing again in the same cove, I proceeded to the work. A description of the camp may be of interest: The house was made of spars and pieces of the ship, about forty feet long, and eighteen or twenty feet wide, completely covered with sail-cloth to protect it from the weather. It was built upon a level piece of rocky ground, some thirty feet above the water level, the whole extent not being of a quarter of an acre. The place had been wisely selected, for all about it were the precipitous mountain-sides, hardly a spot of which would have been tenable in the winter season; and it was evident that the ship had been moored close by, judging by the hawsers already referred to, which had been parted by some undue strain of the ship upon them. The house was a comfortable one, the entrance being effected through double doors, for the better protection of the apartment. This latter contained fifteen berths, supplied with mattresses and coverings; a wardroom extension-table; cabin and wardroom chairs; a large heater, and also the galley-stove of the ship, which was placed in the enclosure between the doors. The table-furniture, such as knives, forks, spoons, table-casters, with bottles and contents, showed that nearly all the mess-traps had been taken from the ship to the shore quarters. The floor was covered with mutilated books, manuscript log-books, and broken instruments of a nautical kind, as was also the ground immediately about the

house. I caused to be taken to the boat such parts of private manuscripts and journals as I could find; the log-book of the *Polaris*, and all the printed notes which were not too filthy and mutilated. The journals and log-book had many pages cut out, and in no case could we find any written matter relative to the death of Captain Hall, or the separation from those on the ice. The pages of those dates had been carefully removed. The ground about the house was covered with *débris* of all kinds pertaining to a ship. A careful survey was made of all such material, and I never witnessed the result of so much apparent wanton destruction. Whether the destruction was caused by the whites or the natives may be a question. Sufficient to say that the Esquimaux carefully avoided touching anything belonging to the camp. The provisions which they found were not to their liking, and they seemed to be somewhat superstitious relative to the effects left by the crew. The nautical instruments had evidently been smashed with intention. The small screws of a Cambey sextant had been removed, and the shade-glasses thrown in different directions, as well as the telescopes, etc. Such was also the case with Colby's fog instrument, steam-gauges, clock, anemometer, aneroid-barometer, and the patent log. The boxes of preserved potatoes were piled up in tiers, and each box had received a blow of an axe on its side.

Close to the house was erected a temporary carpenter's bench, with shavings in plenty about it; and near by was a chest containing a portion of the carpenter's tools, in a rusty and imperfect condition. Near at hand, also, a forge, which had evidently been used for the fabrication of the iron used in the construction of the boats. My next object was to discover, if possible, the existence of a cairn, in which instruments and records, too bulky to be taken in a boat on so hazardous a journey, should have been deposited. But a careful survey brought to light no such place of concealment, except in one case, of native construction, containing a large part of a walrus's body, thus secured to protect it from the voracious dogs, of which the natives had many. Several piles of stones attracted our attention, and raised hopes that perhaps a cairn might be amongst them. But they proved to be only native graves. Conversing with the Esquimaux through Tyson, whose eighteen years of Arctic experience had made him familiar with the language, I learned that the *Polaris* had been tied up near the place all winter; and that, a northerly gale coming on only about the 1st of August, she had parted her moorings, and drifted on to the rocks in a little cove further to the southward, where she had sunk. He further stated that the party had abandoned the ship many moons before, and that she had floated up to the time already

referred to, only two weeks previous to our arrival. Buddington, with his thirteen associates, had gone about two moons since (about two months) in a couple of boats of their own construction, fitted with oars and a sail each, to go towards the sun, or the south; but to what locality none seemed to know, all being ignorant of the geography of any portion of the country. Taking the leader of the party, which numbered seven persons, in the boat, I pulled over to the inlet where it was stated the *Polaris* had sunk. It was a well-sheltered cove, and was free from ice, except in one place, where two heavy floe-pieces *were resting, not floating*; and their general appearance caused me to believe that, inasmuch as there were ten fathoms of water about the edges of the floes, they rested on the *wreck*, and not on *the rocks*. The natives had come to this locality to get the walrus, with which the waters about Littleton Island abound. They came in the winter, with their sledges, before the ice had begun to crack and float away in the driving currents, and, securing their stock of food, would return to Pond's Bay, whence they had come, as soon as the ice should be strong enough. Aroth, the leader, was on Littleton Island hunting when the *Polaris* heeled over and went down, and I had no reason to doubt that his statement was correct, and that this was the locality of the wreck.

There seemed now nothing more to be done, and I turned my attention towards the *Tigress*. But she was shut out of view by the dense snow-storm, which was but the continuation of the one in the afternoon off Cape Isabella. The investigation at the camp had proved one thing, and that was: the crew of the *Polaris* had gone south, and for the purpose of sighting a whaler. So, after landing the Esquimaux, we pulled for the ship. A certain journal has charged Commander Greer with inhumanity in not taking the natives aboard the *Tigress*. The statement is almost too absurd to meet with any notice; but, inasmuch as the letter which contained the statement purports to be written on board a national ship, I will give it a moment's attention. The statement that the natives wanted to be taken aboard ship is untrue. Supposing they had desired it, what could have been done with the so-called "dusky natives"? Upon what would they have subsisted? Cooked provisions they did not eat, and the pork left in the deserted camp was untouched. They were in their own country, and better conditioned natives were never seen during our cruise; with plenty of dogs and sledges, plenty of skin clothing, abundance of the food they sought, with two comfortable skin tents to shelter them—of this world's goods, desirable to them, they were well supplied. As well might the commander of a national ship be charged

with inhumanity on the coast of France for not making his ship a public transport for all the Frenchmen who desired to go from one port to another.

About half a mile distant from the ship the snow-storm abated, and we perceived the great northern pack, not many miles away, coming down before the wind, and approaching quite rapidly. I had spent about five hours on shore. It was now about four o'clock of the morning of the 15th. The examination of the camp had been a hurried one, but still a very thorough one; for the circumstances of wind and weather demanded that no time should be lost. A few hours more might fill the bay and the straits with portions of the northern pack, which would force us to remain north the winter. We knew the people had gone south. The people must be sought, or the object of the cruise would be lost. The order was given to go southward; and the engines were started, while we looked wistfully to the north, wondering why so short a distance from the pole could have baffled all attempts, thus far, to reach it. To the satisfaction of every officer on board the *Tygress* I believe that question was answered.

Our journey southward to Cape York was of much the same character as the one already described—bright lookouts, constant vigilance, bright, sunny nights, and generally sleepless ones too, for the excitement was intense fore and aft the ship. It fanned the imagination of the lookouts, which often brought the report of a boat, or a sail, or human being, an inspection of which proved to be a piece of ice in one of the myriad forms it assumes. On the 16th of August we arrived off Cape York, finding the condition of the ice not materially changed. At this point it was a question in the mind of the commanding officer whether to return across Melville Bay to the Danish settlements, or to go westward and follow up the whaler's course inside the pack. The recollection of Lieut. Hartstene's experience in the *Release* at the same season of the year in '55 caused the decision to return across the bay. Hartstene had followed down the west coast, and, finding none of Kane's party, stood for Godhaab, Disco, where he found the missing crew, and discovered that he had passed them while on their journey southward in this very bay; the presence of the heavy bergs had shut them out of sight of the *Revas*. Our course across the bay was somewhat different from the former one, but the experience was the same, with the exception of one gale of wind which lasted for twelve hours, during which time the coal in the starboard bunker took fire from the overheated bulkhead which separated the bunkers from the boilers. It was



extinguished with little damage. The crew had been much exposed, and began to feel the desire for fresh meat. Fortunately, in the passage across the bay a white bear was shot, which gave for many days fresh provision for all hands. Arrived at Tessuissak on the 19th of August, and the next day at Upernivik. Nothing had been heard of the *Polaris* at either place.

Up to this time the boilers had been in constant operation, and their faulty construction necessitated a thorough overhauling. Consequently we remained four days at Upernivik, and then, all being ready, we started south for Disco, to send by the first conveyance tidings of progress to date; for it was the intention of Commander Greer to go at once from Disco to the west side of Davis's Straits in search of the whale fleet, on board one of which Buddington and his party surely were. Arrived at Disco on the 25th at 2 A.M., and eight hours later left for the west coast. An easterly gale favored our progress, and on the 27th we fell in with the pack, which, floating down with the Polar currents, gets caught in the bight of land, the termination of which is Cape Walsingham; and, finding no lead by which to enter it, stood southward, skirting the ice in search of such an opening. Our progress now was slow, comparatively speaking, for the nights were very dark and the sky generally cloudy. Several small leads were entered, and an attempt made to crush through the ice to a lead beyond; but our power was insufficient, and we did not succeed. And learning that, when the pack is closely pressed by the currents into the shore, the whalers go to Cumberland Sound to fish, it was determined to push for those waters. While attempting to go there one of the violent gales, common at this season in the Arctic, assailed us, and for three days our position was a most precarious one, and caused many apprehensions; for the ice, driven by the fierce winds and currents, often threatened to nip us. The ship was hove to, but at times it was necessary to ease the helm and to run to avoid being caught. Those nights were anxious ones, and many a hard blow did the little vessel receive from the bergs and floes. But the gale finally broke, and we found ourselves near Cape Mercy, and, heading up the gulf, brought to anchor at Niantilik on the 4th of September. Ballast was here taken on board to replace the coal which had been consumed, and of which there was scarcely a score of tons remaining, and the boilers and engines were again thoroughly overhauled. Two whalers were found at this place, but neither had any tidings of the missing crew. However, we obtained the information that in South Greenland, at a place called Ivigtut, there is generally a supply

of coal, used at the Kryolith mines of that place for pumping and for hoisting the cars; and, moreover, that vessels had at times been supplied with coal from this stock. Accordingly, on the 16th of September, with the repairs to the machinery hardly finished, the *Tigress* sailed for Ivigtut. Favored by a westerly gale, in four days we were within twenty miles of the anchorage we were seeking, but were driven down near the Thorstein Island, just north of Cape Desolation, and were eleven days getting in. We were enabled to get all the coal we desired, and took about one hundred and seventy-five tons. Even in Ivigtut our experience was a trying one. The water of the harbor is exceedingly deep and surrounded by mountains from 1,000 to 4,400 feet high. But, notwithstanding its sheltered position, the gales are terrific. In one blast we received down the mountain-side our starboard chain parted, and the port cable only held because of a turn which it took around a high boulder as the ship sheered when the first chain parted. There is no such thing as holding ground on the coast of Greenland. The bottom is generally smooth, and the ship is held by the weight of her anchors and chains. In the gale to which I now refer we saw a length of fifty fathoms of chain, of the size given a frigate, stretched from the quarter of a ship to shore, so taut that not a link of it was in the water.

We sailed from Ivigtut on the 4th of October, bound to the northward and westward, on the whalers' track. Since the 21st of September, not a day had passed without some indication of the lateness of the season. But the 6th of October proved its lateness satisfactorily. We encountered a gale, which developed into a hurricane, and made our position the most critical of any thus far experienced. The sea was white with ice and the driving spray, which froze as it touched our ship. The crew, from exposure and cold, were much weakened, and the officers volunteered their services to replace the worn-out men, and often aided the men in their work of pulling and hauling. It was a necessity apparent to every officer on board. During this particular gale the wind and sea were not from the same direction. Our proximity to the Greenland coast caused the wind to be deflected from the course which had raised the sea, and our decks were never free from the water, as wave after wave broke over her, and our lee boats were constantly in or under the water. Let one picture to himself the worst gale he has ever witnessed, and then add to the imaginative picture, icebergs, and floe-ice, and a ice shore like the Greenland coast, only twelve miles away, with no power to head the sea or steam away from impending dangers—such will be the picture, that cannot be drawn, of this scene.

On the 7th of October the gale moderated, and we stood northward again, searching for whalers. In this low latitude (62 degrees) the ice was fast making, and another gale would render the ship helpless, covering her rigging and sails with ice, which could never be handled with our much-reduced force. Our crew had been a most hardy one; but of our twenty-one seamen and coal-heavers, it was not uncommon at this time to have one half under medical treatment. One man was paralyzed, four or five others very ill with pneumonia or bronchitis, while others were threatened with the same diseases. A consultation with the proper officers, on the 8th of October, caused Commander Greer most reluctantly to stand to the southward. But the whalers had evidently gone, the cruising season had undoubtedly closed, and another gale would hazard the safety of the ship. We kept in the whalers' track until clear of Cape Farewell, when the course was changed to St. John, which port we reached in ten days.

I have referred to the dangers of getting "nipped" in the ice between two ice-floes, driven by conflicting currents. An instance or two may serve to describe what I mean. Captain Bartlett, who commanded the *Tigress* when she received the Tyson party from the ice, told me that two years since he commanded a vessel in the seal trade, and was standing in towards the coast of Labrador, in search of seals. The season was a comparatively open one. Two floes were seen approaching, and all that skill and seamanship could do *was* done to retreat from the position in which the ship was. But it was too late; the floes touched the ship, and crushed her like an egg-shell, giving the crew scarcely time to reach the ice and save themselves. They saved nothing but the clothes on their backs and a few biscuits which each man had in his pocket. The land was twelve miles distant, and was reached the next morning by walking on the ice and jumping from floe to floe. While on the beach, a vessel was seen standing in, and, to obtain her services, Captain Bartlett started to meet her, walking on the ice. He succeeded in reaching her, and was invited to breakfast with her captain. She also had been nipped during the night, but it was thought no serious damage had been done. Before that breakfast was finished the ship went down, and so suddenly that the boats were barely launched to save the crew. Four strong ships, built for the ice, went down that same night. In 1855 Captain Duchars, of the ship *Princess Charlotte*, was standing across Melville Bay. Everything indicated a pleasant and prosperous voyage. The north water was almost reached. A few yards more, and the ship would have passed her dangers. It was a fine morning, with light breezes blowing from the south-

ward. The captain observed two small fœes, which seemed to have a converging course, and took the deck to see the ship safely through. She was so far out of danger that the ice did not touch the ship till abreast of the mizzenmast. Its sharp points pierced her side, and in ten minutes the royal-yards disappeared beneath the surface of the water. How closely danger besets the arctic navigator, yet how insidiously, can only be understood by those who have been in that region, and have seen the operations of the treacherous ice.

To describe the myriad forms which ice, in the shape of bergs, assumes, is a task too difficult. Perhaps an idea of their immensity may be conveyed by giving the size of one measured not long since by Dr. Hayes, and undoubtedly not overestimated in size or weight. It was seen just off Tessuissak, where I have already stated that the horizon was obscured by these masses. It was wall-sided above water, and its altitude above the water was three hundred and fifteen feet, the base-line being a fraction over three-quarters of a mile long. Its cubical contents could not have been less than twenty thousand millions of feet, and in weight two thousand millions of tons. And I am not mistaken when I say that this is not an uncommon sight. This berg, as many undoubtedly, seen by the *Tigress*, had grounded in two thousand two hundred feet of water, and its disintegration was so slow that it had remained in its position for two years. Another fact about the ice of these bergs: it is formed under great pressure and extreme cold. And on one occasion I remember that one of the ice-masters, who had been sent alongside of a berg to obtain some ice for the water-cooler in the officers' quarters, returned to the ship, and said that with an iron ice-chisel he had been unable to make any impression upon its surface, so intensely hard was it. The formation of the bergs, as such, is a matter of daily occurrence; and although the plastic state of the glacier is not thoroughly understood, still enough is known of the ice-deposit to follow the rain-drop from its distillation to the time when it adds its crystal to the ice of ages in the mountain gorges of Greenland. The snow which covers the mountain-tops in winter, melted by the summer's sun, trickles down the mountain-sides, filling the cracks and crevices of the glacier below, or runs over its surface, till stiffened by the cold of the early fall, when it becomes part and parcel of the glacier itself. This latter has a motion, caused by gravitation, and moves bodily down its inclined bed between the mountains, not being arrested in its course by inequalities of the rocky surface beneath it, or even by the chain of hills which may, perhaps, form the coast-line. It moulds itself to these, and, with the force of a mighty river, pursues its course to the

sea, reaching which it runs into it and beneath its surface, maintaining always the inclination of the whole surface of the glacier, until it is pushed far beyond the coast-line of nature, and has created its own. Some suppose that the bergs break from the glaciers by the force of gravitation. This is undoubtedly true of the hummock ice, but hardly probable in relation to the berg. But rather, by the buoyancy of the ice, it tends to rise, like a plank forced at an angle under the water. And when a sufficient quantity is thus forced beneath the surface of the sea, its buoyancy overcomes the strength of the material, and it rises, breaking its connection with its origin, and tumbling and rolling, dashing the sea high into the air, finally assumes a position of equilibrium, and floats away into the element which will finally conquer it, as it does the rocks of which its bed was made, and send it back again to commence its work as snow upon the mountain-tops. This law of circulation seems to be as applicable in the ice region as in the temperate zone. In the latter the rivers which flow to the sea are analogous to the glaciers of the former. The glacier is but the river of the warmer latitudes; its current not so rapid.

Of the manners and customs of the natives of Greenland we had little opportunity to judge, as our sojourn there was very short. However, we saw enough to know that away from the Christianizing influence of the Danish settlements they are savages, and in some respects beneath the more elevated orders of the animal kingdom. They belong to tribes wandering from place to place, and their religion is more vague than that of the aborigines of our own country. Their marriages are matters of convenience. They have a plurality of wives, and, if they have a faith, its first article is to steal, under all circumstances, as much as possible without being detected; and they are most dexterous thieves. They live in huts, the site of which is generally on a hill-side to save the labor of building; in shape they are like an old-fashioned country clay oven, square in front and sloping back into the hill. The room is entered by means of a subterranean passage twelve or sixteen feet long, naturally dark, and the floor of it is covered with snarling, savage dogs and half-grown puppies. This passage is so low that it is necessary to crawl on one's hands and knees to pass through it. The room is about sixteen feet diameter, into which are huddled the members of the family, consisting of the lord of the household, with many wives and very few children, oftentimes no children at all. The race is fast dying out. The number of deaths will nearly be double the births in the same year for the northern tribes. They sleep all together

o. skins thrown upon the earth-bottom of the hut; the skins are half cured, and emit an odor never to be forgotten, if once perceived in the stifling atmosphere of one of these huts. Their only lamp during the long winter night is a sort of saucer made from stone, in which is placed seal-oil; for a wick, moss is used. They are the filthiest of people, seeming to know nothing of the excellent use to which water might be put, and the utter filth of the huts defies description. I never experienced such a feeling of suffocation as in the first hut I visited, nor such a feeling of relief when once I had<sup>d</sup> reached the open air. The natives are always blessed with good appetites, and are always ready for an excuse to have a feast. The coming of a stranger among them is a sign for feasting. On such momentous occasions the greatest delicacy is a sort of soup made of seal-oil, blood, and seal intestines. And if the unfortunate visitor can manage to swallow the potion, and, at the same time, maintain the equilibrium of his stomach, he is at once blessed with the title "In nuk si si ma vok," which means, "As good as a native." But what an ordeal to pass to obtain this honor! When the feast is one of raw meat, a general gathering is made around a part of a carcass, and each, with his razor-like knife, cuts a piece from it weighing, perhaps, two pounds. This is carried to the mouth, and the teeth planted firmly on a convenient morsel, while a well-directed blow of the knife, passing between the meat and the lips, severs the morsel from the large piece. So quickly is this done that the motion of the knife can scarcely be perceived. Children three and four years old feed themselves after this manner; their parents seemingly have no apprehension as to this blow of the knife. It is the height of gentility among them, when they wish to show especial marks of esteem to a guest, for one of the wives to proceed with the operation thus described, including the cutting, and then, instead of eating the several morsels, they transfer it by means of extremely dirty fingers from her own lips to the mouth of the thus highly-honored guest.

The question is often asked: "Can the North Pole be reached?" From what we saw in the *Tigress* I believe that the opinions of the officers would yield a ready answer in the affirmative. There are three things essential, which, in that region, will be more than elsewhere necessary, if the Pole is to be reached: first, and the most essential of all, Discipline; secondly, Pluck; and, thirdly, Perseverance, of course aided by judgment and good seamanship. Armed with the knowledge of the present day of the Arctic Sea, with improved architecture in the building of ships for ice-work, and with steam-power at the will of

the commander, coupled with the essential qualities just mentioned, there is no doubt in my mind as to the results of a trial to reach the Pole. The expeditions which have hitherto undertaken the task have failed from want of the main quality. I do not refer to the earlier expeditions before steam placed the motive power under control, but to more recent attempts, when good ships and powerful engines have been supplied to the expeditions. Of the existence of an open Polar Sea there seems to be little doubt. Of the causes why it exists little is known. According to all notes upon Arctic research, the *Tigress*, at the time she had arrived off Littleton Island, had passed the greater dangers to be apprehended. But I imagine that there is no one who stood on the decks of the *Tigress* and faced the northern pack but felt that, had occasion demanded, we could easily have diminished the number of miles which separated us from the Pole. The middle ice is never stationary; open water always exists between the two currents. Tyson's ice drift and McClintock's drift in the *Fox* prove this beyond doubt. And with two vessels, one as a reserve to remain at Port Foulke, (the best port we saw in Greenland) to fall back upon in case of need, and the other properly fitted to push forward in the early season of open water, I believe the Pole could be reached, and, moreover, that it *will* be done, if the results to science will repay the attempt.

But as far as our own cruise is concerned, it opened a new world of thought and experience to all. It presented nature as we had never before seen her, clothed in her grandest and most sublime livery; and long after its hardships, privations, and dangers shall be forgotten, that cruise will be a source of infinite gratification and pleasure, as remembered by those who made their home for nineteen weeks on board the little *Tigress*.

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#### DISCUSSION.

At the conclusion of the reading of the paper Lieutenant-Commander White stated that many points of much professional interest had not been discussed for two reasons: first, because the expedition was not fitted with instruments for executing scientific research; and, secondly, because of the limited time usually accorded, which did not admit of a complete narrative, coupled even with the meagre scientific knowledge obtained by the *Tigress*. But he also stated that if there were points upon which the

members would like to ask questions, he was willing to answer them as far as possible.

Commander Terry then asked if the whalers ever went north of Melville Bay.

Answer. They seldom go north of Cape York, because it is their object to get only as far north as will bring them into the open water—or north water, so-called—which saves a tedious and dangerous “horing” through the middle ice to get upon the whaling grounds on the west side of Baffin’s Bay. The rule is to keep the coast of Greenland on the passage up, following the “leads” or lanes of open water in the loose ice, and avoid the “middle pack ice” as much as possible. When in May, or sometimes as late as July, the body of the pack has passed to the southward, leaving the entrance about Smith’s Sound comparatively free, then the course is shaped to the westward, and then southward to the neighborhood of Lancaster Sound.

Question by Commodore Rodgers :

Will you be kind enough to tell us something relative to the action of the compasses you used, and what kind of compass do you consider the best for work in the high latitudes ?

Answer. The variation at Northumberland Island was about 10 points, and at Camp Polaris 12 points. Little or no dependence can be placed upon the compass. The ordinary compass-card seems to lose all its sensitiveness, and remains in any position in which it may be placed. The liquid compasses were the most reliable, and in thick weather our only dependence was on the liquid binnacle compass. Whalers say that the best place for the compass in the Arctic Sea is in the storeroom. The headlands are very distinctly marked, and in thick weather the proper mode of proceeding is to anchor, by means of ice-anchors, to a substantial floe ; for if the compasses *were* perfectly reliable, they could not point out in thick weather the dangers of the ice. I have seen the tell-tale in the cabin spin upon its pivot by the hour. The magnetic force was so slight that the motion of the propeller caused the card to revolve so rapidly that the compass points were not at all distinguishable. Except for experimental purposes ashore, compasses in the Arctic are practically of no value.

Question by Lieutenant-Commander Harrington :

How did you manage to get the ship’s position ?

Answer. It was obtained by the usual methods, whenever the horizon was not obscured by ice, which was often the case, or where proximity to the land would not permit.



Question by Commander McNair :

Could not an artificial horizon be used with advantage ?

Answer. Yes, if used on the land or on the ice. The ships would never be sufficiently quiet to use such an arrangement on shipboard. But for the determination of latitudes or longitudes to test the correctness of the charts (which are very imperfect), the artificial horizon is always resorted to, the ice serving as well as the land for that purpose.



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First Assistant Engineer, J. C. KAUFER, U. S. N., in the Chair.

### COMPOUND ENGINES.

BY CHIEF-ENGINEER C. H. BAKER, U. S. N.

DURING the past ten years some modifications in the practice of marine steam-engineering have been effected, having economy of fuel as their object, for which so large a measure of success has been claimed, that they have attracted much attention among persons to whom steam-engines are at all interesting, and have occasioned a great deal of discussion in the engineering journals.

The machines in which these improvements are exhibited are known as COMPOUND ENGINES, and their great popularity, as manifested in their adoption by the most important lines of oceanic steam communication, is a conclusive proof, with many persons, of their decided superiority to the non-compound engines in common use.

There is nothing new in the compound engine, so far as its organs and their arrangement are concerned. Its essential feature, in regard to those points, is borrowed from the precedents of Hornblower and of Woolf, inventors who put forward their systems severally in 1781 and 1801.

The object of these contrivances was the use of a high measure of expansion, with less strain upon the organs of the engine than those encountered in the attempt to realize the anticipated benefits of the practice with engines of the ordinary type. For in the latter, with the same

speed and stroke of piston and the same initial pressure, it is plain that, for the development of the same power, the area of the piston must be increased with every augmentation of the measure of expansion, and that at one period of the stroke of the piston a greater strain will be brought upon the engine—greater as the measure of expansion and the area of the piston are greater.

And as the strength that must be provided in any construction is that which shall be adequate to resist the greatest strain brought upon it, the same mean pressure may require greater or less strength in the material, accordingly as the extremes from which that pressure is determined may vary.

The engines of Hornblower and of Woolf were known as *double-cylinder engines*. Steam was admitted to the lesser of two cylinders, and, having in filling it carried the piston along its length, was exhausted into a second or larger cylinder, where its remaining expansive force was expended in impelling the larger piston.

Some double-cylinder engines have been worked in Cornwall in raising water from mines, but the common pumping-engine of the region has held its own against them.

With the pressures employed in marine service until within a few years, the principle upon which the use of the double-cylinder engine was justified is founded upon a delusion. The advantages of what is called expansion were deduced not from experiment, but from *à priori* reasoning, based upon the supposed correspondence in the action of steam, and that of gases in general, as enunciated in the law of Marriotte.

It has been found, however, that the advantages anticipated from the use of high measures of expansion with engines of the common type are not to be obtained in practice. Many experiments, among them a great number by the Navy Department, have been made upon the scale of ordinary practice, by which it has been proved that, for the common pressures employed in marine engines, a measure of about twice the initial volume is attended with the most satisfactory economical results.\*

Any increase of the number of expansions above that measure is attended with the aggravation of several losses, the ratio of which to the whole useful effect obtained is greater with the greater rates of expansion.

\* See Professor Rankine's paper—Appendix C—"Report of Admiralty Commission, 1872." Compare Prof. Rankine's remarks upon the efficiency of the steam-jacket in the above connection with what he says in Art. 286, "Steam and Other Heat Engines." See also Isherwood, "Researches in Steam-Engineering," Preface to Vol. II.

For since the cylinder must be larger for the development of the same power with equal initial pressures, it follows, 1st, the direct losses by radiation of heat outward to the surrounding medium will be greater; 2d, the ratio of the whole back-pressure of the condenser vapor to the whole mean pressure of the steam will be increased; 3d, the ratio of the quantity of steam required to fill the space contained in clearance and steam-passages to the whole quantity used will be greater. And besides these losses there are others, not so evident upon mere reflection, but nevertheless decisive as to the claims of the high measures of expansion.

First, there is the loss due to the expansion itself. The work accomplished in the process requires the conversion of heat; and as this must be furnished by the steam, there is condensation as the result. And this condensation must needs engender further expansion, attended by further condensation.

Again, the interior walls of the cylinder and the sides of the piston are chilled during every communication with the condenser, a large quantity of heat being abstracted from them by direct radiation into the mass of vapor in the cylinder about to be ejected towards the condenser, and by the re-evaporation of water that has been deposited upon their surfaces, and this quantity also is augmented with every increase in the size of the cylinder. The water thus re-evaporated has been condensed from steam that has performed no work whatever, and the process gives rise to the most important of those effects of high expansion that so greatly modify the value of the principle.

In the extensive experiments of the Navy Department, to which allusion has been made, the cost of the power developed was expressed in pounds of water evaporated from 212° Fahrenheit per total horsepower per hour. These quantities were ascertained by the actual measurement, by means of tanks, of the water evaporated, and, being compared with the quantities of steam discharged from the cylinders, as measured by the indicator, the sum of the condensations I have noted was ascertained.

The data may be relied upon to determine the performance of any engines of the kind experimented with, by applying them in correction of the results obtained from indicator measurement alone.

In any investigation of the claims made in behalf of the compound engine, it will be necessary to compare its performance with that of ordinary engines that have, in common with their rival, the latest improvements hitherto devised.

Such a comparison has been lately made by a Board of Naval Engi-

reers,\* and the results embodied in a report to the Navy Department.

It is upon the materials of that report that I shall proceed to draw in the following discussion of the comparative merits of the two types of engines.

Among the various types of steam machinery employed in the naval service are three, known respectively as the 60" x 36" engines of the *Guerrière* class; the 50" x 42" engines of the *Benicia* class; and the 36" x 36" engines of the *Saratoga* class. They may be taken as excellent examples of the most approved type of non-compound engine, as generally employed in screw-propulsion in our own and other naval services.

In common with the modern compound engine, they work surface-condensers.

Apart from the difference in the arrangement of the cylinders, the disposition of the organs of these engines is very similar to that adopted for engines of the compound type in the British Navy.

The remarkable functional difference is in the pressure of steam employed.

The engines of the three classes I have particularized are simple, durable, substantial in construction, and convenient of management. In these respects they are not inferior to any engines now on board naval vessels, whether of the compound or any other type. They are designed to work steam of a boiler-pressure of forty pounds to the square inch, and their valve gear is arranged so as to admit of the use of steam expansively at measures ranging from one and one-half to two and one-half times the initial volume. They are quite as economical in fuel as any other non-compound marine engines now in use.

The type of compound engine most generally adopted abroad is that in which two cylinders are employed, both working through cranks set at right angles to each other upon the same shaft, their axes being parallel and lying in the same plane. The cylinders are of different diameters, but of the same stroke of piston, and the larger is connected with the condenser. The smaller of the cylinders alone has any direct connection with the boilers. It is surrounded by a cylindrical shell, having the same outside diameter as the larger cylinder, and the wide annular space between the outer and the inner cylindrical shells is termed the *receiver*. Into this receiver the steam from the smaller or high-pressure cylinder is delivered at every stroke of the piston, in expanded volume. From the receiver the steam passes to the larger or low-pressure cylinder, and is therein worked as in common condensing engines.

\* 1873. Chief-Eng. C. H. Loring, President.

TABLE

Exhibiting for comparison the cost of the power, in pounds of steam per horse-power per hour, of a number of compound and non-compound two-cylinder engines; the quantities, as ascertained by indicator measurement, being corrected by adding, in the case of the non-compound engines, the known condensations in the cylinders for their several measures of expansion, as determined by the experiments of the Navy Department; and in the case of the compound engines, the quantity condensed in the steam-jackets, as estimated upon the basis of an experiment made with the pumping-engine of the Brooklyn Water-Works in 1860.

DESCRIPTION OF ENGINE.	Pounds of steam consumed per hour per total horse-power, inclusive of the quantity condensed in the production of the power.	Pounds of steam condensed in the steam-jackets per total horse-power, calculated upon the basis of an experiment with the engine of the Brooklyn Water-Works.	Pounds of steam condensed in the cylinders per total horse-power due to all causes other than the production of the power.	COST OF THE POWER IN POUNDS OF STEAM PER HORSE-POWER PER HOUR.			Pounds of steam consumed per total horse-power developed in the low-pressure cylinder, inclusive of the quantity condensed in the steam-jackets.
				Total.	Indicated.	Net.	
<i>60 x 36-in. Navy Engines.</i>							
U. S. S. Guerrière.....	23.67	.....	4.99	28.66	35.70	40.59	.....
U. S. S. Delaware.....	25.95	.....	4.00	29.95	36.40	41.03	.....
U. S. S. California.....	21.50	.....	5.10	26.60	35.40	41.00	.....
U. S. S. Congress.....	25.95	.....	4.40	30.35	35.55	40.85	.....
<i>50 x 42-in. Navy Engines.</i>							
U. S. S. Alaska.....	23.40	.....	4.10	27.70	35.30	41.40	.....
U. S. S. Benicia.....	23.50	.....	4.20	27.80	35.20	40.90	.....
<i>35 x 33-in. Navy Engines.</i>							
U. S. S. Resaca.....	23.83	.....	5.00	28.83	34.80	43.00	.....
U. S. S. Swatara.....	23.00	.....	4.20	27.20	33.70	38.60	.....
<i>Compound Engines.</i>							
Steamer.....	15.9	2.18	.....	18.03	22.53	27.16	29.18
Steamer Italy.....	16.7	2.18	.....	18.88	21.49	23.10	24.57
Steamer Spain.....	16.6	2.16	.....	18.76	21.35	22.54	23.77
Steamer City of Bristol.....	16.2	2.11	.....	18.31	21.01	22.85	23.67
Steamer Gracia.....	18.3	2.22	.....	20.62	21.97	23.31	.....
Steamer Patagonian.....	15.9	2.04	.....	17.94	21.16	25.09	29.12
Steamer Batavia.....	17.6	2.27	.....	19.87	21.78	23.09	24.14
Steamer Egypt.....	17.7	2.23	.....	19.93	21.89	23.42	24.09
<i>Mean.</i>							
11 x 33-in. engines.....	25.02	.....	4.62	29.64	25.76	40.86	.....
51 x 42-in. engines.....	23.45	.....	4.29	27.75	35.35	40.85	.....
35 x 33-in. engines.....	23.40	.....	4.50	28.00	34.25	40.80	.....
<i>Mean.</i>							
Navy engines.....	23.95	.....	4.47	28.46	31.75	40.83	.....
Compound engines.....	16.36	2.19	.....	19.05	22.46	27.18	31.02

The admission of the steam from the boiler to the high-pressure cylinder is usually governed by an adjustable expansion valve. A similar valve is sometimes employed with the low-pressure cylinder, not in order to effect expansion—for that results from the relative capacities of the cylinders—but for the purpose of properly distributing the power between them.

The high-pressure cylinder, and commonly the low-pressure cylinder also, is furnished with a *jacket*, surrounding it at the ends as well as at the sides. The jacket is kept filled with steam of the boiler-pressure. Heat is conducted from the jacket inward to the cylinder and outward through the inner shell towards the receiver. The steam contained in the receiver, therefore, is superheated by the jacket. The same effect is sometimes enhanced by the use of a steam-coil within the receiver.

When the low-pressure cylinder is provided with a jacket, the latter is also kept full of steam of the boiler-pressure. But in many good examples this cylinder is not jacketed.

Figure I. roughly represents a compound engine such as I have just described.

Figure II. represents an arrangement of cylinders often resorted to, in which both pistons are fixed upon the same rod, the smaller cylinder being at the end of the larger. This is the type employed on board some of the steamers of the White Star Line, and also by the Morgan Iron Works, of New York, for the new engines of the *Tennessee*. It will be observed that no receiver is provided in this type, the steam expanding directly from one cylinder to the other. When four cylinders are provided, as in the engines for the *Tennessee*, no special provision is needed for equalizing the distribution of the power upon the two cranks.

Examples of the economical performance of several English compound engines of the latest and most approved construction, are given in the table exhibited on the blackboard,\* in which the cost of the power developed by them, expressed in pounds of steam per horse-power per hour, as measured by the indicator, is collated with the cost, ascertained in like manner, and corrected for the known condensations in the cylinder, due to the production of the power, and to other causes, of the several examples of the navy engines already specified.

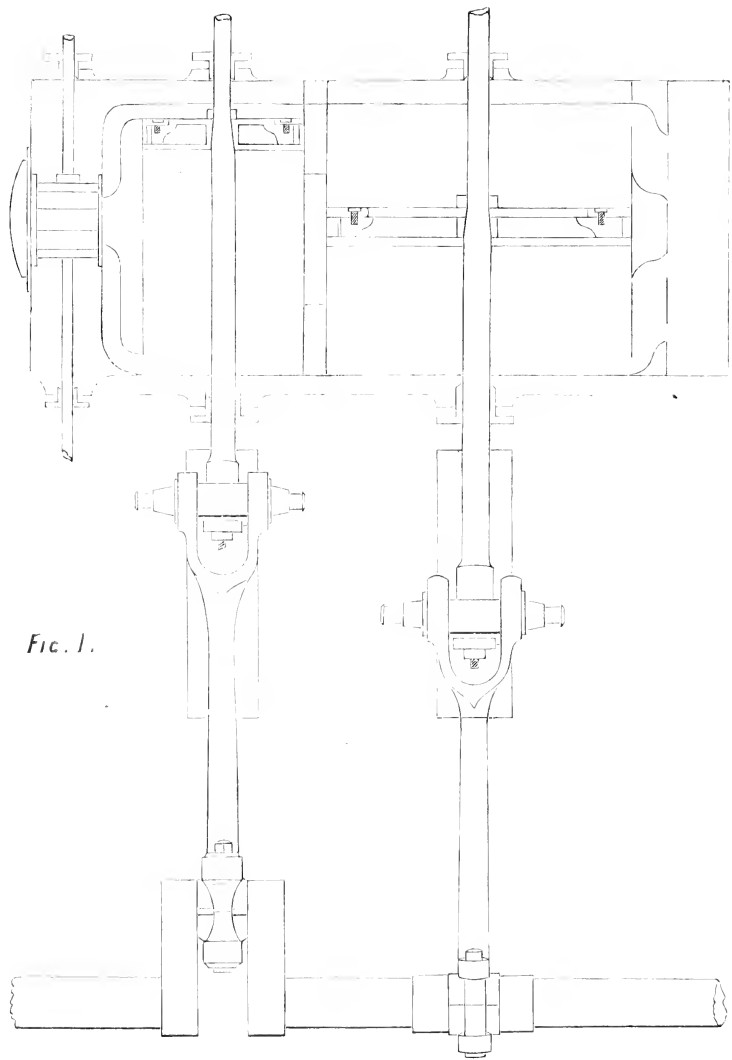
The former is the sum of the following quantities :

1. The number of pounds of steam per horse-power per hour discharged from the high-pressure cylinder, as measured by the indicator.

\* See page 63.







*Fig. 1.*

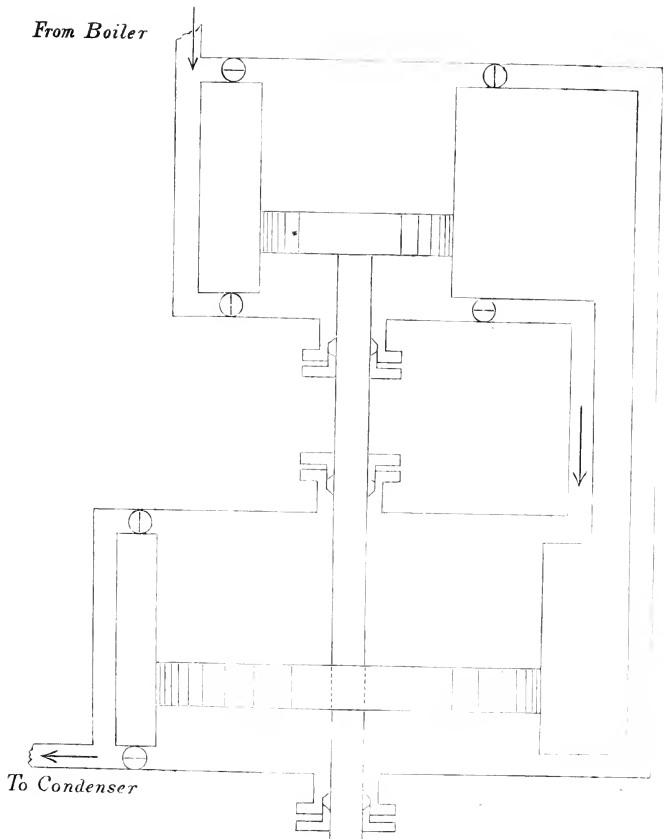
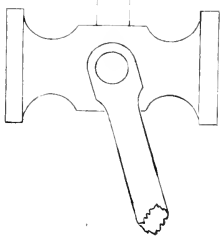


FIG. 2.





2. The number of pounds of steam per horse-power per hour condensed in the high-pressure cylinder in the production of the power, calculated upon the basis of Joule's equivalent.

3. The number of pounds of steam per horse-power per hour condensed in the steam-jackets, estimated upon the basis of an experiment made in 1890 with the pumping-engine of the Brooklyn Water-Works.

I may here remark that the expression of the cost of the horse-power in pounds of coal, in comparing the performance of engines and boilers, is often impracticable, and, in a question of engines alone, it is entirely unsatisfactory.

It is better to accept the quantity of steam as the criterion. Computed, as it is, from diagrams taken from the cylinders, under the ordinary circumstances of practice, it is independent of all conditions that depend upon the boilers alone. In computing the quantity of steam consumed by the compound engines under discussion from that discharged from the high-pressure cylinder, as per indicator, it is assumed that the condensations in that cylinder, due to causes other than the production of the power, are covered by the condensations in the steam-jackets.

Whatever condensations occur, due to the difference of temperature between the interior surfaces of that cylinder and the entering steam, are counterveiled by the re-evaporation of the water thereby precipitated upon those surfaces, or suspended in the steam; and the water thus re-evaporated becomes available as steam for the development of power in the low-pressure cylinder.

The mean cost of the horse-power developed in the non-compound engines will compare with the mean cost of the horse-power in the compound engines as follows:

1. Cost of the total horse-power of the non-compound engines, 28.46 pounds of steam; of the total horse-power of the compound engines, 19.05 pounds; the difference in favor of the latter is

$$\frac{28.46 - 19.05 \times 100}{28.46} = 33.06$$

per centum of the former.

2. Cost of the indicated horse-power of the non-compound engines, 31.75 pounds of steam; of the indicated horse-power of the compound engines, 22.46 pounds; the difference in favor of the latter is

$$\frac{31.75 - 22.46 \times 100}{31.75} = 29.26$$

per centum of the former.

3. Cost of the net horse-power of the non-compound engines, 40.83

pounds of steam; of the net horse-power of the compound engines, 27.18 pounds; the difference in favor of the latter is

$$\frac{40.83 - 27.18 \times 100}{40.83} = 33.43$$

per centum of the former.

The total power is that computed from the mean gross pressure upon the piston.

The indicated power is computed from the mean unbalanced pressure.

The net power is computed from the gross mean pressure, minus that required to overcome the resistance of the back pressure and the friction of the engine.

The indicated horse-power is the standard of comparison commonly employed in current discussions of the performance of compound engines, although the net power affords the more rational standard. The gain of 29.26 per centum in the cost of the indicated power is much less than that usually claimed for the compound engines by persons interested in their manufacture.

If, as is often asserted, the indicated horse-power is obtained at a cost of only two pounds of coal per hour, the boilers must evaporate 11.23 pounds of water per pound of coal. This quantity is much greater than has ever been evaporated by boilers of the type employed with the compound engines under consideration. The quantity evaporated in such boilers per pound of coal, at the high rates of combustion generally employed in English practice, will be found not to exceed eight pounds of water from a temperature of 100° Fahrenheit. When the apparent evaporation is greater, the increase may be due to superheating the steam, the results of which practice would be equally advantageous in the case of engines of either type. The cost of the indicated horse-power, then, in pounds of coal per hour, would be

$$\frac{22.46}{8} = 2.81.$$

Taking the evaporation of the boilers used with the non-compound engines at their maximum rate of combustion to be nine pounds, the cost of the indicated horse-power in pounds of coal will be

$$\frac{31.75}{9} = 3.53.$$

This quantity corresponds very nearly with the results recorded in the steam-logs of the engines in question when burning anthracite of the best quality

The difference in favor of the compound engine is therefore

$$\frac{3.53 - 2.81 \times 100}{3.53} = 20.29$$

per centum of the cost of the indicated horse-power of the non-compound engines in pounds of coal per hour.

The boiler-pressure employed with the compound engines in question is sixty pounds per square inch above that of the atmosphere.

The employment of so high a pressure has occasioned the adoption of a type of boiler, cylindrical in form, constructed of thicker plates than have been commonly used for marine purposes. This type is thought to promise some advantages over that hitherto preferred for the naval service. The latter is for the most part of the vertical water-tube variety, quadrangular in form, and unrivalled in economy of fuel. It has been found lacking in durability since the use of surface-condensers has become general.

It is thought that from the greater facility with which means for the prevention of corrosion, both internal and external, may be applied, due to the greater simplicity of their construction in the reduction of the bracing and otherwise, the cylindrical boilers may be made to render service for a longer period than those they will replace.

For equal areas of grate surface, however, the space occupied upon the floors of the vessels by cylindrical boilers of diameters practicable in naval vessels of the lesser rates, exceeds that occupied by boilers of the quadrangular form, by about thirty per centum of the latter. Reducing the grate surface in proportion to the expected gain in net power developed, the space required for the cylindrical will be nearly the same as for the quadrangular form for the development of the same power with equal rates of combustion.

A great deal has been written in the current engineering journals in discussion of the causes to which the gains accomplished are ascribed. The explanation most generally accepted is that which refers the improved results to the greater facility with which steam of high pressure can be employed at high measures of expansion. But this does not suffice. The gain in economy does not increase in the ratio of the augmentation of the measure of expansion, or nearly so even.

There is really no correspondence between the gains that should result according to the law of the expansion of gases, and the gains accomplished in the use of compound engines.

The practical measure of expansion that has been found most econo

mical in cylinders working steam of low pressure into a condenser, is not greater than two times the initial volume.\*

The low-pressure cylinder of the compound engine works under precisely the same conditions as the cylinders of ordinary condensing engines. The initial volume of the steam received by it per stroke of piston is governed by the capacity of the high-pressure cylinder. If, therefore, a measure of two times the initial volume be employed in the low-pressure cylinder, that should have twice the capacity of the high-pressure cylinder.

The latter works under nearly the same conditions as the cylinders of ordinary non-condensing engines. The practical measure of expansion that has been found most economical in working steam of sixty pounds pressure in such cylinders is not more than four times the initial volume.

Now, the compound engine is essentially an arrangement by which two engines—a non-condensing and a condensing engine—are conjoined, and the best results will be obtained from it when the steam is worked in its several cylinders with that measure of expansion which would be appropriate to either, were it detached and worked by itself.

The several measures of expansion in the two cylinders are, then, the factors which make up the total measure effected, and this practical measure is  $(4 \times 2) = 8$  times the initial volume. To increase either of these factors by any considerable amount, for the sake of effecting a higher total rate for the development of the same power, would result in a direct increase of the cost of the power.

With a given capacity of high-pressure cylinder, therefore, it would seem useless to employ a low-pressure cylinder of a relative capacity greater than two or two and one-half times the former.

The best examples of English compound engines have cylinders whose relative capacity is as one to three, and there are many in which the proportion is as one to four. That the low-pressure cylinders of the compound engines whose performance is given in the table, and the measures of expansion employed in them, are too large for economy, will appear if we compare the cost of the total horse-power developed in them alone, with the cost of the total power developed in the cylinders of the navy engines.

The mean quantity representing that cost is, for the compound engines, inclusive of the quantity condensed in the steam-jackets, the benefit of which is obtained in the low-pressure cylinder, 31.02 pounds of steam. The difference is

\* Isherwood, "Researches, etc." Rankine, "Report of Admiralty Com., 1872."



$$\frac{31.02 - 28.46 \times 100}{28.46} = 9$$

per centum of the latter in favor of the non-compound cylinders. This comparison is made with those compound engines only in which the powers developed in the several cylinders are nearest equality.

Had the low-pressure cylinders been smaller, the ratio of the back to the effective pressure in them would have been reduced—and reduced in a greater proportion than the ratio of the back-pressure in the high-pressure cylinder to *its* effective pressure would increase—and a direct gain accomplished by a decided reduction of the total measure of expansion.

Notwithstanding the defective proportions of the cylinders and the apparent inferiority of the boilers employed in the steamers whose engines we have taken as examples of the new system, it appears that there is a considerable gain in economy to be expected from the adoption of the compound engine for the naval service. The gain in power for the same quantity of coal consumed, expressed in per centums of the power obtained by the non-compound engines, is 25.6.

Whether they will fulfil the requirements of the service in other respects as well as is done by the engines now in use, is a question that can be determined only by experience. They are more complex in arrangement, and the details include a greater number of parts; at least one of the cylinders must be fitted with a separate cut-off valve and gear.

There is a greater number of joints, and hence, as well as from the higher pressures employed, a greater liability to leakage.

The action of the cylinders depends each upon that of the other, and neither can be made to act by itself without the employment of special appliances of a complicated and normally useless character, in the absence of which the disabling of one cylinder means the disabling of both.

Against these apparently not insuperable disadvantages we have to set the promised gain of 25.6 per centum in the indicated horse-power obtained from the same weight of fuel consumed, and the probable greater longevity of the boiler.

In adapting the system to the circumstances of American practice, the English precedents cannot be exactly followed. Designs of machinery for vessels of war are made under conditions that differ greatly from those that determine its arrangement and disposition in vessels of commerce. And the difference in the character of the fuel commonly used in this country from that used in Great Britain, enforces a variation in practice, so far as the boilers are concerned, entailing a necessity for the occupation of more space in the vessels for that portion of the motive power.

It is only by experience, as has been said already, that the actual value of the improved machinery, and its merits for adoption in the naval service, to the exclusion of other types, can be determined. In the pursuit of economy the conspicuous modification of engineering practice is in the pressures of steam employed. There is nothing new in the compound engine except this feature. The mere combination of mechanical devices that distinguish it from engines of the common type has never availed for the reduction of the cost of steam-power, although the attempt to compass that object by their use has been made again and again.

The new system can only be judged after competition with such modifications of that now in vogue as may result from the employment of the steam-jacket and of the higher pressures and speeds of piston to which the superiority of the former in economy is chiefly due.

Let the compound engine compete with the older type, so modified as to increase the speed of the piston to that employed in the former; let the cylinder be reduced in diameter to suit the increase of the steam-pressure; let the practical point of cutting off—in other words, the practical measure of expansion—be ascertained for the higher pressures, just as it has been determined for the pressure of forty pounds; let the steam-jacket be applied, as it may be with great increase of efficiency, to the reduced cylinders, and we shall have a formidable competitor with the compound engine.

A very considerable gain in economy of fuel is certain to result from such modifications, and it is also certain that they will produce engines convenient of management, simple in construction, not specially liable to derangement, and capable of operating singly by simple disengagement, in case of injury to either.

If justice has been done the compound engine in this discussion of its merits, it will be plain to all who have noted the claims put forward in its behalf, that some of its advocates have permitted themselves greatly to exaggerate its performances.

And that no injustice has been done in this discussion is clear enough when we reflect that all the possible errors in the method of investigation pursued are in favor of the compound engine. If there is error, it may be that the cost of the power is greater than has been stated; it cannot possibly be less.

It has been often urged that misrepresentation of such facts as have to do with the performance of machinery is without sufficient motive, and that what so many unite in declaring must needs be true.

But a very close observer of human conduct has felt himself moved to say that "where personal interests come into play, there must be, even in men intending to be truthful, a great readiness to see the facts which it is convenient to see, and such reluctance to see opposite facts as will prevent much activity in seeking for them."

#### DISCUSSION AFTER CHIEF-ENGINEER BAKER'S PAPER.

The reading of the paper concluded, upon motion of Commodore Foxhall A. Parker the thanks of the Institute were voted to Chief-Engineer Baker.

Several diagrams, representing some new forms of engines and boilers, were examined and discussed.

Commodore Ammen remarked that he had witnessed the application of the principles of the compound engine on the Ohio River twenty years ago. He stated that there was said to be considerable economy as the result.

Mr. Kafer said: "Compound engines were used on the lakes many years ago, but soon abandoned on account of the increased consumption of fuel, chiefly due to the low pressure of steam used. If there is any economy in the compound engine of the present day, it is mainly due to the use of high-pressure steam when compared to the single-cylinder or non-compound engine using steam of a lower initial pressure; but comparing them with reference to economy, using the same initial pressure and the same rate of expansion, the advantage would seem to be in favor of the non-compound. If the same quantity of steam be used during each stroke from the boiler in the high-pressure cylinder of the compound as in the non-compound engine, the work performed by the steam before the cut-off valve on either cylinder closes will be the same, the work performed during expansion in the non-compound will be greater than in the compound, as in the former the steam expands from the initial pressure to the terminal doing work, while in the latter the steam expands from the initial to the terminal pressure in the high-pressure, and then escaping to the receiver or steam-ports leading to the low-pressure cylinder, decreasing the pressure without doing work; and when the piston starts in the low-pressure cylinder, it is with a much less initial pressure than the terminal pressure of the high-pressure cylinder, while the rate of expansion and the terminal pressure before the steam escapes to the condenser is the same in the compound as in the non-compound; the

loss in the compound engine being due to the free expansion without doing work.

“The clearance space in screw-engines is approximately ten per cent. of the stroke displacement. This clearance space at the beginning of the stroke is filled with steam, compressed by the piston after the exhaust-valve is closed, of a pressure less than the boiler-pressure. The nearer the pressure in the clearance space at the end of the stroke approaches the initial or boiler pressure, the less steam is required from the boiler to fill this space; with a single-cylinder engine it is practically impossible to compress the steam from the pressure in the cylinder at the time of closing the exhaust-valve (about four pounds per square inch, absolute pressure) to the initial pressure commonly used in compound engines—say seventy-five pounds per square inch, absolute pressure; while in the high-pressure cylinder of the compound engine, with the back pressure fifteen pounds per square inch, absolute, at the moment of closing the exhaust-valve, the steam remaining in the cylinder can be compressed to seventy-five pounds per square inch at the end of the stroke as readily as to twenty pounds in the non-compound engine, which is about the pressure at the end of the stroke in a well-designed non-compound engine.

“This gain in filling the clearance spaces by compression does not lessen the power of the engine materially, and is beneficial in its working, as it brings the piston and rods to rest at the end of the stroke without straining action on the crank-pin.

“There are many other points to be considered, which apparently are against the compound engine, such as increased external radiating surface, complexity of mechanism, in addition to the loss by free expansion; but the gain by compression, and possibly the smaller difference in the temperature of the steam, and consequently of the walls of the cylinder that are in direct communication with the condenser, seems to more than offset all its disadvantages, if the statements of compound-engine builders are to be relied on.

“What is needed is a set of reliable experiments with a non-compound and a compound engine, using the same pressure of steam and same piston-speed; but the non-compound engine, to compete favorably, must have a minimum of clearance space, and be well jacketed.”

The Institute then proceeded to executive session.

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Professor J. H. C. COFFIN, U.S.N., in the Chair.

## CONSIDERATIONS RELATIVE TO CERTAIN FUNDAMENTAL REQUIREMENTS OF THE MARINE COMPASS, WITH SPECIAL REFERENCE TO THE CONSTRUCTION OF THE NAVY COMPASS.

BY PROFESSOR B. F. GREENE, U.S.N.,

*Superintendent of Compasses, Bureau of Navigation.*

### *Introductory Observations.*

It is sufficiently well known to the members of the Naval Institute that a change in the compass equipment of our ships of war has been gradually going on for a number of years past, until there has come to be a nearly complete substitution of the liquid compass for the air or dry compass previously in use.

The first introduction into our service of this kind of compass was about eleven or twelve years ago, in the form of a liquid boat-compass, the original models of which were imported compasses of English make, with flat porcelain cards.

The superiority of these instruments over the old and comparatively

useless form of air boat-compass was soon evident and generally acknowledged ; and yet, for various reasons (possibly from a little conservative prejudice), the new compass was only partially accepted, the outfit for boat equipment continuing for some time to consist partly of liquid and partly of air compasses.

Meanwhile, Mr. E. S. Ritchie, of Boston, who had long been distinguished for his intelligence and skill as a maker of the higher grades of philosophical instruments, finding it expedient, like many others at that time, to turn his attention to the fabrication of "war material" of some kind, solicited and obtained orders to make compasses for the Navy. It was thus that, while making some liquid boat-compasses after the English model, he was led to propose an important improvement, in the substitution of a *buoyant card, with a pivot-pressure entirely at control*, instead of the heavy flat disk otherwise in use.

This was the fruitful germ of Mr. Ritchie's idea, which, from the time he first put it into a practical form, has been in course of continual development, until the compass of the past year, although preserving its original distinctive features, is immeasurably the superior of its early predecessor in all the details of its construction.

Still, our naval authorities, while admitting the improvement, were far from precipitate in changing the compass equipment of our ships ; and thus it happened that the new liquid compass was hardly brought into exclusive use, even for the steering-binnacle, until about five years ago, and for azimuth purposes only during the last two or three years. In reality, however, it is but few years since the first attempt was made to adapt the compass-card to azimuth observations by giving it a suitably-divided circle ; and it is only within the past year that I have been satisfied the true construction of the compass-card had been finally reached.

It was thus by these cautious and tentative steps, and rather behind than in advance of established convictions, that the liquid compass came at length into general use in the Navy ; and the time has arrived when we may, I think, with some propriety, put on record, in a public manner, some of the reasons which have appeared to justify a position in this regard so much at variance with the general practice of all other countries.

I propose, therefore, with your indulgence on this occasion, to present a few considerations relative to the principles which, as I am led to believe, should control the construction of the marine compass ; and then, by way of application, to show wherein our practical conclusions have been, or are likely to be, justified by the particular type of compass now recognized in our naval service.

The subject is certainly not a hackneyed one ; for, notwithstanding the considerable antiquity of the marine compass, in the general form by which it has been known to the nations of Western civilization—with volumes of history, popular description, and panegyric—I am not aware that a single attempt has hitherto been made to give a rational explanation of its magneto-mechanical action, or of the principles upon which its construction, as an instrument of observation, should depend. And yet the theory of this instrument rests upon a few simple considerations of certain established conclusions of science. The neglect in this particular may, perhaps, afford a sufficient explanation of what appeared, in my first acquaintance with the marine compass, as one of the most remarkable facts in its history—that, as commonly seen in the hands of navigators, *it should be one of the rudest and most imperfect instruments for the accomplishment of one of the most important purposes among the practical pursuits of life.*

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There are three properties of the marine compass, so essential to its reliable action and convenient use that they may very properly be regarded as fundamental desiderata. They are :

#### MAGNET-POWER, SENSIBILITY, STEADINESS.

Let us consider, for a few moments, the precise significance of these terms in their present application ; the conditions that appear to be requisite for the most favorable realization of the properties which they represent ; and how nearly they are likely to be satisfied by the present Navy compass.

#### I. MAGNET-POWER OF THE COMPASS.

The more or less complex system called a compass-card, alike with the simple magnetic needle, when balanced for motion in a horizontal plane, has a tendency to return to its position of equilibrium, or rest, whenever deflected from it, which may be called its *moment of deflection*.

The moment of deflection is equal to the *moment of motive force* less the *moment of resisting force*. The moment of motive force is composed of three factors : of which one is the magnet-power (or, perhaps, in more precise phrase, the magnetic moment) of the card ; another is the directive force acting on the compass, meaning the whole exterior magnetic force acting in the horizontal plane of the card ; and the third fac-

tor is the sine of the angle by which the zero-line of the card is deflected from its position of rest.

The moment of resistance is the moment of all the resistances, of whatever kind, to the motion of the card.

All these moments are referred to the point of the pivot as the centre of the compass and centre of moments.\*

In relation to the *directive force*, it will here be understood that this term refers to the whole external magnetic force actually effective upon the compass; this being known, in general, on shore, as the horizontal magnetic force of the earth, and on board ship as the resultant of the horizontal magnetic forces of the earth and ship, for the particular heading of the ship, the particular place, and the particular time under consideration.

And, similarly, in relation to the *position of rest*, it will also be understood that the zero-line of the card (supposed to coincide with the magnetic axis of the card), while at rest, is in the position of equilibrium in respect of all the forces, magnetic and otherwise, acting upon it; this being known, in general, on shore, as the magnetic meridian or direction of the earth's horizontal magnetic force, and on board ship as the deviated direction of the compass, or resultant direction of the directive force on board.

The moment of motive force, the directive force remaining the same, varies, therefore, with the magnet-power of the card multiplied into the sine of deflection. It is *greatest* as the card is deflected 90 degrees from its position of rest, when the moment of deflection is equal to the product of the magnet-power by the directive force, less the moment of resistance; and it is *least* as the card comes to rest, at or near its previous position, when the moment of deflection is equal to zero; the moment of the motive force being reduced to an equality with the moment of resistance, whatever that may be.

Accordingly, we have for the sine of the *angle of set* (or terminal angle of deflection), or for the arc of set, if the angle be not very large,

\* If  $M$  represent the magnet-power of the card,  $H$  the directive force acting upon the card, and  $\delta$  the angle of deflection of the zero-line of the card, then the moment of motive force, or moment of rotation, tending to restore the card to its position of rest, or statical equilibrium, is expressed by the product of  $M$  and  $H$  into the sine of the deflection from the direction of  $H$ ; or,

$$\text{Moment of motive force} = M H \sin. \delta$$

Putting, also,  $R$  for the moment of all the resistances, and the moment of deflection is equal to the difference of these two moments; or,

$$\text{Moment of deflection} = M H \sin. \delta - R$$



*the moment of resistance divided by the product of the magnet-power and directive force.\**

In order, therefore, that the card may always return exactly, or very nearly, to its position of rest, whenever deflected from it, it is necessary either that the moment of resistance be extremely small in comparison with the product of the magnet-power by the directive force, or that this product be extremely large in comparison with the moment of resistance.

Now, the directive force of the earth, in different places traversed by the navigator, varies from about one-half to about twice its mean value; while the directive force on board, especially of iron-built ships, may vary quite as much on different courses of the ship, even in the same locality. Consequently, if, from developed defects of the compass, the moment of resistance be unavoidably large, or, on the other hand, if the directive force on board be much below its mean value, the angle of set, even with the magnet-power of the card unimpaired, will become so much the more appreciable.

It is, therefore, quite essential to the reliable behavior of the compass, under the varying circumstances of a ship's cruise in different parts of the world—

First, that the magnet-power of the compass-card should be as great, in every case, as can be conferred upon it, compatibly with other necessary conditions; or, in other words, that our aim should be to secure not only enough magnet-power for ordinary or average circumstances, but a surplus or reserve for extraordinary occasions of special requirement.

Secondly, that the magnet-power of the card should be as nearly permanent as can be realized through the formation of the card-magnets; and, to this end, that the greatest care should be used during every stage of that process.

\* When the deflection  $\delta = 90^\circ$ , we have the maximum—

$$\text{Moment of deflection} = M H - R$$

and when the card comes to rest, the minimum—

$$\text{Moment of deflection} = 0 = M H \sin. \delta - R$$

and, accordingly, the sine of the angle of set,

$$\sin. \delta = \frac{R}{M H}$$

or the arc of set, if small,

$$\delta = \frac{R}{M H}$$

*Estimating the magnet-power of a compass-card.*—These conditions will, perhaps, be more truly appreciated if we consider for a moment the means by which the magnet-power of a compass may be correctly estimated. Three different methods may be employed, with greater or less convenience, for this purpose.

*First, the method of deflections.*—By this (statical) method, the compass-card whose magnet-power is required is made to deflect a standard magnetic needle at a certain measured distance between their respective centres. The magnet-power of the card is then equal to one-half the cube of the distance multiplied by the product of two factors, of which one is the tangent of the observed deflection, and the other is the directive force; it being understood that the card is so presented toward the magnetic needle that its zero-line is in the magnetic equatorial through the centre of the needle.\*

*Secondly, the method of oscillations.*—By this (dynamical) method, the compass-card is made to oscillate in its own plane, and the time of one oscillation noted. The magnet-power is then equal to three-tenths of the moment of inertia of the compass-card, divided by the product of two factors, of which one is the square of the oscillation-time and the other is the directive force; it being understood that the units of distance and time are the foot and second.

For the same card, the moment of inertia is constant, and the magnet-power is proportional inversely to the square of the oscillation-time multiplied by the directive force.

For different cards, with the use of the same auxiliary weight, the moment of inertia of the card may be expressed in terms of the moment of inertia of the weight; and the magnet-power is then proportional inversely to the difference in the squares of the oscillation-times (with and without the weight) multiplied by the directive force.†

\* Representing the distance between the centres of the compass-card and magnetic needle by  $\epsilon$ , the deflection of the needle by  $\delta$ , and, as before, the effective directive force by  $H$ , and we have, for the magnet-power,  $M$ , of the card, approximately,

$$M = \frac{1}{2} \epsilon^3 H \tan. \delta$$

This expression results in neglecting the small terms of a series of which  $\epsilon^5$  is a common factor, and is the more nearly exact as the ratio of the distance  $\epsilon$  to the length of the needle is greater.

† Representing the moment of inertia of the card for rotation in its own plane by  $I$ , the time of one oscillation (supposed small) by  $t$ , and we have, for the magnet-power,

$$M = \frac{\pi^2}{g} \cdot \frac{I}{t^2 H}$$

in which  $\pi$  is the ratio of the circumference to the diameter,  $g$  the gravity-acceleration for one second,  $H$  the directive force, as before. Or, taking the mean numerical value of

*Thirdly, the method of torsion.*—By this (also a statical) method, the compass-card is suspended in a torsion-balance, and the moment of deflection at any angle balanced by the corresponding moment of torsion. In this case, the magnet-power of the card is equal to the moment of torsion divided by the product of two factors, of which one is the sine of the deflection and the other the directive force.

For the same conditions of torsion, the moment of torsion varies directly as the angle of torsion; and, accordingly, with the same angle of deflection, the magnet-power of any compass-card is proportional directly to the angle of torsion divided by the directive force.\*

$g$  at 32.2 feet, the constant coefficient becomes 0.367 foot, which, for the purpose in view, may be taken at 0.3 foot, and—

$$M = \frac{0.3 I}{t^2} H$$

For the *same* card,  $I$  is constant, and—

$$M \sim \frac{I}{t^2} H$$

With the use of an auxiliary weight, whose moment of inertia is  $\iota$ , the moment of inertia of the card is found by—

$$I = \frac{\iota \cdot t^2}{t^2 - t'^2}$$

in which  $t$  is the time of an oscillation with the weight on the card; whence the moment of inertia of the card may be eliminated, and we have—

$$M = \frac{0.3 \iota}{(t^2 - t'^2)} H$$

in terms of the moment of inertia ( $\iota$ ) of the auxiliary weight. Hence, for *different* cards, with the same auxiliary weight,  $\iota$  is constant, and—

$$M \sim \frac{I}{(t^2 - t'^2)} H$$

\* The equation of statical equilibrium between a twisted wire and a compass-card suspended by it is—

$$M H \sin. \delta = T \cdot \theta$$

in which the first member is the expression previously given for the moment of magnetic motive force for a deflection,  $\delta$ ; while the second member is the moment of torsion, consisting of the two factors,  $T$  and  $\theta$ , of which the first is a constant depending on the form, dimensions, tension, and torsional coefficient of the wire, and the second is the variable angle of torsion. Thus, we shall have for the magnet-power—

$$M = \frac{T \cdot \theta}{H \sin. \delta}$$

and for the same wire and a constant tension—

$$M \sim \frac{\theta}{H \sin. \delta}$$

or for the same angle of deflection—

$$M \sim \frac{\theta}{H}$$

The angle of torsion,  $\theta$ , is found from—

$$\theta = a - a' - \delta$$

in which  $a$  is the reading of the torsion-circle for  $\delta = 0$ , or the position of equilibrium, and  $a'$  the corresponding reading for the observed deflection,  $\delta = \delta$ .

The directive force is thus seen to be an element in each of these methods, as, indeed, it must necessarily be in every estimate of the magnet-power of a compass-card, or of any simple magnetic needle. Still, so long as the required determinations are made at the same place on land, it will be sufficiently exact, within moderate periods, to regard the directive force as constant, in which case the proportionality of the magnet-power is independent of the directive force.

But, as already mentioned, since this element, under the combined influence of geographical position and the ship's heading, may vary in a several-fold ratio, a proportional change must result in the remaining elements of the determination, provided the magnet-power of the card is unchanged. Hence, generally, in order to any reliable estimate of the magnet-power of a compass, under the varying circumstances of its use at sea, *the directive force must always be known as a necessary preliminary.*

Now, there is no physical difficulty in obtaining absolute determinations of the directive force by well-known methods whenever required; and with this element absolute determinations of the magnet-power of a compass-card could be had, if desired, by either of the foregoing methods. Nevertheless, for all practical purposes connected with the use of the compass, it is always quite sufficient to obtain relative values of the magnet-power for the directive force taken as unity at some convenient initial point.

It would lead me too far from the immediate object of this communication to enter more into details, of a purely determinative kind, in relation to the magnet-power of a compass. It may be sufficient to say, in passing, that the relative directive force, either on board or on shore, may always be found by very simple means, and with sufficient precision for the purpose in view. With respect to the several methods indicated, the second has certain advantages for use at sea: first, that no auxiliary instrument is required; and, secondly, that the removal of the card from the compass-bowl is unnecessary, which, in the case of the liquid compass, is attended with some inconvenience.

*Developing the magnet-power of a compass-card.*—Now, with respect to the two conditions of the magnet-power previously noted, it will be evident, from the second of the preceding methods, that the question of gaining magnet-power in a compass-card will depend on the possibility of producing a greater increase in the moment of inertia of the card than in the square of its oscillation-time. If, by introducing a different weight and distribution of steel, the moment of inertia is thereby increased  $m$  times, while the square of the time is only increased  $n$

times,  $n$  being less than  $m$ , there is a *gain* of magnet-power in the ratio of  $m$  to  $n$ .

Practically, this question resolves itself into two parts: first, that of increasing the magnet-power in the formation of single magnets of given weights and dimensions; and, secondly, that of distributing the magnets upon the compass-card in a manner to increase the magnet-power of the card.

*First, the development of magnet-power in the formation of single magnets.*

—This question, which is essentially one of experimental research, has been the subject of numerous special investigations; but by far the most exhaustive inquiry which has ever been made, although open, perhaps, to criticism on certain unimportant points, was that of the late Rev. Dr. Scoresby,\* from whose elaborate research the following conclusions may be summarized, as applicable to our present subject:

1. That the selection of steel for compass-magnets should be made from that known generally as the “very best,” in the form of thin plates.

2. That the steel, after being cut into pieces of the requisite length and width, should be hardened uniformly throughout, and only annealed or tempered sufficiently to prevent too great brittleness.

3. That the hardened laminae should be magnetized to their utmost capacity by the most powerful inductive action at command, and each lamina separately tested for magnet-power.

4. That the magnetized laminae, after being laid together, *in contact*, with the like poles pointing in the same direction, should again be separately tested for magnet-power, and all rejected that show any sensible deterioration.

5. That the proved laminae should finally be built up in magnet-piles of two or more laminae in each; it having been conclusively shown that a *compound* magnet, consisting of several proved magnetized laminae, takes on a higher development of magnet-power than a *simple* magnet, in one piece of the same weight and dimensions.

It is not, however, to be understood that the gain in magnet-power from piling is proportional to the number of laminae in the pile; on the contrary, with equal increments of steel, the corresponding increments of magnet-power are successively smaller, decreasing, approximately at least, in a geometrical ratio with the number of laminae added to the pile; so that the practical limit of available gain in this manner is soon reached.

\* “Magnetic Investigations.” By the Rev. William Scoresby, D.D. London, 1832.

The conclusions of Scoresby, established more than thirty years ago, with respect to the formation of compass-magnets, have been frequently confirmed, although little has been added thereto since that time.

These several conclusions may, therefore, be adopted, until, at least, we are better informed, not only as the rules of procedure in obtaining compass-magnets of the highest *intensity*, but as also generally favorable to securing them of the greatest *permanency*.

At the present time, with the use of the comparatively unlimited resources of electro-magnetic induction, the means of magnetization are greatly in advance of those employed by Scoresby. Quite recently a means of heating and tempering the laminae for compass-magnets has been used by Mr. E. S. Ritchie, which ensures much greater uniformity, not only in the distribution of the degree of hardness sought, but also in the subsequent magnetization.

*Secondly, the development of magnet-power in the distribution of magnets upon a compass-card.*—If a magnet of uniform section be placed across the centre of a card-circle, its length being equal to the diameter of that circle, its magnet-power and weight will be proportional to the diameter, and its moment of inertia to the cube of the diameter.\* If, now, we conceive this magnet to be moved in either direction outward, parallel to its first position, taking up positions and reductions of length according to the successive chords, its weight and magnet-power will progressively decrease in proportion to the cosine of the angular distance of the chord from the diameter, while its moment of inertia will progressively *increase* in proportion to a certain function of that angle, reaching its maximum at an angle of  $45^\circ$ , after which it will diminish, till, at the angle of  $90^\circ$ , the chord and all that depend on it vanish together.

Thus, with a magnet at the angular distance of  $45^\circ$  from the centre, its weight and magnet-power are each decreased to 0.7 and its moment of inertia increased to 1.4 of their values, in comparison with a magnet equal to the diameter of the centre; and if two such magnets be placed upon two equal parallel chords at  $45^\circ$ , each of those quantities will be doubled, or their weight and magnet-power each be 1.4 and their moment of inertia 2.8. Hence, it may be concluded that, by placing magnets symmetrically on equal parallel chords, it is possible to gain in magnet-power, though at the expense of additional weight to be carried by the compass-card.

\* The moment of inertia upon the diameter is proportional to  $\frac{d^3}{12}$ , and that upon a chord to  $\frac{1}{2}(3 \cos. a - \cos. 3a) \frac{d^3}{12}$ , in which  $d$  is the diameter, and  $a$  the angular distance of the chord from the diameter. The maximum of this function of  $a$  obtains for  $a = 45^\circ$ . It is, of course, to be understood that the rotation-plane is that of the card itself.

It will be shown hereafter that there are certain considerations which establish a choice of these symmetric chords for magnet positions. There are two such arrangements which are substantially equivalent, namely, the single pair on chords at  $30^\circ$ , and the double pair on chords at  $15^\circ$  and  $45^\circ$  respectively. The following table illustrates these several relations at one view :

*Distribution of Magnets on a Card.*

Designation.	One Magnet at Centre.	One pair of Magnets on Chords at $30^\circ$	Two Pairs of Magnets.		
			On Chords at $15^\circ$ .	On Chords at $45^\circ$ .	Sum.
Magnet-Power . . . . .	1.0	1.7	1.9	1.4	3.3
Moment of Inertia . . .	1.0	2.6	2.2	2.8	5.0
Weight of Magnets . . .	1.0	1.7	1.9	1.4	3.3

Thus it may be seen that, in assuming a certain practical limit to the increase of section by piling magnetic laminae in the formation of single magnets (which would be essentially the same for lengths varying between 1.0 and 0.5), and distributing these magnets of equal section upon the parallel chords, according to either of the above-named systems, there will be a material gain in magnet-power, and a larger gain in the moment of inertia, in comparison with the single magnet at the centre.

## II.—SENSIBILITY OF THE COMPASS.

If a compass-card, on being deflected to any extent in either direction from its position of rest, and then left to itself, return precisely to that position, it may be said to possess *perfect sensibility*; but, on the contrary, if it fail to come precisely to its previous position, the angle of set by which it deviates from that position may be called its *defect of sensibility*.

Now, if there were no resistances to the motion of a compass-card, and if it had any appreciable magnet-power, it would invariably return to its previous position of equilibrium, whenever deflected from it by virtue of the motive action of its moment of deflection, and, consequently, no defect of sensibility could arise.

But, in point of fact, it is a physical impossibility that there should be no resistance to the motion of any body within our immediate cognizance; and, consequently, we must expect, in accordance with our previous assumption, an angle of set, or defect of sensibility, whose value is represented by *the moment of resistance divided by the product of the magnet-power of the card and the directive force acting upon it.*

There are, in reality, two different resistances to the motion of the card: one is the friction of the pivot; the other is the resistance of the medium, air or liquid, in which the card moves within the compass-bowl. The former is a constant; the latter is a variable, depending on the velocity of the card at any particular instant of its motion. The moment of resistance, already referred to, consists, therefore, of the moment of friction at the pivot and the moment of resistance in the medium, both moments being referred to the point of the pivot as the centre of moments. The moment of resistance opposes the motion alike during the increase and during the decrease of the angle of deflection.

¶ The moment of friction consists of three factors: the pressure between the rubbing surfaces, the mean radius of the area in contact, and the coefficient of friction; the latter depending on the physical qualities of the pivot and cap, such as hardness, smoothness, etc. All these factors are essentially constant for the same card, except as they may be liable to change with changes of condition.

The resistance of the medium is more complex; for it not only involves several distinct elements, but its law of action is somewhat uncertain under considerably varied circumstances of the form and velocity of the moving body. Nevertheless, it appears to be certain that the resistance of a medium, properly so-called, is solely a function of the velocity of the moving body, involving no absolute term independent of that velocity. As to the form of this function, it is far less certain; but we are justified, from the results of experimental research on this subject, in concluding that the moment of resistance of the medium to the motion of a body of unyielding form, like that of a compass-card, is represented by a product of five factors—the square of the velocity of the card, its section of resistance, the mean radius of that section, the density of the medium, and the coefficient of resistance; the latter depending on the form of the card, and possibly, also, on the velocity, in view of the considerable variation in this element during the motions of the card. Of these factors, all but the first and fifth are sensibly constant for the same compass; and of the fifth there is only some doubt



whether it can always be expressed as a constant for the same compass, or must be modified somewhat for the variable velocity.\*

I have entered somewhat more into dynamical details, especially in regard of these resistances to the motion of a compass-card, than might at first sight seem to be necessary; but, in order to form an intelligent judgment of the conditions which should control the construction of the marine compass, we must take into consideration the laws of the resistances to the card motion, and these cannot be duly appreciated without, at least, a definite recognition of all the elements of these resistances.

Now, with regard to the relation of these resistances to the sensibility of a compass, it will be evident, I think, that the resistance of the medium, however great it may be during certain stages of the motion of the card, cannot give rise to any part of the defect of sensibility: for, in the first place, in regarding this resistance as solely a direct function of the velocity, it must decrease with the velocity and completely vanish with the cessation of motion; secondly, and with still stronger reason, it should follow from the assumption that the resistance varies directly as the square of the velocity; that, as the velocity of the body diminishes in approaching its final position of rest, the resistance of the medium diminishes in the much more rapid ratio of the velocity squared;

\* With equilibrium between the motive and resisting forces, we have, as already seen, the angle of set, or—

$$\text{The defect of sensibility} = \frac{R}{MII}$$

But we have the moment of resistance—

$$R = f + F(v),$$

in which  $f$  is the moment of friction at the pivot, and  $F(v)$ , a function of the velocity, the moment of the resistance of the medium.

Again, we have the moment of the friction—

$$f = \phi m p$$

of which  $p$  is the pressure,  $m$  the mean radius of the bearing surface, and  $\phi$  the coefficient of friction.

Also, the moment of resistance of the medium—

$$F(v) = \zeta s n K v^2$$

in which  $v$  is the velocity of the card at the centre of section,  $K$  the section of resistance,  $n$  the mean radius of the section,  $s$  the density of the medium, and  $\zeta$  the coefficient of resistance, which is possibly a function of  $v$ .

Finally, with the cessation of motion,  $F(v) \rightarrow 0$ , and  $R$  becomes reduced to  $f$ , so that the angle of set, or—

$$\text{The defect of sensibility} = \frac{f}{MII}$$

so that, with the last element of the velocity, the last element of this resistance is a quantity infinitely smaller in comparison.

Hence, it must be concluded that the resistance of the medium, whether air or liquid, has no influence whatever on the ultimate angle of set by which a compass-card deviates from a previous position of rest after being deflected from it.

It is otherwise with the friction at the pivot; for this being a constant force wholly independent of the velocity, it remains the same, during the smaller elements of the velocity, as during the most rapid motions, until it finally comes into equilibrium with the motive forces, and there results an angle of set, or defect of sensibility, which is represented by *the moment of friction divided by the product of the magnet-power and directive force*.

There may be a question whether, in addition to the friction of the cap upon the pivot, there may not be a certain amount of friction due to the action of the fluid in the cap immediately surrounding the pivot. This point is involved in some obscurity at present. It is not easy to separate a possible frictional resistance like this from what is recognized as the resistance of the medium proper; so that it is quite probable, whenever the former has an appreciable value, that it should be merged in the latter, in the results of experiment.

Consequently, the conditions most favorable to the sensibility of a compass appear to be these:

1. That the pressure of the card upon the pivot and the area of the surface in actual contact between the cap and pivot shall both be as small as possible.
2. That the material of the cap and pivot shall be as hard, as true to form, and as smoothly polished as possible; and,
3. That the magnet-power of the card shall be as great and as permanent as possible.

The pressure upon the pivot remains unchanged for the same compass-card; but both the mean radius of the rubbing surface and the coefficient of friction are liable to increase—the first from the wear of the material and the second from the irregularities and roughness of the wear. The magnet-power is liable to decrease—in some cases very seriously from original defects in the formation of the card-magnets, and in others from accidental causes incident to the handling of the compass on board ship.

But whatever the angle may be which represents the defect of sensibility, either at the outset or as the result of subsequent changes in the

compass-condition, it is always *an error of the compass*. Moreover, it must be regarded as one of the most dangerous errors to which the compass is liable; because, whenever the actual condition of the compass is unknown, its value is as uncertain as that of the function upon which it depends; and this may vary from an extremely small quantity, when the *sensibility is practically perfect*, to a quantity as large as unity, when the *sensibility is nothing*.

In passing from the present topic, a remark may be permitted on the preceding definition of sensibility. It will hardly escape notice that the definition here given is not strictly in accord with a prevalent habit of verbal expression, not only among nautical men, but in ordinary popular language. Thus, a compass is said to possess sensibility when "it is lively," when "it moves quickly," etc., without regard, so far as I am aware, to the condition which I have regarded as essential to the idea of compass-sensibility.

Now, a compass-card, when nicely balanced at a jewelled cap upon the point of a hardened pivot, is extremely susceptible to motive influences from purely mechanical causes, independently of any magnet-power whatsoever in the card. The slightest disturbance actually applied to it may be sufficient to set it in motion. It is true that the motion will be different in certain respects when the card at the same time possesses any magnet-power. But the mere excitability of a compass-card, however great, and whether resulting in vibratory or other motions, cannot be regarded as a true or sufficient criterion of its sensibility from a magnetic point of view.

The intrinsic property of a compass-card, alike with that of a simple magnetic needle, is its tendency to return to its position of magnetic equilibrium whenever deflected from that position; and this is realized under the combined influence of the exterior directive force and its own magnet-power. If it fail in any degree to do this, its most characteristic, not to say its most useful, property is so far imperfect. The question, as it seems to me, is not whether the card is more or less excitable in its movements about its position of rest—for this may depend on several distinct circumstances—but solely whether, in whatever way done, it accomplishes unerringly, and with a nicety of precision that admits of no doubt, its prime function. When it does this—which it never can do except by accident, unless the resistances to motion are so small in comparison to the motive forces as to be uninfluential—then I think that the specific term *sensibility* is both significant and appropriate as the expression of such a fact.

## III.—STEADINESS OF THE COMPASS.

A compass-card is said to be stable, or *steady*, when it maintains its position of equilibrium, under the magnetic forces which act upon it, without sensible disturbance by the various mechanical influences which are liable to be called into action on board ship. A compass may possess sufficient magnet-power and perfect sensibility, and yet be so deficient in steadiness, during the rolling, pitching, yawing of the ship, as to be practically useless. But any apparent compatibility of deficient steadiness with perfect sensibility can only exist for a very brief period; for the effect of much motion of the card must be to blunt or otherwise injure the pivot, or to wear the cap, with the inevitable consequence of increasing the friction, and thereby diminishing the sensibility.

Card-unsteadiness is a mechanical difficulty, and the remedy must be mechanical, so far as it is practicable to have one without compromising the sensibility.

There are two conditions of steadiness, which, at the outset, are always applicable to the cards alike of dry and liquid compasses. These are—

First, that the card shall have a tendency, whenever tilted to one side, to return to its position of horizontal equilibrium. This condition is satisfied by placing the centre of suspension well above the centre of gravity of the card, and also, in the case of the liquid compass, above the centre of buoyancy in the card.\*

Secondly, that the card shall have no tendency to rock in one direction more than in another; that is to say, no tendency to *wobble* about any of its diameters. And this condition requires that the material of the card shall be so distributed as to give equal moments of inertia about all its diameters. It is satisfied by arranging the relatively heavy card-magnets in one or more symmetrical pairs, on equal parallel chords of the card, at certain calculated distances from the centre.

\* The equation of stability of a compass card about one of its diameters may be represented by

$$S - \left\{ (P-B)c \pm Pc \right\} \sin u$$

in which  $P$  is the weight of the card in air acting downward at the centre of gravity;  $B$ , the buoyancy (weight of displaced liquid), acting upward at the centre of buoyancy;  $c$ , the distance between these two centres;  $c$ , the distance between the centre of suspension and the centre of buoyancy;  $u$ , any angle of tilt from the horizontal plane; and  $S$ , the stability; the sign  $\pm$  answering to the two cases of a downward and upward pressure.

But these conditions, although on the side of stability, so far as they go, and quite essential to a well-made compass-card of any kind, fall far short in practice of realizing even tolerable steadiness in the air or dry compass; for, while the card may not be liable to wobble, it is still prone to rock in every direction, and, although prevented from actually tilting over, it is liable to spin entirely round in its own plane under the influence of sharp jars or shocks.

Various remedies have been proposed at different times for this serious defect of the air compass. One of these consisted in fixing several projecting pins upon the upper surface of the card, which, by their friction against the glass cover above, might subdue excessive whirling and rocking motions, although no actual contact need exist while the card was in its more quiet and normal condition.

Another compass, well known and still in use, of a celebrated maker, has the provision of a very heavy card, weighing not much less than ten ounces, supported on a fixed spindle passing through it, with upper and lower bearings; and this arrangement, whenever its resistance to motion proves insufficient, is aided by a *friction-brake*, which may be turned on *ad libitum*, until the card becomes quite steady, as it undoubtedly should with the means at command.

The simplest and probably the best provision of this kind is that of a merely heavy card, with enlarged bearing surfaces at the pivot.

These, however, are not a tithe of the different devices which have been resorted to from time to time, as remedies for the evils of an unsteady compass. I have referred to them merely as illustrations of a kind of relief much resorted to even by intelligent navigators of the present day; and yet they certainly appear no more rational than the recourse of the less-informed skipper, whose little craft, dancing like a cockle-shell upon the waves, infects his compass with an excitement which he endeavors to allay by putting brick-dust in its cap. In principle they are the same. The remedy, so far as it proves effective, consists in the production of a moment of friction capable of counteracting the mechanical excitements to motion.

Without entering into any descriptive details, I think it may be said that the prevailing idea of these provisions is that of a heavier card, with more powerful magnets and the use of more rounded pivots. But, with the increase of pressure and bearing-surface at the pivot, there comes a proportional increase in the moment of friction; and thus, while the magnet-power is increased in a certain ratio, the moment of friction is augmented in a much higher one; so that, on the whole, there

results at the outset a considerable sacrifice of sensibility, attended by a corresponding error of the compass. And this is not all, for these heavier weights develop proportionally greater wear at the pivot; and, if to this be added the possible deterioration of the magnets, it is not difficult to see that, even if the defective sensibility be tolerated at the beginning, the error from this source is liable to become so great, and withal so uncertain, as to make the advantage gained in mere steadiness (never, I believe, very satisfactory at the best) of doubtful value, in view of the possibly very serious sacrifice in precision.

If practicable, therefore, such a remedy should be found for unsteadiness of the compass-card as shall not impair its sensibility. And this we have by combining with the two preceding conditions a third, namely, *that of placing the compass-card in a liquid instead of a gaseous resisting medium.*

By the use of a liquid rather than an air medium, we gain the advantage of the greatly-increased resistance due to the superior density of the former, which, for the liquid likely to be employed, would not be much less than 800 times that of the air. The law of the resistance would be the same in both.

With this provision, the more violent the impulse to motion, the more energetic the resistance; since, as the velocity of the card increases, the resistance of the medium increases in the more rapid ratio of the velocity squared, while, as already noticed, the resistance decreases in the same rapid ratio as the velocity becomes less.

This is illustrated by a glance at the two horizontal rows of figures, of which those in the upper row represent velocities, and those in the lower row the corresponding proportional resistances:

Velocities . . . . .	32,	16,	8,	4,	2,	$1\frac{1}{2}$ ,	$\frac{1}{2}$ ,	$\frac{1}{4}$ ,	$\frac{1}{8}$ ,	$\frac{1}{16}$ ,	$\frac{1}{32}$
Resistances . . . . .	1024,	256,	64,	16,	4,	$1\frac{1}{4}$ ,	$\frac{1}{16}$ ,	$\frac{1}{64}$ ,	$\frac{1}{256}$ ,	$\frac{1}{1024}$	

Thus, a velocity represented by 32 encounters more than 1,000 times the resistance that a velocity of 1 encounters; while a velocity diminished to  $\frac{1}{32}$  encounters a resistance of less than  $\frac{1}{1000}$  of that due to a velocity represented by 1.

Hence the admirable facility with which a liquid compass may adapt itself to such opposite requirements; in one case presenting the most effective resistance for the destruction of all actual motions of the card, however great; in the other, offering the least possible obstacle to such motions, when in small arcs about the position of rest, whether in their incipient or terminal stages.

Nevertheless, the advantages even of a liquid medium are greatly enhanced by a certain auxiliary provision, of sufficient importance to be regarded as a fourth condition of steadiness, to wit, *that of the use of a buoyant skeleton-card with a minimum pressure at the pivot.*

With this provision, the resistance to circular motions is greatly increased, not only from the larger effective section of the card, but also from the larger coefficient due to its skeleton-form; and, at the same time, the evil effects of the severe vertical shocks upon the pivot, experienced by the heavy disk-like cards, are greatly mitigated, in a higher proportion even than the reduction of pressure at the pivot.

Of course, the well-known advantage of the gimbals action is not to be overlooked as a fundamental condition of steadiness. But this provision is a condition of all marine compasses, besides being entirely outside of the compass-bowl. Without this, or its equivalent, no other provision of compass-steadiness would be of any avail whatever, and even the existence of such an instrument as the marine compass impracticable.

I have thus presented an outline at least of the considerations which, in my judgment, should control the construction of the marine compass, upon the basis of the three fundamental properties assumed at the outset to be essential to its most perfect action on board ship.

#### IV.—THE NAVY COMPASS IN THE LIGHT OF THE PRECEDING REQUIREMENTS.

The Navy compass, as already intimated, has the distinctive peculiarities of a buoyant card in a liquid resisting medium; the mean density of the card being so adjusted to the density of the liquid as to produce a small *downward* pressure upon the pivot in the ordinary forms of ship and boat compasses, or a small *upward* pressure against the pivot in the special form of "tell-tale" or cabin compass. The compass-bowl is provided with a self-adjusting expansion-chamber, by means of which the bowl is kept constantly full, without the show of air-bubbles on the one hand or the development of undue pressure on the other, from changes of temperature.

The ship compass of general use has a  $7\frac{1}{2}$ -inch skeleton-card, with provision for one symmetrical pair of magnets, a division on the outer ring to quarter-points, and a card-circle adjusted to the ring, which is divided to half-degrees. The bowl-circle, or outer edge of the rim upon the bowl, is made rigid and turned strictly to gauge, so as to admit of the interchange, from one bowl to another, of every azimuth-circle of

its class. The compass is alike used in the steering-binnacle or for azimuth purposes.

I shall now briefly consider, under the three general heads previously treated, how nearly this compass appears to be capable of satisfying the conditions therein set forth.

*First, with respect to magnet-power.*—The magnet-system of this compass consists of two equal compound magnets, inclosed in parallel tubes in the two chords of the circle, a little within the angle of 30 degrees from the parallel diameter. Each magnet is built up of six laminae; each lamina being  $6\frac{1}{2}$  inches long,  $\frac{1}{16}$  of an inch wide, and about  $\frac{1}{40}$  of an inch thick. Each compound magnet weighs about 880 grains, or a little less than two ounces, with but slight variations.

The steel of which these magnets are made is that known in commerce as “Stubb’s sheet,” which, from numerous experiments by Mr. E. S. Ritchie, has proved to be the best for this purpose, not only for its uniform excellence, but for its magnetic capacity in both intensity and permanence. In this Mr. Ritchie has but confirmed the conclusions of Doctor Scoresby, of thirty or more years ago, as to the superior qualities of this (English) steel for magnetic purposes.

The laminae, having been cut to the proper size, are hardened and tempered throughout their entire length, the process being so conducted as to secure a remarkable degree of uniformity in the results. The magnetization is then effected by means of a very powerful electro-magnet to their utmost capacity. After this, the laminae are separately tested for their relative magnet-power by a deflection-needle, and the angle of deflection marked on each; and, finally, they are laid aside for a little time in promiscuous contact. As required in the formation of card-magnets, these laminae are next subjected to a careful scrutiny, being taken, one by one, and again tested for magnet-power; and every piece which shows any sensible falling off, as compared with the previous test, is thrown out.

Although I was hardly satisfied, a year ago, with certain details in the formation of our card-magnets, I am convinced that the present process, as just described, is substantially in accord with our best knowledge on this subject, and is destined to leave little to be desired in point of completeness and thoroughness for the end to be attained, namely, *to secure the most powerful magnets, compatibly with the condition of the greatest permanency, for given weights of steel.*

As to the actual magnet-power of the Navy compass, it was important to know how it compared with that of other well-known compasses.



For the purpose of a comparison, I selected two 7½-inch cards of well-known English makers, the best of their kind, and designed especially for steadiness, as "heavy cards." One is designated as card "B, 468," the other as card "D, 305," the latter being a spindle card for double bearings. The former has two magnets, and the latter four, in symmetric pairs. Both cards belong to compasses of the collected specimens in my rooms at the Bureau of Navigation, and both appear to be in good condition; but whether either has suffered any loss in magnet-power, as compared with its original condition, I am of course unable to determine.\* The Navy card is one of recent make.

The results of these comparisons, by each of the three methods for finding the magnet-power, are given below.

COMPARATIVE MAGNET-POWER OF THREE COMPASS-CARDS.

I.—By the method of deflections.

Designation of compass.	Relative weights of cards.		Distances between centres.	Angle of deflection.	Relative magnet-power.	
	In units employed.	That of N. C. = 1.				
	<i>Ounces.</i>	<i>Inches.</i>	<i>Degrees.</i>			
N. C. ....	8 $\frac{1}{2}$	28.8	7.4	3102.4	1.000	
B, 468. ....	3 $\frac{1}{2}$	26.8	4.5	1514.6	0.488	
D, 305. ....	9 $\frac{3}{4}$	30.3	9.2	4504.0	1.453	

The observations were taken at equal distances east and west of the needle, and the angle is the mean of the two observations. The needle was three inches long.

II.—By the method of oscillations.

Designation of compass.	Time of oscillation.		Relative moment of inertia.		Relative magnet-power.	
	Of card solely.	With the additional weight.	In units employed.	That of N. C. = 1.	In units employed.	That of N. C. = 1
	<i>Seconds.</i>	<i>Seconds.</i>				
N. C. ....	11.69	12.94	4.441	1.000	0.0325	1.000
B, 468. ....	10.31	12.96	1.725	0.388	0.0162	0.500
D, 305. ....	9.79	10.82	4.520	1.018	0.0471	1.449

The respective times are means of 10 to 16 oscillations; suspension by threads without twist; in small arcs; protected from currents of air.

\* These two cards have always been kept on their pivots, in free suspension, taking their respective positions of equilibrium, in a condition to gain rather than lose in magnet-power. The Navy compass-card has, on the contrary, been kept on a shelf, but with its N. pole toward the north.

## III.—By the method of torsions.

Designation of compass.	Tensions.	Angle of deflection.	Readings of torsion-circle.	Differences of readings.	Angle of torsion.	Relative magnet-power.	
						Mean torsion.	That of N.C. = 1.
	<i>Ounces.</i>	<i>Degrees.</i>	<i>Degrees.</i>	<i>Degrees.</i>	<i>Degrees.</i>	<i>Degrees.</i>	<i>Degrees.</i>
N. C.....	12.5	0	328				
		90 W.	122	154	64		
		90 E.	177	151	61	62.5	1.000
B, 468. ....	11.5	0	108				
		90 W.	234	116	26		
		90 E.	349	119	29	27.5	0.440
D, 305.	12.0	0	291.5				
		90 W.	113.0	181.5	91.5		
		90 E.	112.0	179.5	89.5	90.5	1.448

The tensions for this method were reduced to a condition of approximate equality by the application of weights.

The results by the three methods are in quite close accord, with the exception of that for the card "B, 468," by the method of torsions, the somewhat smaller value of which being due probably to the less favorable conditions under which the observations by torsion were made for that card.

It will thus be seen that the magnet-power of the navy-card, while somewhat more than twice that of card "B, 468," is less than that of card "D, 305," in the ratio of 1.000 to 1.450.

It will also be noticed, in comparing the oscillation-times and moments of inertia in the second and fourth columns of Table II., that a longer oscillation-time is not a certain indication of a lower magnet-power, unless due account be taken of the moment of inertia. Thus, the oscillation-time of the navy-card is about thirteen per cent. greater than that of card "B, 468," but its moment of inertia is nearly three times as great, so that the magnet-power is, on the whole, more than twice as great as that of the latter. On the other hand, as compared with the card "D, 305," the oscillation-time of the navy-card is still greater, but its moment of inertia is actually smaller, so that in this case the magnet-power is smaller, as it should be, than that of the card "D, 305."

Although, as shown by these observations, there is a good comparative degree of magnet-power in the navy-card, my principal doubt is, at present, in regard to the question whether we have yet reached the

practical limit of magnetic development to which the card may be judiciously pushed. No case even of apparent deficiency in the magnet-power of this card has ever been brought to my notice; and my doubt on the point is, therefore, not based on the supposition of actual deficiency in this respect for ordinary circumstances, so much as on the conviction, heretofore expressed, that the compass-card should always possess a liberal reserve of magnet-power—up to the very limit which may be imposed by other conditions of card-construction—in order to provide for those large fluctuations in the directive force the effect of which might be to seriously diminish the moment of motive force, and thus to proportionally increase the defect of sensibility.

With respect to the question of magnetic permanency, our experience is too recent with the present process of magnet-formation to permit the expression of any opinion as based upon actual results. This, however, may, I think, be said: that the recent changes in some of the details of that process are precisely such as, while obtaining a somewhat higher average of magnet-power in the magnet-piles, are well adapted to secure the most reliable state of permanency.

It should not be inferred that our previous experience has been particularly unfavorable with the results of the old process. So far as I am aware, not an instance has occurred, within several years past, of a reported discovery of any serious declension in magnet-power of the navy compass. Still, this is a kind of negative evidence, to which I am inclined to attach very little value, in the face of one positive fact to the contrary; and I hope to have the means hereafter of ascertaining the facts, on the return of our compasses to store after considerable periods of service on board ship.

In this respect, as in many others, there is an important advantage in favor of the navy compass—that the compass-card, being always delicately balanced on its pivot in the bowl, is in the best practicable condition for maintaining its magnet-power, other things remaining the same.

But, whatever may be revealed hereafter by a closer enquiry into the facts of our navy experience with the present form of compass, I am fully convinced that magnet deterioration is a much more prevalent and more serious evil than it is generally supposed to be by nautical men. I have had occasion, within a year past, to notice a number of instances of this kind, some of which were serious enough, and in one or two instances where I least suspected it, and by which I was considerably astonished.

The whole subject of the magnet-power of a marine compass, in its twofold aspect of intensity and permanency, has appeared to me of such fundamental importance that I have determined to devote some time to

its special study, with the hope that I may be able to clear up certain points not now as well established as I should be glad to have them.

*Secondly, with respect to sensibility.*—It will not be very difficult to understand why the navy compass should be expected to possess a high degree of sensibility.

Keeping in mind the condition already stated, that the defect of sensibility is equal to the moment of friction divided by the product of the magnet-power and directive force, let us consider the actual relations of these elements in the navy compass.

Now, as to this compass, the mean density of the submerged card admits of being so adjusted to the density of the liquid as to secure any desired buoyancy, and consequently produce any desired pressure of the card upon the pivot, however small, and whether upward or downward.

The minimum pressure at the pivot of the seven and a half inch card has thus been adjusted to about *sixty grains*, at the mean temperature of sixty degrees Fahrenheit, in order to provide for the variations of temperature and consequent changes in the density of the liquid ordinarily encountered at sea. It is necessary and sufficient that the least pressure to which it may ever be reduced shall be such as to secure actual contact at all times between the cap and the pivot; and, on the other hand, it is desirable that no greater excess of pressure should be had, beyond the prescribed mean limit, than what is actually sufficient to satisfy the first condition

It should be understood that these conditions of the card-pressure at the pivot are alike applicable, or nearly so, to the ordinary case of the downward pressure and to the special case of an upward pressure.

The relations of these pressures, downward and upward, to certain specified temperatures, for a liquid of normal mixture, at a pressure of fifty-eight grains at sixty degrees, have been noted by Mr. Ritchie, as shown in the subjoined table :

Temperature of liquid.	Pressure at Pivot.	
	Downward.	Upward.
<i>Deg. Fahr.</i>	<i>Grains.</i>	<i>Grains.</i>
85	88	28
60	58	58
20	27	89
13	18	98

Again, so far as the choice of materials for the cap and pivot and the forming of the bearing-surfaces are concerned, the advantage is still with the Navy compass; for, inasmuch as the bearing-pressure of the card is so greatly reduced, it will be allowable to use still harder materials and more sharply defined pivots than would be admissible in air compasses of the same size, whose lightest cards seldom fall below fifteen hundred grains; and hence it follows that not only the mean radius of the bearing-surface, but the coefficient of friction, may be reduced to smaller values than they could have with the best possible form of air-compass card.

Accordingly, the moment of friction of the Navy compass is materially smaller than that of any air compass. Thus, without placing any estimate on the possible reduction of the two elements just named, the pressure alone, as compared with that of the lightest air-compass card, is not more than one twenty-fifth part, while it may be less than one-sixtieth part as compared with that of the heavier cards.

And to this must be added the further advantage in favor of the Navy compass: that, in consequence of the extremely small working-pressure of the card, the wear of the cap and pivot is so small, even during all the vicissitudes of the longest cruise, as not to materially increase the friction or diminish the sensibility. In some instances a perceptible wear of the agate in the cap has been observed on the return of the compasses for examination; but in general the change is scarcely appreciable.

We have, then, in brief, two signal advantages of the Navy compass in point of sensibility: first, that of the extreme smallness of the moment of friction; and, secondly, that of the proportionally small liability to change of that friction. And the second is scarcely inferior in importance to the first.

How much should be added, if anything, for the friction of the liquid in the cap, is a question which cannot be readily answered with the present state of our knowledge on this subject. That it must be very small, if, indeed, it be an appreciable element in the resistance of friction, appears quite certain, in view of such direct observations as I have been able to make on the sensibility of these compasses.

In order to illustrate the preceding view by the facts of experience, I shall first give the results of some recent inspection-tests for sensibility of a number of new Navy compasses received from the makers.

The test for sensibility consists in bringing the vertical cross-hair of a telescope into precise coincidence with a division on the card-circle—as, for example, one of the zero-divisions; then deflecting the card a few degrees\* to one side by means of a small magnet, and allowing it

\* The smaller deflections are generally more severe tests than the larger ones.

to come to rest, to note the angle of set or defect of sensibility. The card-divisions are half-degrees; and it is not difficult by means of the telescope to estimate tenths of a division, or twentieths of a degree, and to appreciate still smaller parts—as small even as one-sixtieth of a degree.

The tests were actually made by deflecting the card  $3^\circ$ , first to one side and then to the other, waiting in each case for the card to complete its vibrations and come to a perfect rest, before noting the deviation of the zero-division from the cross-hair. I thus obtained the following results, in an examination of 16 No. 1 or  $7\frac{1}{2}$ -inch Navy compasses:

	<i>Def.</i>	<i>Set.</i>	
Of 12 compasses.....	{ $3^\circ$ E.	0 <sup>o</sup> .00	Not appreciable.
	{ 3 W.	0 .00	Not appreciable.
Of 1 compass.....	{ 3 E.	0 .00 + W.	Appreciable.
	{ 3 W.	0 .00	Not appreciable.
Of 1 compass.....	{ 3 E.	0 .00	Not appreciable.
	{ 3 W.	0 .00 + W.	Appreciable.
Of 1 compass.....	{ 3 E.	0 .00 + W.	Appreciable.
	{ 3 W.	0 .00 + E.	Appreciable.
Of 1 compass.....	{ 3 E.	0 .05 W.	Error of 3' W.
	{ 3 W.	0 .05 W.	Error of 3' W.

It is so seldom that any appreciable defect is observed in the tests for sensibility of these compasses that I am led to regard them, in their normal condition, as in this respect practically perfect.

I think it needs but a single observation, with the cross-hair of a telescope nicely adjusted upon a division on one of these cards, to be convinced of its exceeding delicacy of action. By observing in this manner the behavior of a card after being deflected, as it approaches its final position of equilibrium, it will be seen to perform a series of minute oscillations about that position, so small and relatively so slow as to be scarcely appreciable by the unaided eye; suggesting most conclusively, I think, as already indicated on theoretical grounds, not only that the resistance of the medium at this stage is practically evanescent, but that the friction itself must be extremely small, in order that the moment of the motive forces acting at such small angles should be capable of overcoming it.

It might naturally be asked, after what has been said of the Navy compass, How does the test for sensibility result when applied to other compasses? In answer to such a question, I present the results of a few observations upon compasses of different makers, from the collection at

the Bureau. With the exception of the three Navy compasses, they are all imported specimens of English makers; partly liquid and partly air compasses. None has ever been in service, and all are kept with the cards freely suspended upon their pivots.

In making the experiments the zero or N point of each card was first adjusted to nice coincidence with the east side of the *lubber-line*, and the deflections were made with the aid of a small magnet.

Navy, 6½-inch, No. 4794.		D, No. 1514 (liquid).		Navy, 7½-inch, No. 6211.		Navy, 10-inch, No. 4725.		H, 6½-inch (air).		D, No. 468, card J (air).		D, No. 305 (air), 7½-inch.		W (liquid).	
Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.	Def.	Set.
<i>Pts.</i>	<i>Pts.</i>	<i>Pts.</i>	<i>Pts.</i>	°	°	°	°	<i>Pts.</i>	<i>Pts.</i>	°	°	°	°	°	°
1-2 E.	0	1-2 E.	0	5 W.	0.0	6 E.	0.0	1-2 E.	3-16 E.	5 E.	1.3 E.	5 W.	0.6 E.	6 W.	5 W.
1-2 W.	0	1-2 W.	1-16 E.	5 E.	0.0	6 W.	0.0	1-2 W.	1-8 W.	5 E.	0.0	5 E.	0.6 W.	19 E.	15 E.
3-4 E.	0	1 W.	1-8 E.	10 W.	0.0	10 E.	0.0 E.	1-2 E.	1-8 E.	5 W.	1.7 E.	5 E.	0.1 W.	9 W.	6 W.
3-1 W.	0	1 E.	1-8 W.	10 E.	0.0	10 W.	0.0 W.	1 E.	3-16 E.	5 W.	1.7 E.	5 E.	0.3 W.		
		2 E.	1-16 W.			20 W.	0.0	1 W.	3-16 E.	5 * W.	2.0 W.	5 E.	0.5 E.		
		1 E.	1-8 W.					1-2 W.	3-8 W.	5 E.	2.0 W.	5 W.	0.7 W.		
		1 W.	1-8 E.					1-2 E.	3-16 W.	5 E.	2.0 W.	5 W.	0.1 W.		
										5 W.	0.1 E.	5 W.	0.2 W.		
										5 W.	0.6 E.	5 W.	0.3 W.		
										5 W.	0.7 W.	19 E.	0.5 E.		
										5 E.	2.0 W.	10 W.	0.8 W.		
												20 E.	0.1 E.		
												20 W.	0.2 W.		
												40 E.	1.0 W.		
												45 E.	0.1 W.		
												45 W.	0.7 W.		

Those experiments which are preceded by a \* were made after having readjusted the N point of the lubber-line.

It has not been my purpose, in giving these results, to suggest comparisons which should be regarded as in the least degree invidious; nothing could be further from my own taste or the temper of mind with which these or any similar inquiries should be conducted. The compasses are of excellent workmanship, as those which I have seen of the well-known London makers generally are; and their deficiencies in this respect are to be attributed to the inherent defects of construction, if, at least, the preceding views are accepted; namely, to the sensibly large moment of friction (as compared with that of the Navy compass), and in one or two instances to the added defect of insufficient magnet-power, both of which, as we have seen, concurring in the production of an angle of set, or defect of sensibility.

*Thirdly, with respect to steadiness.*—The Navy compass is hardly less remarkable for steadiness than for sensibility. For this there are several reasons:

First. In the elevation of its centre of card-suspension, decidedly above both the centre of gravity and centre of buoyancy of the card.

Secondly. In the distribution of its heavy weights, not concentric with the centre, in two equal parallel chords, a little within the angle of 30 degrees from the parallel diameter, thus securing nearly equal moments of inertia about all diameters of the card.

Thirdly. In the use of a liquid-resisting medium, with the advantages resulting therefrom.

Fourthly. In the use of a buoyant skeleton-card, adjusted to a very small pressure at the pivot, from which result the several advantages in favor of steadiness already enumerated under the general head.

Fifthly. In the preponderating inertia of the liquid mass over its friction against the interior surface of the bowl, in consequence of which any sudden impulse given to the latter causes it to slip over or round the liquid without communicating any sensible motion to it and through it to the card.

A remarkable illustration of the steadiness of the Navy compass came under my observation, a year or two ago, at the Messrs. Ritchie's, in Brookline. One of the earliest appliances devised by Mr. Ritchie, Senior, for the practical study of the behavior of a marine compass, is a very effective arrangement for testing its steadiness. This apparatus, which was erected in the attic story of the workshop, consisted of a strong frame-work, with moving parts on opposite trunnions, so as to admit of giving to a projecting head-piece rolling and pitching motions, mingled with occasional severe jars and shocks of the most exaggerated kind. He called it his "model of a ship"; but a ship could hardly live in a sea that would cause such motions.

I mounted this arrangement on one occasion with Mr. Ritchie, when we had one of the Navy  $7\frac{1}{2}$ -inch compasses and one of the  $7\frac{1}{2}$ -inch air compasses of the best construction. The two compasses were placed side by side on the projecting head-piece, about three feet apart. The effect, as seen by us from our more elevated position, was sufficiently striking. The card of the air compass not only would roll and vibrate in the most extraordinary manner, but frequently spin round and round; while the card of the liquid-compass had hardly any appreciable motion, the only apparent motion being a slight swing from left to right, and from right to left, and even this was synchronous with the alternate motions in azimuth of the head-piece on which the compasses were placed. Although I made no measurements to strictly confirm this impression, I could hardly resist the conviction that the small apparent motion of the card was in reality



due to the actual swing in azimuth of the lubber-line. It seemed to me, from such a test, that the steadiness of the liquid-compass might justly be regarded as sensibly perfect.

Before concluding my review of the Navy compass, in which I have not hesitated to set forth with some prominence its manifold advantages, I should not omit, I think, to mention its defect, not as a peculiarity of this compass, but as inherent to the construction of all liquid compasses. It is the practical difficulty in effecting readjustments of the card equilibrium, if found necessary for the correction of defective horizontality, resulting from any considerable changes in the magnetic dip.

This difficulty is simply one of inconvenience in opening the bowl to gain access to the card. It is easily enough managed by a person accustomed to it, with the appliances of the workshop, but it is a rather troublesome operation under different circumstances.

At present, the only remedy is the provision previously mentioned as one of the mechanical conditions of a steady card, namely, that of elevating the centre of suspension "well above" the centre of gravity of the card. By this means, it is intended to give to the card such an excess of stability as to overcome its tendency to obey the varying vertical component of the earth's magnetic force in different magnetic latitudes. That this provision is sufficient, within moderate limits of the change of dip, to prevent any appreciable error from defective horizontality, is, I think, quite probable; but how far it may be relied on, under more extreme changes, is a question that must be settled by careful observations with the opportunities that may be furnished by practical experience. So far as I am aware, not an instance has been reported to the Bureau of Navigation, during all the Navy experience with this compass of any difficulty in this particular, or of any apprehended error from this source.

But, as remarked in another case, merely negative evidence (or, in this case, the absence of any express reference to this matter in the reports of navigating officers) can hardly be accepted as conclusive that it is entirely safe to neglect this possible source of error when sailing in high southern latitudes.

Nevertheless, I apprehend no serious difficulty in providing a practical remedy for this trouble, should it ever be deemed necessary or expedient.

Another objection has sometimes been made to this compass, that it is inconvenient to handle, as a portable instrument, on a tripod for observations on shore. This I shall dispose of in a word by saying that I

can conceive of no occasion for the use of any marine compass on shore, when a good surveying compass, costing less than a third as much, would not be greatly preferable for convenience in handling, facility of use, and precision of results.

#### CONCLUSION.

I had originally intended to include in this communication some remarks on the several instrumental errors to which the marine compass is liable, besides the defective sensibility already noticed—errors essentially of compass-adjustment; and, especially, to have given some account of the adjustments of the Navy compass and of the degree of precision actually attained, as shown by our recent inspection-tests; but this must be deferred to some other occasion. It may suffice to say that I believe the Navy compass is susceptible of a high degree of precision, and that it may be furnished to the service in a condition which shall be practically perfect in this respect. I have said nothing of the *azimuth-circle*, because the compass itself is what claims our first attention; it being wholly fallacious to expect reliable results with the use of an azimuth-circle, however excellent, upon a compass which is liable to serious errors of adjustment and of defective sensibility.

It has doubtless been presumed, from the general tenor of what has been said on compass sensibility, that considerable importance is attached to this as one of the instrumental errors of the compass. In reality, I believe its importance can scarcely be overestimated. The errors of adjustment, even when quite large, are at least of a fixed character, and, if once definitely ascertained, may either be disregarded in ordinary cases of setting courses and in working up, or possibly allowed for in cases of greater urgency. It is otherwise with the error from defective sensibility. This, even at the outset, may be sufficiently serious; but, whether more or less so, there can be no certainty with air compasses, however excellent in workmanship, as to the amount of this error a few weeks later after a little rough weather at sea.

It is sometimes asked, Of what use is all this refinement of an instrument (generally concluded to be incapable of precision), so long as the navigator is unable to profit by it, and when, if he could, he is well enough satisfied if he can steer his courses to the nearest quarter of a point?

To this it may be said that, if we concede the sufficiency of such steering in an open sea (although there may be some who might regard it as hardly close enough in these days of “swiftest transit by the shortest

route"), how is the navigator to be certain of doing even that with a compass whose instrumental errors, unknown alike in name and amount, may be much greater than the assigned limit to his error of observation; and especially when, in addition to the assumed errors of observation and the unknown errors of the instrument, the compass error is further complicated by the uncertainties of the variation and the deviation?

My own conviction is, as the result of considerable study of the subject, that, in view of the inevitable errors of observation to which the compass is liable under the trying circumstances of its use at sea, it should be our object, in the first place, to insure in the construction of this instrument not only its practically perfect condition when put on board ship, but its continuance sensibly in that condition during at least one cruise of the ship; and, in the second place, to facilitate the determination of the magnetic variation and compass deviation, considered as compass errors in the reduction to the meridian, and to bring the uncertainties of these determinations within such definite limits as it may be possible to assign with a sufficient knowledge of the circumstances of the case.



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## THE ARMAMENT OF OUR SHIPS OF WAR.

BY CAPTAIN W. N. JEFFERS, U.S.N.

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### INTRODUCTORY OBSERVATIONS.

REASONING from the numerous applications made by commanding officers to the Bureau of Ordnance, as soon as they join their ships, for some change of battery, it must be a general belief that the total weight and character of the guns is determined hap-hazard, and without any reference to known principles.

In fact, the writer can call to mind only two or three instances during the many years in which he has been conversant with the affairs of this branch of our Naval establishment where some change has not been proposed, generally on insufficient grounds, and often without any reasons being assigned, except a desire for change.

The object of this paper, therefore, is to remove these erroneous impressions, and to point out the basis on which the assignment of total weight and character of the guns composing a ship's battery is made.

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### THE ARMAMENT OF OUR SHIPS OF WAR.

The main points to be considered in determining the armament of a ship are :

1st. That the aggregate weight of the guns should be in proportion to the tonnage.

2d. Having decided what this weight shall be, the next point of importance is to dispose of it in the best manner to develop the greatest power of which it is susceptible.

3d. The relation of the battery to the speed of the vessel; for although it is absolutely necessary that a ship of war should exercise a full power of offence and defence within the circle of which she is the centre, next to this, and to this only, in importance, is her ability to transfer this power to another point with certainty and rapidity.

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We will proceed to consider these points *sciatim*:

If we were about to evolve the battery of a ship from our inner consciousness, we should find the subject surrounded with many difficulties. But, fortunately, the gradual progress of naval construction enables us to proceed with cautious but certain steps from the known to the unknown without risk of serious error.

To exemplify our first point, we may take the old sailing frigate *Constellation* as a type of what was considered to be, at the time she was built, a well-armed ship. Her tonnage was 1,226, and the battery consisted of thirty 18-pdr. cannon on gun-deck, and sixteen 22-pdr. carronades on the spar-deck, weighing in the aggregate 160,700 lbs., and throwing a broadside weight of 530 lbs. of shot.

In 1845, the Ordnance Board recognized the importance of reducing the number of guns and increasing the calibres, and assigned a battery of thirty-eight 32-pdrs., weighing 174,048 lbs., throwing a broadside weight of metal of 674 lbs., and 22 lbs. of explosive material.

In 1853, her sister ship, the *Macedonian*, carried a battery of two 10-in. in pivot, sixteen 8-in. and two 32-pdrs. in broadside, weighing in the aggregate 158,422 lbs., and throwing a broadside in metal of 672 lbs., with 26 lbs. of explosive material.

Finally, Admiral Dahlgren proposed for these ships a battery of eighteen 9-in. guns, weighing 164,000 lbs., broadside weight of metal, 721 lbs., with an explosive content of 30 lbs.

It will be observed that in these changes, made by competent authority, the relation of weight of battery to tonnage of ship was closely adhered to, while augmenting the power of the armament by reducing the number of guns and increasing the calibres.

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With the first introduction, however, of steam into the navy, a departure from the law of relation of armament to tonnage of ship became

unavoidable, because the pioneer paddle-steamers did not afford the requisite room and conveniences for proportionate batteries. It was evident to all seamen that the few guns carried by these vessels were entirely disproportionate to their tonnage, and the success of the screw was at once accepted by our best thinkers as a solution of the problem. The *Princeton*, the felicitous conception of Commodore Stockton, was a move in the right direction, which we failed at the time to follow up, and still continued to build side-wheel steamers.

Even after the screw was determined on as the motor, there was manifested a great indisposition to sacrifice gun-power to facility of shifting one's position; and, although the five frigates of the *Wabash* class had only auxiliary power, the conservative spirit of the day reduced the effective force of the battery one-fourth by substituting on the spar-deck 8-in. and 10-in., in lieu of 9-in. and 11-in., as originally assigned. This defect, however, has since been remedied by the unification of the broad-side battery, and the ships of this class now carry a weight in guns better proportioned to their tonnage, though not excessive, viz., forty-two 9-in., two 11-in., and two 100-pdr. rifles.

We may remark, in connection with these ships, that the plans of Admiral Dahlgren contemplated for all of them an entire spar-deck battery of 11-in. guns; and the details exist for mounting six on the spar-deck of the *Franklin*; in which, however, he was overruled. The *Niagara* alone was the first ship to realize the conception of speed and power combined; but owing to faults of construction, she never was a favorite ship.

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We next come to vessels of the *Hartford* class, which were constructed to carry a respectable armament combined with full power of movement.

If we assume these ships to have been well armed, as is admitted by every one, and take the ratio of weight of battery to tonnage, the lightest armed (*Hartford*, *Richmond*, sixteen of 9-in. in broadside) will give us a factor of 108 lbs. of gun to each ton. The heavier ships of the class, *Brooklyn*, *Pensacola*, armed with twenty 9-in. and one 11-in., give a factor of 130 lbs. to the ton.

Applying the least of these factors to the later full-powered ships of the *Plymouth* class, we have a total weight of battery of 121,176 lbs. = fifty-four tons, proportionate to their tonnage.

Now, these ships were originally designed to carry two 11-in. in pivot;

but, for constructor's reasons, the after-pivot was omitted, and the battery modified to consist of—

<i>Guns.</i>	<i>Weight of Broadside.</i>
One 11-in. . . . 16,000 lbs.	136 lbs. (shell).
Six 8-in. . . . 39,000 "	150 " "
One 60-pdr. . . . 5,000 "	60 " "
<hr/>	<hr/>
60,000 lbs.	346 lbs.

a weight of guns and broadside entirely disproportionate to their tonnage.

Substitute six 9-in. for the 8-in. increases the weight of battery and of broadside to 75,000 and 400 lbs. respectively. But, in fact, these ships should carry—

<i>Guns.</i>	<i>Weight of Broadside.</i>
One 11-in. . . . 16,000 lbs.	136 lbs. (shell).
Ten 9-in. . . . 90,000 "	350 " "
One 60-pdr. . . . 5,000 "	60 " "
<hr/>	<hr/>
111,000 lbs.	546 lbs.

It may be claimed, however, by some that these ships have not sufficient breadth for the 9-in., and that their deck-beams and scantling are too light to support such weights. If this be really the case, then we would propose, as a compromise, for such a ship, an armament of—

<i>Guns.</i>	<i>Weight of Broadside.</i>
Three 11-in. . . . 48,000 lbs.	468 lbs. (shell).
One 100-pdr. . . . 9,200 "	100 " "
<hr/>	<hr/>
57,200 lbs.	508 lbs.

which, with a less weight of guns than the battery first assigned, would give a power of 508 to 346.

It is also to be observed that the pivot-carriages cover so many of the beams, and the weight being thus distributed over a greater surface, the 11-inch strains the vessel less than the 9-in. mounted at the side on a Marsilly carriage.

From actual measurement, however, it appears that the ships of this class have at least five (5) ports of a side, which will allow the muzzle of a 9-in. gun to come twelve inches inside the port, affording ample space for loading and sponging in actual firing, at which time trifles generally disappear. In mere exercising, there may not be convenient space for the in-tackle blocks, but this inconvenience is surely not of so much importance as to sacrifice to it the grave consideration of calibre.



We next essayed two classes of vessels, with different powers, in the effort to realize the idea of a fast gunboat, heavily armed with cannon of great range and accuracy. To these belong the *Ticonderoga* (1,049 tons) and the *Wachusett* (695 tons).

Both of these ships are melancholy examples of the incoherent reasonings of their several commanders and of the desire of the Bureau to satisfy their wishes.

To the *Ticonderoga*, Construction assigned 78 tons for armament, of which only 22 tons were for guns and howitzers.

The Bureau of Ordnance therefore determined upon three of 11-in., with four 24-pdr. howitzers; but before the vessel was finished, the 150-pdr. (8-in.) rifle made its appearance, and the battery was modified to—

## FIRST BATTERY.

		<i>Weight of Broadside.</i>
Two 11-in.....	32,000 lbs.	272 lbs. (shell).
One 150-pdr.....	16,000 “	150 “ “
Four 24-pdr. howitzers..	.....	---
	48,000 lbs.	422 lbs.

(Howitzer weights are omitted as too light to affect the question.)

This was an excellent arrangement, combining range, power, and facility of handling.

Her first commanding officer, however, wished to have some broadside guns; therefore, in order to satisfy him, the detail was changed, and the first battery actually mounted was—

## SECOND BATTERY.

		<i>Broadside.</i>
One 11-in. . . .	16,000 lbs.	136 lbs. (shell).
One 150-pdr. . .	16,000 “	150 “ “
Four 9-in. . . .	36,000 “	144 “ “
One 50-pdr. . . .	5,000 “	50 “ “
Two 24-pdrs.	.....	--
	73,000 lbs.	480 lbs.

Here the absolute weight of battery was increased one-half, while its power of broadside remained practically the same, but imperilled by the introduction of two new calibres, and a diminished facility of handling in a sea-way.

A few months after, at the request of her commander, sanctioned by the commandant of a navy-yard, there was substituted a

## THIRD BATTERY OF

Twelve 9-in. broadside . . . . .	432 lbs.
One 100-pdr. pivot . . . . .	100 "
117,200 lbs.	532 lbs.

Unfortunately, this 100-pdr. rifle burst during the first attack on Fort Fisher, and the ship went into a second action with fourteen of 9-in. in broadside. (This battery was shortly after landed at Philadelphia.)

The ship was now ordered to be fitted out for a foreign station, and the original weights restored; but the foremast having been shifted, and a forecastle built upon her, there remained only room enough for *two* pivot guns; therefore, there were mounted as a

## FOURTH BATTERY,

		<i>Broadside.</i>
Two 11-in. . . . .	32,000 lbs.	272 lbs. (shells).
Two 9-in. . . . .	18,000 "	72 " "
One 60-pdr. . . . .	5,000 "	60 " "
Four 24-pdr. how's. . . . .	----	--
55,000 lbs.		404 lbs.

(This battery was reported by her commander as altogether inadequate.)

It will be observed that in all these changes of battery, the original idea was lost sight of. However, the ship having now become deprived by natural causes of the prime element of speed, it only remained for the Bureau to make her as formidable as her construction would admit of to all enemies which might come or be brought within her reach; and reverting to the factor of weight proportionate to tonnage, we have 110,100 lbs. to be distributed in a

## FIFTH BATTERY OF

		<i>Broadside.</i>
Two 11-in. . . . .	32,000 lbs.	272 lbs. (shells).
Eight 9-in. . . . .	72,000 "	248 " "
104,000 lbs.		520 lbs.

which gives a fair mixed battery for pivot and broadside, and tends to supply the deficiency of weight on the spar-deck, which is needed to modify the heavy roll of this class of vessels.

The other ships of this class are to be similarly armed, after having experienced, however, a round of changes which would give a dozen different batteries.

The *Wachusett* was particularly the exponent of the "cooper-around-the-cask" idea—a swift, handy, light-draught, powerfully-armed craft, which should be able to keep the sea, in all weather, under canvas.

The armament assigned was—

FIRST BATTERY.		<i>Broadside.</i>
Two 11-in. . . . .	32,000 lbs.	272 lbs.
Four 32-pdr. 27 cwt. . . . .	12,096 "	52
One 30-pdr. rifle . . . . .	3,500 "	30
One 20-pdr. . . . .	-----	..
	<hr/>	<hr/>
	47,596 lbs.	354 lbs.

Commodore Wilkes, who had his flag on board when she first fitted out, proposed an alteration of the battery to—

SECOND BATTERY.		<i>Broadside.</i>
One 100-pdr., 9,200		320
Ten 8-in. 55 cwt., or twelve 32-pdr. 43 cwt., 61,600 or 57,792 lbs.		or
One 30-pdr. rifle, 3,500 lbs.		267

He argued that the removal of the heavy 11-in. guns, and a distribution of their weight in broadside, would tend very much to prevent the vessel from rolling so much. Said he :

"As for using the large pivot-guns, it is entirely out of the question in a sea-way.

"There is not an officer under my command but is satisfied with the inadequacy of the armament of these vessels, and the uselessness of having such large and heavy calibres"; and he recommended a broadside battery for all small steamers then in commission.

This subject of broadside and pivot-guns will be discussed further on ; but my own experience is that the 11-in. can be cast loose and handled in a sea-way when it would be difficult and dangerous with the broadside guns.

The vessels of the *Wachusett* class were not intended to perform the functions of a broadside vessel like the old frigates and corvettes, as it is evident they would be very feeble in this respect, the weight thrown from their broadside not exceeding 300 lbs.

But they were intended to have high speed, so as to overtake or leave broadside-armed vessels, and harass them by deliberate practice with a few heavy shells at ranges where the guns of broadside could not reach.

Their light draught was also to permit them to move in shoal water not accessible to heavy vessels.

If the vessel was deficient in the primary condition—speed—the proposed change in battery would not afford a remedy.

As regards excessive roll, *that* belongs to all propellers, and increasing the weights should moderate the movement; but it does not appear that this can be carried to a profitable extent for want of capacity, nor is there sufficient room for 9-in. guns.

However, her armament has been increased to a

THIRD BATTERY OF		<i>Broadside.</i>
Two 11-in. . . . .	32,000 lbs.	272 lbs.
Four 9-in. . . . .	36,800 “	140 “
Three 20-pdr. rifles . .	3,900 “	40 “
	72,700 lbs.	452 lbs.

This battery is reported as “too heavy,” “not room sufficient for 9-in. guns,” etc.—facts entirely within the cognizance of the Bureau, but overlooked by commanding officers in their desire to secure increased number of men.

There have also been added to the ships of the *Ticonderoga* and *Wachusett* classes poop-cabins and forecastles; the weight of these, added to that of the battery and supplies, without doubt increased the comfort of everybody on board, but converted the ships into “tubs” which inefficiently perform any service.

The *Junitta*, *Ossipee*, and *Mohican* have had even greater changes.

The light cruisers of 410 tons—*Kansas* class—were designed to carry the 10-in. Parrott rifle (300-pdr.) of 26,000 lbs., but such guns were never provided, and the vessels were, therefore, heterogeneously armed. At the end of the war the

*Kansas* carried one 11-in., two 9-in., one 30-pdr. rifle;

*Nipsic* carried one 11-in., one 30-pdr. rifle;

*Nyack* and *Shawmut* carried one 100-pdr., two 9-in., one 30-pdr. rifle, two 24-pdrs;

*Yantic* carried four 9-in., one 30-pdr. rifle;

*Saco* carried one 60-pdr., six 32-pdrs., one 30-pdr. rifle;

*Pequot* carried one 150-pdr., six 32-pdrs., one 30-pdr. rifle, two 24-pdrs;

while the battery originally assigned to these ships was

One 300-pdr. rifle,

Two 24-pdr. howitzers.

Sufficient has been stated to show the principles on which the armament is based.

*First*, the aggregate assigned to ordnance by the Naval Constructor in distributing his weights.

*Secondly*, the weight of battery, which experience shows can be safely and conveniently carried; which is from one-third greater to double that allowed on the given displacement.

*Thirdly*, the smallest number and heaviest pieces which can be conveniently handled, having due regard to space and tonnage.

It is to be observed that, since the introduction of full power into steamers, the space below has to be carefully apportioned; and that the addition of even a single gun with increase of crew crowds the magazine, shell, and store rooms, and cumpers the berth-deck.

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Having, then, determined the *total* weight of battery for a given tonnage, next in importance is its distribution, with a due regard to the accuracy, power, and range of the guns.

The power of a ship of war may always be in proportion to her capacity, and the largest ship can always be made the most powerful in offence as well as defence; the smaller ship, on the contrary, can never be made more effective than the larger, unless the means of the latter are misapplied.

It has always been urged that a small vessel, with a single heavy gun, can annoy and injure a larger vessel having, like itself, only a single heavy gun.

But when the large vessel can bring several heavy guns against the one gun, the chances are increased in the same ratio, and the one gun cannot attack with impunity.

One of the first elements to be considered is the ability to handle the projectile in the confined quarters of a ship, subject to violent motions of rolling and pitching. For obvious reasons, only one man can conveniently handle the shot of a broadside gun, and but two that of a pivot gun; and experiment proves that the 9-in. and 11-in. are the largest shells which can be so handled with ease.

There are, however, many persons of the opinion that some smaller calibre, 32-pdr. or 8-in., substituted in broadside for 9-in., may by celerity of fire, and being more numerous for the same weight of battery, more than compensate for diminished accuracy and power.

This is entirely fallacious, and has been completely refuted by Admiral Dahlgren in "Shells and Shell-Guns."

But we will here repeat the argument.

The reasoning in favor of the 8-in. against the 9-in. is that, with the same weight, one can have more cannon, and, firing faster, the weight of metal thrown is much increased.

This argument is not new; it was offered in 1812 by the English for preferring the 18-pdr. to the 24-pdr., and has no better foundation now than it had then.

The 8-in. weighs 6,500 lbs., the 9-in. 9,200 lbs., the rates being 65-92, or nearly two-thirds—that is, three 8-in. cannon weigh as heavy as two of 9-in.

The 8-in. throw three shells of 51 lbs. = 153 lbs.; the 9-in. two of 72 lbs. = 144 lbs.

In actual trial at the battery here, the 9-in. gun has been fired five rounds at an average of 53 seconds per round.

Is it likely that an 8-in. gun can be fired more rapidly?

On board the *Plymouth*, commanded by myself, and then cruising as the ordnance ship, a trial was made for rap'd firing, with the following results:

U. S. SHIP PLYMOUTH,  
OFF CAPE CATOCHE, Sept. 10, 1858.

Guns manned by the regular crews:

17 to 9-in. and 15 to 8-in.

Guns run in and all ready.

	9-IN.		8-IN.	
	<i>Min.</i>	<i>Sec.</i>	<i>Min.</i>	<i>Sec.</i>
Sponge	28	40	28	40
Fire	29	25.45	29	25.45
"	20	12.47	30	12.47
"	30	57.45	31	00.48
"	31	47.50	31	55.55
"	32	38.51	32	59.64

Average time of fire, 47½.

Shifted the 15 from 8-in. and 15 from 9-in., leaving the roller hand-spikeman and one other.

	<i>Min.</i>	<i>Sec.</i>	<i>Min.</i>	<i>Sec.</i>
Sponge	45	00	45	00
Fire	45	30.30	45	30.30
"	46	7.37	46	6.36
"	46	44.37	46	40.34
"	47	23.30	47	22.42
"	48	3.40	48	3.41

Average time of fire, 36½.

Both crews had been under careful drill for more than three months.

Of course, no other pointing was possible than to preserve the guns nearly in their original position when fired.

The *celerity* of fire, then, from the 8-in. and 9-in. guns will not vary materially under like circumstances.

At the same time I may remark that every officer knows that the time required to load, fire, and run out is never the standard for accurate practice; that is controlled on shipboard by the difficulty of pointing amidst the smoke, and disturbed by the rolling and progressive motions of both ships, etc.; so that, as a general rule, under fair conditions, the rate of good firing may be two to three minutes.

The original difference in weight of metal thrown by the 8-in. and 9-in. guns should not be affected, therefore, by the *rate of fire*.

But it will be influenced by another condition, not generally considered in estimating the value of the lighter guns, viz., *the inferior accuracy of the inferior calibre*.

That of both guns has been tried, with the most extreme care, at a target 1,200 yards distant. The 9-in. was found to strike 75 per cent. of its fires, and the 8-in. 50 per cent.

This difference was due entirely to conditions of weight and resistance of spherical bodies moving through the air, and to the pointing of them; both being adjusted with equal care.

A sample of this practice may be seen at page 242 of my work on "Shells and Shell-Guns," though introduced then to illustrate another application of the same principle.

The weight of shell, then, that strike from an 8-in. gun, will not, when accuracy is involved, be equal to that of a 9 in. gun, and the difference in accuracy will reduce the weight of metal which strikes from 153 lbs. and 144 lbs. to 77 lbs. from the 8-in., and 108 lbs. from the 9-in., or in that proportion.

Again, the charges of the shells enter into the question; the three 8-in. contain 6 lbs. of powder, and the two 9-in. a like quantity; but each of the 8-in. shells contains only  $1\frac{2}{3}$  lbs., while each of the 9-in. shells contains 3 lbs., and we know that the action of powder is in far greater ratio than its weight; that is, the explosive force of the 8-in. to the 9-in. charges is in a greater ratio than the weights of the charges 2 to 3.

This is an important consideration, as well as that of concentration by reason of greater weight.

Again, the penetration of the 9-in. shell is greater than that of the 8-in. shell; so that the former not only enters further into the opposing

ship, but will carry with it a far greater bursting effect individually.

In the foregoing data enough is stated with exactness to show that the ordnance power of the two guns is hardly comparable, and that no effort should be spared to use the heavier calibre; whenever possible to go above the 9-in., I would advise it, but never below it.

And the *Ironsides* has shown the power of the 11-in. broadside, as well as the facility of using such cannon.

Whenever there is space on the deck that will allow the muzzle of a cannon to come in, if only clear of the inside, the gun may be fought, and any obstacles that are removable ought to be made to give way without scruple.

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The next point to be determined is, should the guns be mounted in pivot or broadside?

The same reasons which cause the 9-in. to be superior to the 8-in. may also be urged in favor of the 11-in.

The higher the calibre, the greater the range, accuracy, and power.

The 11-in. shell has the content and nearly the weight of two of 9-in.; and since the pivot-gun can be fought on either side, and usually the 9-in. cannot be shifted over, it is practically equal to four of 9-in., whilst its weight with carriage is little more than that of two 9-in.

The concentration of effect due to the explosive capacity of the 11-in. shell is even more important than that due to penetration and size of orifice.

It will be seen by comparing the *Ticonderoga's* battery as first assigned, and the last one, now carried, that increasing the total weight of battery from 22 to 54 tons only increased her power one-fifth, from 422 to 520 lbs. of broadside.

Notwithstanding Admiral Wilkes's opinion, quoted above, it seems hardly credible that a gun should be more manageable on a carriage placed upon the deck than on a carriage upon a slide.

Guns are generally used when the ship is in motion, and a pivot-gun is always more under command than one in broadside. If a pivot-gun cannot be easily controlled, then much less can one be which takes any direction when fired, and is only limited by its breeching in the extent of its movements. In action, on either carriage, a gun requires free



space in every direction in its rear, and it is only when the gun is secured out of action that the slide becomes an encumbrance.

The misfortune of the larger calibre is that its substantial benefits are seldom visible before those who continually experience the disadvantages of its greater weight and size.

The bulk of the gun, the toil in handling it and its projectile, are ever enforced to the eye of the officer and to the exertions of the men.

But the great power it confers is not exhibited by the ordinary practice, and remains a myth until the hour of battle discloses the fact, and permits the heavy calibre to tell its own tale more eloquently than the most convincing arguments.

It has, however, been abundantly proved that the 9-in. gun is perfectly manageable on a broadside carriage in any vessel having sufficient room to work them; still, the writer is in favor of mounting them on a *pivoted* broadside carriage in all vessels—having reference here to the greater facility of training and consequent greater accuracy of fire, and the preservation of the decks, the fibres of which are crushed by the great weight resting on the front trucks.

The injury is aggravated by the neglect of executive officers to order the guns run in whenever the decks are washed, and keeping them partly in until the water ways are dry.

I have approached this subject of broadside pivots very gingerly, however, fearing the critical eye of a smart executive, whose snowy gun or quarter-deck, the pride of his heart, is encumbered by such troublesome companions.

It will be seen by the preceding list of batteries that the Bureau had definite ideas on the subject of armaments, but often yielded to the importunities of officers who had not very thoroughly studied the question.

There can be no more striking example of this than in the armament of the *Kansas* class.

The basis of armament is either—

Given a ship of a certain tonnage, draught of water, and speed, with so many tons of displacement assigned to ordnance, how dispose of that weight to best advantage?

Or, as in the *Kansas* class—

Given a designated battery, what is the smallest ship which, on a given draught of water, will carry that battery?

In every case, the Bureau assigns the smallest number of the heaviest guns to form the weight, and prefers pivots to broadside when the deck arrangements will permit.

For it is thoroughly established that a small number of large pieces will inflict injuries beyond the power of a large number of small pieces.

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In order that she may exercise her full measure of offence, speed has become the indispensable attribute of every ship of war. Without it her powers are altogether incomplete, and experience appears to have determined that it is judicious to sacrifice a large portion of the armament in order to procure great speed at any cost.

It is very right that when a vessel of war encounters a superior force, speed should be able to make her safe, but the necessary diminution of offensive power should not be so great as to disable a first-class steamer from matching any vessel of her own class of inferior speed, but provided with a proper armament; otherwise her usual business would be running—*fighting* the exception!

Although the large vessels of the *Tennessee* and *Florida* class were constructed on the theory of cutting up an enemy's commerce and flying from his cruisers, yet it is repugnant to our notions to employ such large and expensive vessels for this purpose.

It will often happen that in order to protect important interests, the battle must be fought at all hazards, and that avoiding the action will not serve the purpose. What then will be the chances of these costly fabrics?

It is, moreover, certain that we have a right to demand that our vessels of war shall have equal speed with those of other nations.

It is by this equality only that our vessels shall select and retain the distances they prefer, and less speed than this should not be admitted in any discussion of the subject.

This does not mean that every United States ship shall equal in speed the best ships of other nations, but that the average speed of our navy, taken collectively, shall be equal to that of others, also taken collectively.

If, however, our ship is inferior in speed, then the choice of distance is with the enemy, who is supposed to prefer close quarters; but if our ship is properly armed, he can only reach this position after passing through the deliberate fire of powerful guns.

The small vessels of the *Kansas* class, only 410 tons, were constructed

to carry, and can carry, 10-inch rifles—formidable guns to any but the very latest iron-clads.

In 1862, Assistant-Secretary Fox proposed, Admiral Dahlgren designed the armament, and Constructor Lenthall the hull of a vessel of the same length as the *Lancaster*, but with more beam, to carry twelve 11-inch guns in broadside pivots, on main deck, and two 11-inch in central pivots, on spar-deck; but the resources of our navy-yards were too severely taxed during the war to permit its construction.

This antedates, by some years, the English *Inconstant* and *Shah* (late *Blonde*), with a similar arrangement of armament.

The great majority of cruising ships must continue to be wooden or (its equivalent) composite vessels; but with the introduction of iron-clads of various degrees of resistance, these wooden ships should be capable of effective offensive action against most cruising iron-clads.

And although the preceding reasoning is based on our present armaments and wooden ships, it is equally applicable to an iron-clad fleet, and there is no reason why our ships, heretofore superior to all others in armament, cannot be restored to an equality; for the time has now come when we must prepare for an entire change in the armament of our ships, although the principle for determining it remains undisturbed.

I am also of the opinion that this change must be the introduction of the rifled cannon as the entire armament of our ships, otherwise we shall find ourselves, in a war with any leading power, overmatched not only in numbers but in power of individual ships.

This we cannot afford; our ships, if few, should be the best of their kind, and hitherto, so far as armament was concerned, were superior to all foreign ships.

A clever English writer remarks of our ships in 1812: "By substituting long guns instead of our short ones, they secured for themselves the immense advantage of being able, without loss or damage, luxuriously to pummel us to death, at ranges which they had precalculated they would be completely out of our reach."

But other powers have since adopted our system of a few heavy guns, and have, after many years of experiment and millions of expenditure, established two, or perhaps three, systems of rifled ordnance as worthy of confidence.

1st. The system of breech-loading, known as Krupp's, to whom it owes its experimental development, though it is understood that this system was presented to Captain Wise, one of my predecessors, years before

Krupp adopted it. The essential features, the round-backed wedge, the locking-screw, and the gas-check are due to our countryman, Broadwell. Exhausted by the war, we had no means of experiment, and he received no encouragement. It is, however, probable that it would not have proved a success in our hands, owing to the state of the steel manufacture in our country at that time.

2d. *The French System.*—This, which has been successfully applied to the largest calibres, is also an American invention, developed in France, and is, in my opinion, the best method mechanically of closing the breech, particularly for small calibres.

3d. *The Woolwich* muzzle-loading has met with success as a gun; but its studded projectile is far inferior to our expanding system.

Recent advices show that after pooh-poohing our expanding system for many years, and experimenting on wads and gas-checks to prevent erosion in the bore of their muzzle-loading guns, our English friends are about abandoning the studded projectiles for our own plan.

The principal advantage of rifle cannon consists in their greater penetration, due to the concentration of effect on a smaller and better form of surface; next, in greater explosive contents for same weight; then range; and, lastly, accuracy.

The accuracy of spherical projectiles is, however, quite sufficient at usual engaging distances, and the difference due to a rifle projectile is quite lost in the difficulties of aiming and the motion of both vessels.

That the rifle to be adopted should be a breech-loader is, I think, obvious, and for two principal reasons:

1st. In order to utilize a slow powder less destructive to the gun, the bore must have greater length in order to admit of a longer time for the gases to act.

2d. Since guns wear out by the rush of gas over the projectile in muzzle-loaders, scoring the bore is largely prevented by breech-loading.

To these we may add that, with the increased length of gun, the beam of very few ships will permit the muzzle of the gun to come within the port for convenient loading.

That there is no risk of accident from overloading, and that incipient cracks are easily detected.

Having no colonies, it is not probable that we will ever construct cruising iron-clads, nor does it appear to be necessary, since most of those now in existence may be pierced by their own guns, or such guns as they should carry, if properly armed.

Since the general introduction of armored ships, the conditions of war-

fare have been altered, and the subject of penetration has become of paramount importance.

With wooden ships, the mere lodgment of a shell in the side before its explosion might inflict a fatal injury; but against armored ships complete perforation is essential.

The form of the projectile, its material, cross-section, weight, and velocity on impact, must be such as to ensure this, or it will be practically harmless.

Experiment has proven that shells containing a suitable bursting charge may be driven through plates of a thickness equal to the calibre at short ranges, and this is about the limit of useful effect.

Therefore, with the present types of armored ships, carrying from 4½ to 6 inches of armor, 7" is the lowest calibre on which we can rely to ensure perforation, taking into consideration oblique impact, even at short range.

The English have, however, settled on the 8-in., the Prussians 8¼ (21 centm.), and the French 7.5 (19 centm.), as the gun for general service, weighing from 17,000 to 20,000 pounds, firing with charges of 27.5 to 35 pounds of powder, projectiles from 116 to 130 pounds, capable of perforating 6" of iron at 1,000 yards.

At present we have no guns, except those in the monitors, which will injure seriously the lightest armored vessel.

Substitute a 7-in. or 8-inch rifle for the 11-in. smooth-bore, and few of them would come off without great damage from the more numerous cannon of the unclad ship.

The monitors are deficient in speed: though formidable antagonists at close quarters, their sphere of offence does not extend beyond 500 yards, which might be increased to 3,500 yards by the substitution of an efficient rifle of the same weight, 10-in. or 11-in. calibre, for the 15-in. smooth-bore.

Various projects have been brought forward to convert our present smooth-bore guns into rifles; but these are all make-shifts, permissible in time of war, but unpardonable waste in peace. Our futile efforts to utilize the old small-arms should warn us to make no expenditures in this direction.

Other nations possess much greater stocks of convertible guns, but none have thought fit to convert them, except by lining and reducing the bore; nor can they be converted to breech-loaders, which I consider the essential feature in any rifled system.

A writer in the *Army and Navy Journal* of February 28, 1874, gives a summary of the objections to converted guns, which I commend to your perusal.

It is time this paper should close, its principal object being to remove the apparent impressions of officers that our ships are armed without system, to be changed at the caprice of each succeeding commanding officer; but I have been led into the discussion of other subjects bearing on naval efficiency.

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Commodore C. R. P. RODGERS, U.S.N., in the Chair.

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THE ISTHMUS OF DARIEN AND THE VALLEY OF THE  
ATRATO, CONSIDERED WITH REFERENCE TO THE  
PRACTICABILITY OF AN INTEROCEANIC CANAL.

BY LIEUTENANT FRED. COLLINS, U.S.N.

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*Mr. President and Gentlemen of the U. S. Naval Institute :*

As the subject that I am to bring to your notice has been before the world, as one of the leading questions of the day, for more than three hundred years, it would seem that some apology should be made for bringing it forward to occupy your attention this evening. My apology, then, shall be two-fold. In the first place, in spite of all that has been said and written, the object is as yet unaccomplished ; the isthmus still stands undivided, and he who would to-day sail the great South Sea can do no better than follow the track of him who first navigated its waters. In the second place, in spite of all the attempts that have been made, the isthmus has never been satisfactorily explored until within the past four years.

In view of the formidable nature of the undertaking, it is not, perhaps, surprising that the realization of the canal project should still be in the future; but that the limited region which alone could afford a solution of the problem of its practicability should so long have been allowed to remain unexplored, is inexplicable. Strange as this appears, however, it is nevertheless strictly true. Six years ago "the territory of the Isthmus of Darien east of the Panama Railroad was almost a *terra incognita*, and, according to most excellent authority, there did not then exist in the libraries of the world the means of determining, even approximately, the most practicable route for a ship-canal across the isthmus."<sup>\*</sup>

I propose, with your indulgence this evening, by a brief review of the results of the recent explorations of Commander Selfridge, to show that this long-standing reproach upon the intelligence of the age is no longer true.

In considering the character of the Isthmus of Darien† with reference to its capability of affording a practicable route for a ship-canal, the absolute necessity for a capacious and well-sheltered harbor as a starting-point upon the Atlantic side restricts the range of enquiry at once to the vicinity of the three great gulfs which indent its eastern coast. Various terminal points upon the Pacific side have been suggested, but the proposed lines all radiate of necessity from the Gulf of San Blas, Caledonia Bay, or the Gulf of Darien; for these afford the only shelter from the heavy sea that rolls in upon that rocky shore when the trade-winds blow home.

The most northerly of these, the San Blas Route, has always attracted special attention from the fact that there is the narrowest part of the isthmus. Several explorers had reported attempts to cross at that point, which, however, they were prevented from doing by the hostility of the natives who inhabit the northern coast, so that the only survey, prior to that by Commander Selfridge, from which any definite information was obtained, was that made under the direction of Mr. F. M. Kelley, of New York, in 1864.

His line, commencing on the Pacific at the mouth of the Chepo or Bayamo River, followed that stream some twelve miles, for which distance it is navigable at high water for the largest ships, and then struck directly across the country in a northerly direction for the Gulf of San

\* Rear-Admiral C. H. Davis, U.S.N., "Report to United States Senate on Inter-oceanic Railroads and Canals."

† Under this name I include for convenience all the territory of the isthmus south or east of the Panama Railroad.



Blas. The Cordilleras he proposed to pierce with a tunnel seven miles long.

The fact that this line is so short as to require a cutting of only twenty-six miles impresses one at once strongly in its favor; but the great proportion of this distance that would require tunnelling, even according to Mr. Kelley's plans (which were necessarily defective on account of his reliance upon an aneroid barometer only, for a considerable portion of his altitudes), would render the work almost too expensive to be undertaken; while the recent and more careful surveys show the line to be much less favorable than the previous explorers had supposed.

With reference to our survey of this route Captain Selfridge says: "The principal rivers flowing into the Bay of San Blas are the Mandinga, the Nercalagua, and the Carti. The Mandinga is the largest river on the Atlantic coast between the Chagres and the Atrato, and our main survey was carried up the valley of this stream. The Nercalagua, being in a more direct line, was also levelled up some sixteen miles to its sources. I will not enter into the details of these surveys; they were carried forward to a successful end in spite of the very heavy rains during the month of May, which were greater than ever before known by the oldest inhabitants of the isthmus at this season. The lower portion of the bottom-land of the Mandinga became a vast swamp, with from two to six feet of water on it. In some places one would sink to the waist in mire. Small streams became rivers, only passable by swimming; our bridges were swept away, and it even happened at times that the rise of the water was so rapid as to compel our people to take refuge and pass the night in trees. Happily, the waters would subside rapidly, enabling us to continue after vexing delays; each rise leaving the country in a worse condition than before. Our animals were useless in such a condition of affairs, and provisions, after being sent forward in boats as far as they could be forced against the swift current of the river, were carried on men's backs over miles of country where their path led over steep and rocky hillsides, slippery from moisture, and through streams and swamps. The survey crossed the 'divide' on the 7th of June, with an extreme elevation by level of 1,142 feet. . . . The objective point, the junction of the Marmoni and San José Rivers, the same reached by Mr. Kelley's engineers, was attained. The latter's survey was found to vary but half a mile in position—an excellent verification of its correctness, as it started from the Pacific shore more or less in error, while the initial point of our survey was absolutely determined by astronomical observations.

"The magnificent harbor of San Blas, the shortness of the route, and the general appearance of the interior from the sea, all gave great hopes that we should here find the favored spot for the successful accomplishment of our mission. But the prosecution of the survey, though it showed a more gradual rise to a certain distance than other routes, developed an altitude that it would require tunnelling to surmount. . . . An inspection of the profile gives us a tunnel of ten miles as necessary to span the intermediate distance between the elevations of 190\* feet on each side; after this the excavation would not exceed, for the remaining sixteen miles, an average depth of over sixty feet. A tunnel of ten miles, however, would involve for this line, otherwise so prepossessing, an expenditure too vast for me to pronounce it practicable."

We experienced from the Indians who inhabit this region none of the hostility of which, as before mentioned, some previous explorers had complained. On the contrary, they appeared to regard us with no dislike nor suspicion; never watching our operations on shore, and venturing freely on board our ships, where they showed no little sagacity in turning honest pennies by the sale of bananas, plantains, and pine-apples. They are, I think, in every respect the finest race to be found upon the isthmus, and, though rather undersized, they have a frank, manly bearing that is very engaging.

They do not dwell inland, but, exhibiting great good sense and taste, have fixed their habitations upon the beautiful coralline islands which stud their splendid gulf; where, shaded by graceful cocoanut-palms, and fanned by fresh breezes from the sea, they enjoy a cool, delightful climate hardly known elsewhere within the tropics. As these islands are barely sufficiently large to contain their houses, they are obliged to resort to the mainland to find room for their plantations, and there, in the fertile valleys of the Mandinga and Nercalagua, they raise, with little labor, an abundance of the tropical fruits that are with them the "staffs of life." This insular mode of life seems a feeble image of that in Venice—the place of the sombre-hued gondolas being here taken by light and graceful canoes, hollowed from single logs, in the management of which the Indians are no less skilful than their more famous brethren, the gondoliers, so long celebrated in song and story.

Let us now turn our attention to the next in geographical order, the

\* Captain Selfridge takes the general ground that tunnel work will be cheaper than open cut of more than 190 feet in depth. These views were somewhat modified in the case of the Napipi-Dogwado route, on account of the extremely rapid rise of the dividing ridge at that point. See estimates of that route given further on.

“Daríen route” proper. The commodious harbors presented at either end of this line, by Caledonia Bay\* and the Gulf of San Miguel, early attracted the attention of those interested in the canal scheme, and many attempts have been made to discover a route by which it might be possible to connect them. But it is unnecessary to enter into the details of these explorations. The thrilling story of the sufferings of Strain and his heroic companions, in their ill-starred attempt in 1854, must be fresh in the minds of many of you; and it is sufficient for our present purpose to say that all explorers, except one, had united in condemning the route. The information obtained by them, however, was not sufficiently extensive and definite to settle the question beyond a doubt, as is proved by the fact that the pretended discoveries of that one—Dr. Cullen—were, as late as 1867, considered worthy of serious attention.

This extraordinary individual, professing to have crossed several times directly between Caledonia Bay and the Gulf of San Miguel, published a work descriptive of his remarkable journeys and discoveries. Estimating in this the cost of a canal by his route with the greatest nicety, and illustrating it with a bird’s-eye view of the work as it was to appear when completed, with the largest streams rushing through without let or hindrance from lock or tunnel, he made a profound sensation—so profound, indeed, as to deceive to a considerable extent even the most learned geographers, by whom he was awarded great credit for his discoveries, although it appears that his statements were always received with considerable allowance, as being unsubstantiated by reliable notes and records.

A comparison of his description of a remarkable depression in the Cordilleras, near Caledonia Bay, with the facts as ascertained by Commander Selfridge, will show the limited foundation of fact upon which rested the doctor’s grand superstructure of fancy. He says: “From the sea-shore (Port Escoces) a plain extends for nearly two miles to the base of a ridge of hills which runs parallel to the coast, and *whose highest summit is about 350 feet*. This ridge is not quite continuous or unbroken, but is divided by transverse valleys, through which the Aglaseniqua, Aglatomate, and other rivers have their course, and *whose highest eleva-*

\* This name was conferred by a colony of Scotchmen who, under the leadership of William Patterson and the auspices of “The Company of Scotland trading to Africa and the Indies,” settled here in 1698. They were on good terms with the natives, and flourished for two years, when they were obliged to abandon the settlement on account of the hostility of the Spaniards and want of support from England. The bay and the country thereabout they called Caledonia, and their settlement was known as New Edinburgh. See Burney’s “Pacific Ocean,” Vol. IV., Part II., Chap. IV.

*tions do not exceed 150 feet.* The base of this ridge is only two miles in width, and from its south side a level plain extends for thirteen miles to a point on the Savana River, called Cañasas, which is about twenty miles above its mouth."

Now, had this been true, the exact question would have been most completely and satisfactorily solved, and further search worse than useless; but, unfortunately, it is not true, nor is it even approximately correct. The "highest summit" of the Cordilleras at this place is, instead of "350 feet," not less than 1,500, and the highest elevations of the Aglaseniqua and other rivers of the Atlantic slope would in no case fall below 500 or 600 feet.

Our line of survey crossed the divide at an altitude, by level, of 1,259 feet. This certainly does not represent the lowest possible pass; but, as the line struck the Sucubdi River upon the Pacific slope at an elevation of 553 feet, we have a right to consider the non-existence of any pass under that height to be incontestably demonstrated, else the Sucubdi must flow into the Atlantic instead of into the Pacific.

The following summary from Capt. Selfridge's report will convey, as concisely as possible, an accurate idea of the character of this route: "The Sucubdi, with its tributaries, the Napsati and Asnati, drains all the region on the Darien line; its bed, therefore, represents the lowest possible profile. The height of the junction of the Sucubdi and Chucunaqua was found to be, by careful barometrical observations, 146 feet. Allowing to these observations the extreme error found by experiment, 12 feet, there will be found a distance of 10 miles on the Darien route from the elevation of 160 feet\* on the Atlantic to a corresponding height on the Pacific slope; in other words, a tunnel of this length would be required. In addition, there would be an average cutting of 130 feet for 10 miles or more, and the Chucunaqua to be crossed by a costly aqueduct. The route by the way of the Sassordi and Morti presents pretty much the same results. . . . An inspection of the profile of this line will show a tunnel of not less than 8 miles necessary, besides very deep cutting in the valley of the Sassordi. . . . No further surveys of the routes can be necessary to give proof of their impracticability."

The inhabitants of this part of the isthmus are divided into small tribes that take their names from the rivers upon which they live. Thus, upon the coast, we have the Caledons and Sassardies; and upon the Pacific slope, the Sucubdies, Asnaties, Chucunaquas, and Morties. The coast

\* 160 feet above plane of mean tide, plus 50 feet below for depth of water in canal, gives 190 feet. (See previous foot-note.)

Indians, from their frequent intercourse with traders, who visit them principally to obtain coconuts, are somewhat civilized; but the *bracos* of the interior have never been conquered by the whites, and own no allegiance to any government but that of their own chiefs, chosen according to the traditions handed down from time immemorial. Their government is patriarchal in its character, and not hereditary, the authority of a chief passing, usually, upon his death, to the next oldest man; respect for age appearing thus to be one of their most strongly-marked characteristics.

They had all been represented to us as extremely savage and warlike, it being said that they could muster a thousand warriors, who would resist to the last all attempts to penetrate their territory. Whether or no this sanguinary disposition may be truthfully attributed to the Chucunaquas and Morties I cannot say, as our explorations did not take us in the vicinity of their villages; but it is certainly a libel upon the Sacubdies, for we went through their entire country, and they appeared to be a most mild and inoffensive people—a tribe of farmers rather than warriors, exhibiting the quiet temperament to be expected among peaceful tillers of the soil.

Living, indeed, in a country where nature repays the minimum of labor with the maximum of harvest, and having none of the artificial wants consequent upon civilization, we should naturally expect to find them indolent and quite the opposite of warlike or aggressive,—and such they seem to be.

They are not, however, wanting in intelligence and quick perception, nor in a chivalrous disposition that leads them to succor the weak, admire courage, and despise cowardice. As a case in point, one of our men, whom, being accidentally and severely wounded, we were obliged to leave among them for several days while we were going down the river and returning, was treated by them with the greatest kindness; while another, who, dreading the rough march and possible danger ahead, sneaked from the ranks and started upon his return, was recognized by them at once as a poltroon, and treated, very justly, with great contempt and indignity.

They were not at all in favor of the canal project as they were able to comprehend it from their simple standpoint, evidently fearing that, by the advent of strangers, they would be dispossessed of their fair lands, and driven off, without just compensation, to shift for themselves as best they might. They also expressed great fears lest the canal, should one be constructed, would let the waters of the Pacific in upon them and drown them out. The former apprehension would, I fear, have been only too well justified by the event, had their country proved favorable to the

enterprise ; but, as they live some 500 feet above the level of the sea, the latter would doubtless have proved unfounded.

Some circumstances appear to give the color of truth to the reports of the savage character of the Chucunaquas and Morties. The chronicles of the early Spanish settlers contain frequent accounts of massacres by the former tribe,\* and it is reported that they killed a party of rubber-hunters who penetrated their country during the summer succeeding our visit. The Morties killed four men belonging to an English expedition under Commander Prevost, in 1854, and the same tribe made some threats against one of our parties that operated in their vicinity, which, however, they did not attempt to put into execution ; thinking, no doubt, that our breech-loaders were more than a match for their worn-out shot-guns and bows and arrows.

Let us now take up the next in order, the celebrated "Atrato-Tuyra Route," so-called, the starting-point of which, on the Atlantic side, is the Gulf of Darien or Uraba, and the terminus, as before, the Gulf of San Miguel; the Atrato River being utilized as far as the mouth of the Carcarica, whence a cut had been proposed across the country to such a point on the Tuyra as might afford the requisite depth of water.

Concerning this route many extravagant accounts have been published, all of which, it appears upon candid investigation, could have had but little foundation other than that which existed in the imaginations of their authors. Not, indeed, that I would deny honesty of intention to the gentlemen in question, for I am well aware of the fact that the attempt to gain any idea of these regions otherwise than by laborious and patient examination, with the aid of instruments of precision, is sure to result in the complete misleading of the explorer, no matter how honest his intentions ; while we all know that it is a weakness of human nature to see only what we want to see, and to make our observations agree with our wishes, by dint sometimes, perhaps, of rather violent twisting. At all events, it is certain that the favorable reports of this route are entirely erroneous, as will appear by a glance at the map exhibiting the topography of the locality.

\* I am inclined to think that the Spaniards applied the general name Chucunaqua to all the Indians of that region, otherwise the tribe which now bears the name must have been much larger then than it is now.

The following item, dated Panama, March 22, 1874, would seem to indicate that this tribe is still inclined to defend their domain with as much spirit as of old : "The Indians of Darien, inhabiting the banks of the river Chucunaqua, having refused to allow the caoutchouc gatherers to collect that product on their territories, the Government sent some fifty soldiers to enquire into the matter. It seems that, on the 15th ult., they went up the river and were attacked by the Indians. From news just received, it appears that some sixteen of the soldiers were killed, and the expedition, it is feared, has failed."

You will observe that the Cordilleras of the isthmus sweep to the westward in an unbroken chain to join the coast range of South America. This portion of the ridge, indeed, is of no great altitude, yet it is perfectly well marked and continuous. Our regular survey crossed at an elevation of 712 feet, while, a little further north, Capt. Selfridge found a height of only 400 feet, estimated from rough observations with a pocket-barometer. No great reliance, of course, can be placed on those rough figures thus roughly determined, but there can be little doubt that the "Pass of Carcarica," as the place is called, is the lowest on the continent, except on the line of the Panama Railroad.

But the utility of this route for canal purposes does not by any means depend upon the height of this ridge alone—that is, indeed, of minor importance; for the entire country is filled with hills from the divide itself to the junction of the Yapé and Tuyra Rivers, near which tide ends.

The character of the country is well described by Capt. Selfridge, who, after detailing in his report the results obtained by his extensive explorations in this vicinity, thus sums up the matter: "As the facts unfolded themselves they caused a bitter disappointment; for I had been led by the appearance of the country on the Atlantic slope, and the reports of those who had visited the Pacific side, to expect a different result. . . . The whole country from the Tuyra to the divide is a net-work of hills, and the highland between the mouth of the Cué and the Paya, rising sometimes to 490 feet, was totally unexpected. The long extent of swamp-land on the Atlantic side is another very bad feature of this route. To show its impracticability, I have calculated the amount of excavation necessary, supposing we locked up to the mouth of the Cué River, which is 160 feet above the sea. It amounts to the enormous sum of 45,711,500 cubic yards earth, 62,185,000 cubic yards rock. Two hundred and fifty millions of dollars would not represent the amount necessary for the construction of a canal by this line."

There now remains for our consideration but one other route within the limits of the isthmus proper, and this is known as "Dr. Puydt's Route," from its projector, who claimed to have ascended, in 1865, the valley of the Tenela—a small stream flowing into the Gulf of Darien—and to have discovered a pass only 153 feet high. Discrediting this report, but wishing, as he says, to leave no doubt clinging to any portion of the isthmus, Captain Selfridge obtained from a gentleman who accompanied Dr. Puydt his exact route. Following this, the country was penetrated some thirty-three miles. Having then reached an altitude of 682 feet, by careful barometrical measurement, and the mountains of the

divide being plainly visible yet higher beyond, the officer in command was compelled to turn back for want of provisions. He had, however, gone far enough for the purpose.

We have now glanced hastily at the various lines that have been proposed within the limits of the isthmus proper, and, imperfect as has been my sketch, I think you will be willing to concede that this attenuated neck of land presents no route sufficiently favorable to the enterprise to be pronounced practicable in the proper sense of the term. Wherever the spirit of adventure may hereafter lead men to look for a canal route, Darien may, I think, be safely considered as eliminated from the problem. To have achieved this result; to have succeeded in obtaining, often in the face of the most formidable obstacles, accurate information where so many others have sought for it only to fail, cannot, it seems to me, be regarded otherwise than as a great triumph for our navy, of which we all, as Americans, have a right to feel proud. But our explorers were not rewarded by these negative successes alone, for their labors ultimately resulted in the discovery of a route not only *practicable*, but in many respects eminently *favorable*.

The Atrato River, to which I have already referred, and which is to play so important a part in the route about to be described, rises in the State of Cauca, in latitude  $5^{\circ} 20'$  North, flows in a northerly direction, nearly parallel to the Pacific coast, for about 400 miles—following the bends of the river—and finally empties into the Gulf of Uraba through a delta comprising many mouths. It drains a valley of considerable area, bounded on the east by the westernmost range of the Cordilleras of the Andes, and on the west by a range of low hills rising abruptly from the Pacific shore. The topography of this region does not appear to be generally understood. It is commonly supposed that the Andes are continuous with the Cordilleras of the isthmus; and so, in a certain sense, they are, but the connection is effected only by a range of hills of very moderate elevation. These hills skirt closely the Pacific shore, which is left by the Andes proper at  $3^{\circ}$  North. The intervening valley affords a double water-shed: one to the northward, drained by the Atrato into the Gulf of Darien, and one to the southward, drained by the San Juan into the Pacific.

Humboldt, in his "Personal Narrative," called attention to this fact many years ago, but "drawers of maps" seem to have paid him little attention. He says: "The erroneous idea which geographers, or rather drawers of maps, have so long propagated of the equal height of the Cordilleras of America, their prolongation in the form of continued walls



and ridges, and, finally, of the absence of any transversal valley crossing the pretended central chain, has caused it to be generally believed that the junction of the seas is an undertaking of greater difficulty than there has hitherto been any reason to suppose. . . . The chain of the Andes is divided at 2° and 5° of latitude into three chains, and the two longitudinal valleys that separate those chains form the basins of the Magdalena and Rio Cauca. . . . Further west in the Cocco del Norte the mountains lower to such a degree that between the Gulf of Cupica and the Rio Napipi they disappear altogether."

Humboldt, who did not here speak from personal observation, was somewhat misled as to the height of the ridge between the Napipi and Cupica. Hills 600 feet high are, to be sure, hardly worthy of being called mountains, but they certainly form a very sensible line of demarcation. However, as I said, properly speaking, the Atrato lies entirely to the westward of the Andes, having one branch of that range for the eastern boundary of its valley, while the western boundary is formed by the low hills that skirt the coast.

The mouths of the Atrato are at present obstructed by a bar on which there is only about four feet of water. But within this the channel is broad and clear, and, as far as the confluence of the Napipi, not less than twenty-eight feet deep in any part at the lowest stage of the river. It was surveyed to that point by Commander E. P. Lull during the expedition of 1871, and last winter the survey was continued as far as Quibdo by Commander Selfridge in person.

Throughout this distance the Atrato is truly a most magnificent river. Its valley was evidently once an arm of the sea, which has been gradually filled up by the denudation of the hills upon either side, and by the decay of the vast masses of vegetable matter that yearly spring up and thrive in rank luxuriance under the favoring influences of copious rains and a vertical sun. In the lower portion of the valley this process is still going on, and there are vast swamps, extending for miles upon each side of the main channel, filled with the coarse *gramadote* grass, growing in many places so thickly as to prevent the passage of boats, and presenting the appearance of an immense meadow; yet underneath a deep, strong current sets steadily seaward.

It is not, indeed, before reaching the village of Sucio, some sixty miles from its mouth, that firm banks will be found to the Atrato; but beyond that point they extend in unvarying monotony, ten to twelve feet high, and without a sign of a hill or high land in any part. On both sides of the river stretches a level country, covered with an unbroken

forest, which is filled with precious woods suitable for the builder and the cabinet-maker, and with rubber-trees and valuable dye-woods of various sorts. These forests must one day constitute an important element in the resources of this country.

The scenery upon the Atrato is but an unending panorama of luxuriant vegetation, exhibiting the thousand and one curious and fantastic forms into which nature loves to weave her tropical mantle. Above the dense, rank undergrowth, forcing itself to the very water's edge, rise the tall trees, doubtless centuries old. Here stands one of gigantic dimensions, its trunk and branches blazing with brilliant orchids, and completely hidden by the leaves and flowers of innumerable vines that cling to it for support and nourishment; and there another, with scarce a leaf, holding aloft its giant arms, which afford a resting-place for hundreds of screaming parrots, or a family of chattering monkeys, who grin at the traveller as he passes, and cut strange capers, apparently for his special amusement.

Upon the muddy banks and sandy *playas* enormous alligators sleep in the sun, waking only to slide lazily into the water at the shout of the boatman or the crack of a rifle.

Now and then may be seen a strange-looking craft, crowded with naked negroes, who propel the vessel lazily against the current, walking fore and aft the deck with their long *polancas*, and keeping step to a wild, monotonous chant, strangely appropriate to the surroundings of the scene. These are *bungoes* or *barquetonias*, trading between Cartagena and Quibdo, laden on the upward voyage with cottons, *anisado*, salt, knives, guns, pistols, Yankee notions, and trinkets of all sorts, and on their return taking rubber, ivory-nuts, gold, orquilla, and the various dye-woods of the country.

As may be supposed, the proximity of this stream, in certain portions of its course, to the western shore of the continent, did not fail to attract early attention; and repeated attempts have been made to discover some place where the low range of the Cordilleras of the coast might be cut by a canal, and communication thus carried forward from ocean to ocean.

Prominent among those who have been engaged in this enterprise we find again Mr. F. M. Kelley. His attention was first turned to a route by way of the Atrato and San Juan Rivers—the site of the mythical “Raspadura Canal”;<sup>\*</sup> but, finding that impracticable, he directed his

<sup>\*</sup> I say “mythical,” because the existence of anything worthy of the name of canal seems, by Trauwine's survey, to have been disproved. It is, however, mentioned by

efforts to the discovery of a line for a direct cut from the Atrato to the Pacific.\*

In this his engineers were so far successful as to find a route from Humboldt Bay, by way of the Nerqua and Truando Rivers, to the Atrato, which appeared so favorable as to induce the United States Government to take the matter in hand. Accordingly, an expedition was fitted out under the joint command of Lieutenant (now Brigadier-General) Michler, of the United States Engineers, and Lieutenant (late Commander) Tunis A. M. Craven, of the United States Navy, for the more complete examination of this route.

These gentlemen completed their prescribed task with the result of "confirming, in all essential particulars," the work of their predecessors, and by Gen. Michler a canal line was projected from Humboldt's Bay to the Atrato. The entire length of this line was 45 miles; it involved the construction of two tunnels, one 820 feet and the other 12,250 feet in length, and its cost was estimated at one hundred and thirty-four millions of dollars.†

But, notwithstanding these favorable results, no further action was taken, and in this state the matter rested until the winter of 1871, when Capt. Selfridge, then engaged on the Atrato-Tuyra route, had his attention called to the advantages of Cupica Bay and the so-called "Napipi Route." He accordingly detailed a party which, commencing at Limon Bay, an arm of Cupica, crossed the divide and followed the Napipi River to the Atrato. They crossed the Cordilleras at an altitude of 613 feet, found the country beyond to be exceedingly favorable, and reported a line of thirty-two miles in length, five miles of which would require tunneling.

The lateness of the season prevented any extensive examination of the surrounding country at that time, nor did another opportunity occur till the winter of 1873, when a party was sent out for that express purpose.

Humboldt, who says: "The small canal of Raspadura, which a monk, the Curate of Norita, caused to be dug by the Indians of his parish in a ravine periodically filled by natural inundations, facilitates the inland navigation, on a length of seventy-five leagues, between the mouth of the Rio San Juan below Noanama and that of the Atrato," etc. (Humboldt's "Personal Narrative," Vol. VI., Part I., p. 260.) If such a canal ever existed, it could have been nothing more than a rude ditch, capable of affording passage for the native canoes, which require but a few inches of water.

\* Kelley on the "Junction of the Atlantic and Pacific Oceans, and the Practicability of a Ship-Canal, without Locks, by the Valley of the Atrato."

† Report of Secretary of War, communicating Lieut. Michler's report, 1861. Capt. Selfridge, in his report, calls attention to the fact that, applying to this line the same cost per cubic yard as he allows for the Napipi-Doguada-Atrato route, its cost would exceed \$150,000,000.

The results of their explorations induced the Captain to shift his initial point from Cupica Bay to that of Chiri-Chiri, some ten miles further south. From this point, by crossing the divide and following, in a north-easterly direction, the valley of the Doguado to its junction with the Napipi, and thence that river to the Atrato, the line was shortened to twenty-eight miles, and the distance requiring tunnelling to about three miles.

Some interesting details concerning this route and the work it is there proposed to construct will be given further on ; I now invite your attention for a few moments to the present condition of the country likely to become, before many years, conspicuous as the site of the grand highway of international maritime communication.

The "Sovereign State of Cauca," within the jurisdiction of which this route is situated, is one of the integral parts of our sister republic, the United States of Colombia. The area of this State is about 68,300 square miles ; it contains a mixed population of perhaps 300,000, and it is divided into four provinces : Buenaventura, Pasto, Popayan, and Chcco. With the last of these, as the district within which lies the site of the proposed canal, we are particularly interested.

The mountainous portions of this province are inhabited by the scattered remnants of the Choco Indians, who were the aborigines of the country. The personal appearance of these Indians is similar to that of those who inhabit the isthmus further north, and in disposition these are even more mild and inoffensive than those. They are a frank, honest, and hospitable people. At their hands the stranger may be sure of nothing but kindness, and when engaged as laborers they are faithful, uncomplaining, and industrious. Unaccustomed to systematic labor, however, they soon tire of the monotonous drudgery attendant upon surveying, and they are also apt to suffer severely from home-sickness if kept long away from their friends. They subsist chiefly by hunting and fishing,—game being more abundant here than on the isthmus,—and are tillers of the soil secondarily and to a limited extent only. Each family lives by itself, far removed from any other, as they have neither towns nor villages, but they maintain, by means of their canoes, constant communication with each other, all appearing to be on terms of cordial intimacy.

Nothing can exceed in simplicity the every-day costume of these people. The women wear only a strip of coarse cloth wound about the waist and falling to the knee. The men improve upon this even, and wear absolutely nothing, except a microscopic breech-cloth. The youth

of both sexes roam "fancy free," without artificial covering of any sort. Both sexes paint or stain the body, though the practice is more common among the males than the females. The body of a man in full dress is completely covered with the black *caruto*,\* frequently laid on in some fantastic open-work pattern. The bright red *anoto*\* is more frequently used to stripe and dot the face and forehead, and, by way of contrast, the hands and feet are sky-blue. In addition to this elaborate costume, the neck and loins of the man, if he be well-to-do, are encircled with numberless strings of beads; from a band of beads about his head depend bunches of fragrant roots and bark; he wears broad bracelets of virgin silver, and carries button-hole bouquets in the immense holes in the lobes of his ears.

Their habitations are of the rudest possible construction, far inferior to those of the isthmus Indians, consisting solely of a heavily-thatched roof supported upon posts driven into the earth, and with a rough flooring laid across five or six feet above the ground. The sides of this house—if so it may be called—are usually left entirely open. A fire in one corner, upon a pile of stones, serves for their primitive cooking operations; while an iron pot or two, a few gourd calabashes, and a hollow stone to serve as a mortar, comprise the list of culinary utensils.

The happy description of the Indians of the *tierras calientes* of Central America, given by Chevalier Morelet, is strikingly applicable to those of this region: "The physical education of the Indian commences early. When ten or twelve years of age, a *machete* is put in his hands, and a load proportioned to his years on his shoulders, and he is made to accompany his father in his excursions or his labors. He is taught to find his way in the most obscure forests, through means of the faintest indications. His ear is practised in quickly detecting the approach of wild animals, and his eye in discovering the venomous reptiles that may lie in his path. He is taught to distinguish the vines the juices of which have the power of stupefying fishes, so that they may be caught by hand, as also those which are useful for their flexibility or for furnishing water to the wayfarer. He soon comes to recognize the *leche Maria*, the precious balm with which he can heal his wounds, and the *guaco*, which neutralizes the venom of serpents. He finds out the shady dells where the *cacao* flourishes, and the sunny eminences where the bees go to deposit their honey in the hollow trunks of decaying trees. He learns, or is taught, all these things early, and then his education is complete. When he reaches the age of sixteen or seventeen years, he clears a little spot of

\* *Anoto*, *onoto*, or *arnoto*, is a brilliant coloring matter extracted from the pulp of the *Bixa orellana*. *Caruto* is the black, caustic pigment of the *Genipa Americana*.

ground in the forest with the aid of fire and his machete. He plants it with maize, builds a little hut in one corner, and then brings to it a companion, most likely one who was affianced to him in his earliest infancy. Without doubt he has some regard to the age and attractions of his female companion ; but his marriage, if the union may be so called, is based on none of those tender sentiments and mutual appreciations which with us lie at the foundation of the social superstructure.\* The vine mentioned above as useful for furnishing water is worthy of more extended notice. It is called by the negroes the *vejue blanco*, and is found hanging in immense festoons from the tall trees. So abundantly does this remarkable parasite yield cool, clear, and delicious water that I have frequently half-filled a canteen from a piece not above three feet in length and two or three inches in diameter.

The bulk of the population of this province of Choco is composed of negroes, descendants of slaves introduced from Africa when the country was under the rule of Spain. Many of these have preserved the purity of their blood with singular strictness, and are as black as the princes of Congo. From this extreme they ascend by gradations—as gradual, if not as beautiful, as the insensible blending of the tints of the solar spectrum—to the pale yellow of the octoroon.

They live principally in the low lands along the banks of the Atrato or near the mouths of its tributaries, where they cultivate in their lazy way bananas, plantains, sugar-cane, bread-fruit, and Indian corn. These the rich soil produces almost spontaneously ; yet the negroes are so indolent as to raise barely enough to keep them from starvation, and would frequently suffer for food, were it not for the fish that abound in the Atrato. \*

Their condition is indeed but little superior to that of the Indians, but they are of a more social disposition, and congregate in little villages—sometimes picturesque, but never clean—where their mode of life exhibits a most incongruous jumble of Spanish, African, and Indian customs. Their houses are essentially similar to those just described, but with their sides enclosed with cane. On account of the disposition to overflow its banks which the Atrato is inclined to manifest during the wet season, these structures usually stand raised some four or five feet upon posts ; an arrangement which gives them an air of instability that is frequently enhanced by a sad want of perpendicularity. This latter feature is also, I am pained to observe, frequently to be noticed, particu-

\* "Travels in Central America. From the French of the Chevalier Mozelet." By Mrs. M. F. Squier.

larly upon fête days and other occasions of public rejoicing, in the bearing of the greater portion of the inhabitants.

As a race, the men are tall, well built, and muscular. The women are also well formed, and, when young, comely after their fashion; but they develop early, marry young (usually without the benefit of either priest or magistrate), and, as a consequence, at thirty-five or forty become wrinkled, toothless hags, among whom Macbeth's witches might have reigned as belles of peerless beauty.

Being nominally converts to Catholicism, these people designate themselves as *Christianoes*, in contradistinction to the Indians, whom they regard as pagans. I once endeavored to draw from one of these *Christianoes* his idea of the moral difference which constituted the foundation of this distinction; but could obtain no more satisfactory answer than that the Indians were not Christians because they paid no taxes! Do not our learned theologians sometimes draw the fine shade of separation upon a less tangible basis than this?

The inhabitants of the lower portion of the valley of the Atrato find their principal employment in collecting the rubber which is so abundant in that region that, with proper management, it would afford an almost inexhaustible supply. The trees are thickly scattered over a vast area, and each will yield, it is said, from two to three table-spoonfuls a day for twenty years. But the ignorant negroes, in their short-sighted cupidity, cut the trees down as they find them, thus obtaining a large quantity with little trouble, but "killing the goose which lays the golden eggs."

The rubber-tree is stately, and of remarkable beauty. Upon cutting through its bark the milk-white juice, of a creamy consistency, flows copiously. This is collected in vessels by the natives, deposited in shallow pits dug in the ground, and allowed to harden, turning to a blackish brown in the process. Then, in the shape of irregular slabs, it is sent to Panama or Cartagena, where it is purchased by the agents of the various manufacturing companies; subjected by them to heavy pressure to rid it of water and foreign matter, and then reshipped, to finally appear in the thousand-and-one articles of use or ornament with which every one is so familiar.

In the upper portion of this valley the inhabitants derive their chief revenue from gold *hunting*,—it cannot be called mining,—and this is destined, at no distant day, to become a most important and profitable industry. All the streams—and their name is legion—that come into the Atrato from the eastward, having their sources high up among the An-

tiopian Mountains, bring down this precious metal suspended in their waters. Their gravelly beds and sandy *playas* are rich with gold, which is so abundant as to be carried during the floods of the rainy season into the Atrato itself.

The means employed by the natives to obtain this gold are, as may be supposed, rude in the extreme. Vein-mining is carried on to a limited extent only, and then with machinery of the simplest possible construction. The greater portion is obtained by washing the sands of the streams just after the subsidence of the floods of the rainy months. Most of the metal thus secured finds its way to Quibdo, the capital and principal town of the province; where from \$200,000 to \$300,000 worth is frequently collected in the course of a single year.\* Such an amount as this, considering the means employed and the desultory way in which the search is carried on by the lazy natives, certainly indicates a richness in those gold regions that promises most profitable returns when the influx of labor and capital shall enable the business to be conducted in a systematic and scientific manner.

From the eastern slope of the Antioquian Mountains, which is reached by way of the Magdalena and Cauca Rivers, the exportation of gold now amounts to several millions of dollars annually. On their western slope, accessible by the Atrato and its tributaries, there is, it is estimated, an area of 2,000 square miles over which gold may be collected almost indiscriminately as regards locality.† What a rich field does not this present to American energy and capital!

It should be remarked, however, that the difficulties in the way of transporting the requisite supplies and machinery would, with the present facilities (or want of facilities), be almost insuperable. But when the country shall have been opened up, and depots of supplies and proper means of transportation provided, it can hardly be supposed that so tempting a field will long be allowed to remain unworked and unprofitable.

The climate of this country now demands a passing notice. Two distinctly-marked dry seasons are here presented, with their corresponding

\* This information I obtained while in Quibdo in April, 1873, from Señor Farara, the Jefe Municipal of the Province of Choco, a native of Quibdo, who was educated in the United States, and an exceedingly intelligent gentleman. While there I saw several pounds of the ore as brought in by the natives. It is apparently of a very fine quality, and is mostly in the shape of small flat scales, with an occasional nugget of the weight of a dollar or more. When brought in, it is mixed with quite a percentage of fine magnetic sand, that is, of course, carefully extracted by the purchaser with a magnet before weighing.

† Trautwine.



periods of rain—a consequence of being so situated in latitude as to be twice overshadowed by the “equatorial cloud ring,” under which precipitation is almost constant, as it follows the sun in his grand annual “swing” from Cancer to Capricorn and back. January, February, and March are the months which constitute the pleasantest and driest season. In April the rainy season begins to set in, and in May and June the rain is almost incessant. In July it begins to lessen again, and August and September are comparatively dry; but in October the rains again commence, and in November and December they are at their heaviest.

Throughout this country malarial fevers prevail more or less, especially during the commencement of the dry seasons, when the low rivers and drying swamps present vast areas of half-decayed vegetable matter to the action of the powerful sun; but these fevers are of a mild type, and easily controlled by quinine. The fact that not a man was lost from climatic causes during all the three expeditions of Commander Selfridge, notwithstanding the hardships and exposure to which they were subjected, proves conclusively, it appears to me, that upon the whole the climate is less insalubrious than is generally supposed.

In geological character we find a marked difference between that portion of the isthmus visited in 1870 and the regions farther south visited in 1871 and 1873.

In the former locality the lowland near the coast rests entirely upon a coralline substratum, while the mountains belong to the hypogene formations, consisting mainly of granite and syenite.

In the valley of the Tuyra, however, and to the southward, the formation may be placed under general head of traps, being entirely volcanic, and of recent date in the geological sense of the term, though ancient enough as compared with man. All the characteristics of this region indicate that it must have been submerged, while yet the land forming the Isthmus of Darien had long been upheaved, and had assumed nearly its present form. At that period, then, “the Atlantic and Pacific Oceans must have intermingled their waters and washed the base of the Cordilleras of Darien.”

It was only when nature was preparing to bring man upon the scene that she closed the gate—yet left it almost ajar, seemingly to tempt him to vindicate his manhood and reopen it.

The isthmus does not appear to be very rich in metals, although “numerous veins of pure copper were met with on the Sassandra, and indications of iron were observed in all the mountains.” There are thermal springs upon both the Napipi and Doguado Rivers, the water

being of the temperature of 110° Fahrenheit, and emitting a faint odor of sulphureted hydrogen. These springs are held in high estimation as baths by the natives, many of whom resort thither for the cure of various diseases.

My paper, in spite of my promise to be brief, has already grown to such a length that I fear I am taxing your patience severely; yet I cannot close without attempting, by means of this profile of the Napipi-Doguado route, to give you some idea of the facilities which it affords for the construction of a canal.

It is, of course, impossible at present to determine what plan of construction will be adopted after the requisite careful and extended surveys for locating the line with precision shall have been made. We may, however, gain a good idea of the general character of the proposed work by considering for a moment that plan which in the present state of our knowledge appears most feasible.

The junction of the Napipi and Doguado Rivers upon this route affords an ample water supply for locking up at least ninety feet above the surface of the Atrato, which is itself, at the point where the canal will enter it, forty feet above the plane of mean tide—our datum line. In a canal where locks are to be used, this question of an unfailing water supply is, of course, of vital importance, and it therefore received careful attention. Frequent measurements proved that the Napipi at its junction with the Doguado would give a liberal supply for twenty-four lockages per day,\* while, to put the question beyond dispute, this supply may

* Flow of Napipi, close of dry season, . . . . .	520,000	cubic feet per hour.
	24	
Supply for 24 hours, . . . . .	12,480,000	" "
	<i>Demand.</i>	
Leakage, at 2,000 cubic feet per minute, . . . . .	4,320,000	" "
Evaporation, . . . . .	288,000	" "
Waste, . . . . .	1,000,000	" "
Twenty lockages a day, . . . . .	4,611,600	" "
	10,219,600	" "
Supply, . . . . .	12,480,000	" "
Excess, . . . . .	2,260,400	" "
Flow of Napipi and Caua combined, . . . . .	23,240,000	cubic feet 24 hours.
Forty lockages per day, . . . . .	9,223,200	" "
Leakage, etc., . . . . .	5,608,000	" "
Demand, . . . . .	14,831,200	" "
Excess, . . . . .	8,418,800	" "

be doubled by a feeder three miles long from the Cuia. In this connection it is of interest to note that the valley of the Cuia at the point where it would be tapped by the feeder is some fifty feet higher than the proposed summit level of the canal. This would give ample head to ensure the delivery of as much water as might be required.

Should it, therefore, be deemed desirable to reduce the first cost of the canal by resorting to locks, eight with a lift of ten feet each, let us suppose, might be employed upon the Atrato side. The entire length requiring excavation by this line is 148,840 feet, or 28½ miles nearly. Of this distance 107,960 feet, or 20.3 miles, following the valley of the Napipi (from A to F—see Profile), are through an almost level plain having a slight and gradual rise. Distributing in this section 8 locks, so as to keep the cutting near the surface, the average depth of the required cut would be 45 feet; and the amount of excavation, 5,456,360 cubic yards of earth and 8,163,650 cubic yards of rock.

Leaving at F the valley of the Napipi, and following that of the Doguado, the rise becomes more rapid, so that from F to G, a distance of 16,400 feet, or 3.1 miles, the average cut would be 73 feet, and the excavation 442,200 cubic yards earth and 2,465,400 cubic yards rock. At G the steep acclivity of the ridge may be said to commence; the open cut, however, may be continued as far as I, a distance of 5,240 feet, for which the cutting would average 193 feet. For this last mile the excavation would be 141,300 cubic yards earth, 2,111,200 cubic yards rock.

At I it is presumed a tunnel would become cheaper than an open cut, and would therefore be resorted to. It would extend to J, 15,700 feet, or about 3 miles, and would require the excavation of 2,314,388 cubic yards of rock. The short section beyond the western portal of the tunnel, 3,600 feet in length, would be occupied by 12 locks, by which the descent to or the ascent from the Pacific would be accomplished. Its contents are estimated at 67,880 cubic yards earth and 295,990 of rock. From these we get a grand total excavation of 6,087,700 cubic yards earth, and 16,449,900 cubic yards rock,\* the figures being based upon a canal of the following dimensions: Width at bottom, 60 feet; at water surface, 72 feet; width of tunnel at bottom, 40 feet; at water surface, 60 feet; height from bottom to crown of arch, 112 feet; depth of water throughout canal, 25 feet. As these dimensions will not allow vessels to pass each

\* It is of course understood that these figures are approximate only, being derived from our preliminary survey, which was necessarily hasty and limited.

other in the canal proper, two or more turn-outs or sidings would be required at different points.

From the foregoing data, estimating the cost of removing earth at 33 cents per cubic yard, rock at \$1 25 to \$1 75, according to position, and tunnel-work at \$9 35 per cubic yard, Captain Selfridge obtains the following as the cost of the proposed canal :

Cost of excavation.....	\$41,823,497
Cost of reservoir.....	550,000
Cost of aqueduct, Napipi to Cuia.....	606,000
Cost of culverts.....	500,000
Cost of railroad, narrow gauge.....	1,000,000
Crossing Napipi River.....	1,000,000
Grubbing and clearing.....	500,000
Sea-wall, Chiri-Chiri Bay.....	200,000
Wall, Atrato River.....	25,000
Executive department.....	120,000
Engineer department.....	375,000
Pay department.....	90,000
Quartermaster's department.....	135,000
Commissary department.....	120,000
Medical department.....	80,000
Hoisting and pumping engines.....	875,000
Improvements, mouth of Atrato.....	462,000
Twenty-five per cent. for contingencies.....	12,116,749
Grand total.....	\$60,583,246

You will observe that, in order to place the estimate at its outside limit, the calculated cost has been increased by 25 per cent. of itself for unforeseen contingencies. This certainly should be considered as a liberal allowance ; but if it were to be increased by 50 per cent., or even 75, the grand total would still be a most moderate sum, considering the nature of the enterprise.

And here it seems proper to compare briefly the advantages presented by this route with those offered by its rivals. These may now be considered as practically reduced to two,—Tehuantepec and Nicaragua,—and these are rivals, not on account of any superior advantages for the construction of the canal itself, but solely on account of geographical position. In this respect, especially if we regard the enterprise from a purely American point of view, it is evident that Tehuantepec takes the lead, and that the

other routes follow in order as we go south. But neither Panama nor Truando are sufficiently ahead in this respect to counterbalance their obvious disadvantages in other ways; so that, as I said, we need consider only Tehuantepec, Nicaragua, and the Napipi-Doguado, for at one of these three points the canal will surely be built, if built at all.

Tehuantepec and Nicaragua have both been recently and ably surveyed by officers of our navy, the former under the direction of Captain R. W. Shufeldt, and the latter under that of Commander E. P. Lull. The report of Captain Shufeldt, while it demonstrates the *possibility* of constructing a canal across the Isthmus of Tehuantepec, shows with equal clearness that the project is not practicable in the sense in which that term has been used in this paper. That is to say, it would require such an immense outlay of time and money for its construction as to preclude any idea of its ever proving a paying investment for capitalists.

Captain Shufeldt himself says that it would require *national* resources to build it. Its length would be 144 miles; it would require 140 locks; and a feeder 27 miles long, with 3 miles of tunnelling, passing through a country "subject at all times to serious terrestrial convulsions,"\* would be necessary in order to supply it with water. It would require a vast outlay to provide proper harbors either at the mouth of the Coatzacoalcos River, on the Atlantic side, or at the Bay of Salina Cruz, the proposed terminus on the Pacific. In addition to all these formidable physical obstacles, the present population of the country is hostile to the enterprise.

The report of Commander Lull upon Nicaragua has not yet been made public; so we have no proper basis for comparison. We know, however, from previous surveys,† that the length of actual cutting for a canal by this line would be something over 100 miles; that the region is peculiarly subject to the action of volcanic agencies; and that the line is destitute of good harbors at either end.‡

How, now, is it with the Napipi-Doguado? In the matter of length, it is of course immediately ahead. As for harbors, it has on the Atlantic side the Gulf of Darien, which unites accessibility, security, capacity,—

\* Shufeldt's report.

† Survey of Messrs. Fay and Childs in 1850-51, as reported in Admiral Davis's report in 1866.

‡ Since the above was written I have learned that Commander Lull has found that route to be much more favorable than the previous explorers had supposed. According to the latest surveys, the total length of the proposed canal is 61 74-100 miles. No tunnel is required; and it is thought that the harbors at Greytown and Brito can be readily improved. This being the case, Nicaragua becomes a formidable rival to the Napipi-Doguado.

all the qualities, in fact, that could be desired; while on the Pacific side it opens upon a region where ships may safely lie at anchor in an open roadstead year in and year out. Moreover, there is upon this side, within ten miles, the Bay of Cupica, where ships might conveniently lie, if desirable, while awaiting their turns for passage through the canal.

Then there is the earthquake question, which has already been alluded to as a great objection to both Tehuantepec and Nicaragua. The vicinity of the Napipi and Doguado, according to Dr. Mach, the geologist of the expedition, is of the very oldest tertiary volcanic rock, that gives evidence of having lain undisturbed for ages. This fact and the results of experience go to show that this region is little likely to be affected by volcanic disturbances of such a character as to endanger the permanency of the canal works. Too much stress cannot be laid upon this fact when considering the comparative advantages of the rival routes.

The only point, then, in which the Napipi route appears to be at a disadvantage, is that it requires a tunnel; and this, in the public mind, seemed to be a terrible *l'êe noir*. I will not tax your patience to listen to any argument to prove that such a tunnel is perfectly practicable, but will content myself with stating that it is so considered by the most eminent engineers of our country.

It of course introduces an element of uncertainty into the estimates of cost, since it is impossible to predict what may be encountered in the interior of the hills that are to be pierced. But the liberal allowance in the estimates already given ought certainly to be sufficient to cover all extra expenses that may be caused by unlooked-for contingencies in this direction.

If we regard it as a mere question of engineering, such a tunnel as this line would require would be but a small matter in comparison with some already constructed; for it is the *length* of a tunnel, it should be remembered, and not its *size*, that renders it formidable. The larger it is the easier it will be to excavate it, other things being equal.

The necessity which exists for a canal across some one of the American isthmuses is so generally admitted that any argument upon that head at the present time would be superfluous. I will, however, show you the following table, prepared for Captain Selfridge's report; it is more eloquent than words:

TABLE

Showing the probable saving in time and distance to be effected for Sailing Ships by a Canal across the Isthmus of Darien :

Outward Bound. New York to--	By present Route.		By Canal.		Gain.	
	Miles.	Days.	Miles.	Days.	Miles.	Days.
Hong Kong.....	14,930	110	12,480	83	2,450	27
Shanghai.....	15,200	115	12,200	81	3,000	34
Yokohama.....	15,750	119	11,550	79	4,200	40
Manila.....	13,700	108	12,260	80	1,440	28
Batavia.....	12,170	105	13,425	87	.....	18
Sydney.....	13,220	105	10,480	75	2,740	30
Valparaiso.....	9,760	90	6,510	52	3,250	28
Callao.....	11,100	105	6,710	53	4,390	52
Honolulu.....	14,500	121	7,400	54	7,100	67
San Francisco.....	14,840	130	7,470	58	7,370	72

Homeward Bound. To New York from--	By present Route.		By Canal.		Gain.	
	Miles.	Days.	Miles.	Days.	Miles.	Days.
Hong Kong.....	14,660	110	11,875	87	2,785	23
Shanghai.....	16,000	113	11,305	80	4,695	33
Yokohama.....	16,070	114	10,370	77	5,700	37
Manila.....	14,010	109	12,035	88	1,975	21
Sydney.....	13,410	110	10,390	70	3,020	40
Valparaiso.....	9,780	90	4,965	42	4,815	48
Callao.....	11,120	100	3,690	32	7,430	68
Honolulu.....	15,760	110	8,055	63	7,705	47
San Francisco.....	14,970	125	5,980	50	8,990	75

NOTE.—All distances are given in *nautical miles*. The "days" under "present route" are *actual averages* obtained from various reliable sources. The days under "by canal" are *computed*; the data given in Maury's Pilot and Wind and Current Charts being the basis of the computation.

The question of the probable revenue from the canal is also of sufficient importance to demand a moment's notice. From careful calculations, made upon the basis of the statistics of trade for 1870, Captain Selfridge estimates that the canal will yield, at the end of the second year, a net income of over \$5,000,000, or nearly nine per cent. upon its cost of sixty millions; and there can be but little doubt but that this would be doubled in a few years by the increase of trade stimulated by the canal itself. It would undoubtedly, then, prove a profitable investment.

And now, gentlemen, I have hastily and imperfectly sketched the results obtained by three successive seasons of persevering labor and no little hardship. In endeavoring to sift the immense mass of material at hand, I have been compelled to pass over many important points, and have, perhaps, dwelt longer upon others than their interest would justify. But I have attempted to show you what geographical questions have been answered; to give you an idea of the little-known regions visited; and to put you in possession of the leading facts relative to the newly-discovered route, and the work which it is there proposed to construct, in order that you may be able to judge for yourselves of the comparative merits of the different lines that may be proposed.

As to which of these offers the greatest facilities, there may be room for doubt. As to the imperative necessity for a canal by one or the other, there can be no question.

NOTE.—The discussion of Lieut. Collins's paper will be found at the end of this volume.



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APRIL 9, 1874.

Commodore C. R. P. RODGERS, U.S.N., in the Chair.

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## EXPERIMENTAL DETERMINATION OF THE CENTRE OF GRAVITY OF THE UNITED STATES STEAMER "SHAWMUT."

BY T. D. WILSON, NAVAL CONSTRUCTOR, U.S.N.

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NAVAL CONSTRUCTOR'S OFFICE, NAVY YARD, }  
WASHINGTON, May 8, 1874. }

*To the Hon. Geo. M. Robeson, Secretary of the Navy :\**

SIR: In accordance with a circular from the Navy Department under date of March 17, 1874, I have the honor to respectfully submit a report of an experiment made by me on the United States steamer *Shawmut* the day before she sailed for Key West, for the purpose of ascertaining the height of her centre of gravity.

At the time this experiment was made the *Shawmut* was lying in the Potomac River, below the Navy Yard, Washington, D. C.

\* This report was presented as a paper to be read before the Institute with the permission of the Navy Department. Constructor Wilson being absent, the paper was read by Professor J. M. Rice.

Although the wind blew a little fresh, there was no sea on, thus enabling the draught of water to be taken very correctly.

The ship was complete in every respect and ready for sea; the top-sail yards were on the caps, sails all furled, boats hoisted, and the two broadside 9-inch guns run out; the 11-inch pivot on the main-deck, and the 20-pounder pivot gun on the topgallant fore-castle, were amidships and secured for sea.

She had on board a crew of about one hundred men, with provisions for the full complement for three months, 32,295 pounds of water in casks and tanks, 208,320 pounds of coal in the bunkers, both boilers full of water, and steam up, the weight of water in the boilers being 53,000 pounds.

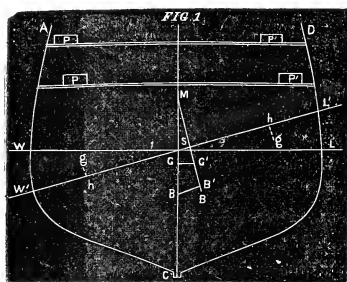
The estimated weight of the articles on board, coming under the Department of Equipment and Recruiting, excepting coal, was 108,160 pounds; the two lower anchors, weighing 6,170 pounds, were down when the experiment was made. The total weight of ordnance, ordnance stores, and equipments was 117,113 pounds. Total weight of engineers' stores and spare machinery, 4,000 pounds. Total weight of carpenter's stores, 7,038 pounds.

The conclusion that it would not be necessary to employ any other means to incline the ship than that of shifting her guns was arrived at with great satisfaction, on account of the great objection to having a large quantity of rusty pig-iron upon the clean deck of a vessel in commission, the expense attendant on transporting it to and from the yard, and also because of the still further departure from the normal state of the ship which its presence would produce, and the necessity for still greater complexity in the calculations.

As this experiment was made for my own gratification, it was necessary that the consent of the commanding officer, Commander Henry L. Howison, should be first obtained, which was freely given, and all the assistance he could afford was cheerfully accorded, for which to him and his Executive Officer, Lieutenant-Commander Norris, I am greatly indebted.

As this is the only instance that I know of where a United States naval vessel has been experimented upon for this purpose (with the exception of the United States steamer *Princeton* and the brig *Somers*, which were inclined by Naval Constructor John Lenthall, late Chief Naval Constructor United States Navy, at the Navy Yard, Philadelphia, in 1844, an account of which was recorded in the *Franklin Institute Journal*. The *Princeton* was inclined by moving weights on her decks, the *Somers* by hanging

weights on her lower yard-arms), I consider it necessary, in order that the subsequent portion of my report may be better understood, that I give a



rationale of the experiment, which may be found recorded in the "Transactions of the Institution of Naval Architects" for 1860, as made by F. K. Barnes, Esq., member of the Council of Construction, H. B. M. N. Let ACD, Figure 1, represent the transverse section of a ship, through G, the centre of gravity of the hull, and every article on board; WL the load water-

line when the ship is floating in upright position; CBGM the middle line, which is therefore perpendicular to WL, and also contains G, the centre of gravity of the ship, and B, the centre of buoyancy (or centre of gravity of the displacement). Let also P represent a weight or weights on any or all of the decks, such as guns, shot, ballast, etc., capable of being readily transported to the opposite side of the deck or decks.

If the weight or weights, P, be moved across the deck to P', the ship will incline through an angle, WSW', the amplitude of which will depend, *ceteris paribus*, upon the weight or weights moved and the distance through which they have been moved.

When the ship has taken up the new position of equilibrium, the centre of buoyancy will have moved from B to B', and the centre of gravity of the ship from G to G', so that the line joining B' and G' will be vertical, and, therefore, perpendicular to W'L', the new water-line, and will make the same angle, B M B', with the middle line, BGM, as the water-lines do with each other, and B'G' produced will meet in the middle line in a point, M.

This point, in ships of the usual form, may, without any appreciable error, be assumed to coincide with the *metacentre* when the inclination does not exceed  $4^{\circ}$  or  $5^{\circ}$ .

From a general and well-known property of the centre of gravity of a system of bodies, such as a ship, we know that since the weight or weights, P, have been moved in a horizontal direction to P', the centre of gravity has also moved in the same direction; therefore G G', the line joining the original and new centre of gravity, will be horizontal. And

from another property of the centre of gravity we have the weight of the ship  $\times G G' = P \times$  distance through which it has moved; or if  $W$  represent the total weight of the ship, and  $e$  the distance through which the centre of gravity of the weight or weights,  $P$ , has been moved,

$$W \times G G' = P e.$$

$$\text{and} \quad G G' = \frac{P e}{W}$$

Now, by trigonometry,  $G G' = G M \times$  tangent of the angle between the middle and the new vertical line  $B' G' M$ , *i.e.* the angle of the ship's inclination from the upright; or, representing the angle of inclination by  $\phi$ ,

$$G G' = G M \tan. \phi$$

$$G M = \frac{G G'}{\tan. \phi}$$

Equating the two values of  $G G'$  thus obtained,

$$\frac{P e}{W} = G M \tan. \phi$$

$$\text{or} \quad G M = \frac{P e}{W \tan \phi}$$

The right hand member of this equation contains all known quantities after the ship has been inclined; and since the *metacentre* corresponding to any draught of water is easily obtained by calculation from the drawings of the ship, and its position fixed, the distance  $G M$  set off below it will give the position of the centre of gravity of the ship.

Finally, the angle of inclination ( $\phi$ ) is found with the greatest exactness in the following manner:

A T-square above twenty feet in length, with a wide, thick blade, is nailed to the combings in the hatchways in a vertical direction, one in the main and one in the fore hatch. The two squares, being independent of each other, are intended to serve as mutual checks, and also to point out any racking of the ship, which might be occasioned by the movements of the weights on board.

From the upper edge of the head of the square a distance of 20 feet is carefully set off upwards, and at the height thus obtained a nail is driven into the board, and to it is attached a plumb-line, the plummet hanging freely at some distance below the head of the square.

When the vessel is upright, and the experiment about to be commenced, the point where the plumb-line intersects the upper edge of the head of the square is carefully marked; and when the ship has obtained

her new position of equilibrium by the movements of the weights, the new point of intersection of the plumb-line and the upper edge of the head of the square is marked in like manner. The distance in feet between the two points marked on the square, divided by twenty, will clearly give the tangent of the angle of the ship's inclination. The first thing done in commencing the experiment was to go to quarters; the powder division having been called on deck, the crew were divided equally on either side of the deck in single file, and along the edge of a seam in the deck equidistant from the centre; the marines being divided and placed in a similar manner on the poop-deck.

The two T-squares having been fixed in position, and the draught of water noted, the men were cautioned to note their position, so that they could resume it again when ordered to do so.

When all were again quiet and the ship steady, the points at which the plumb-lines crossed the upper edges of the squares were carefully marked, as already described—an operation which occupied scarcely half a minute, and it is only during these short intervals, when the marks are being made, that the men need be under any constraint.

The men were then ordered to transport the nine-inch gun from the port to the starboard side of the deck, placing it fore and aft the deck, as far out as it could be got, and close to the nine-inch gun on that side. The nine-inch pivot gun was then swung around to starboard and run out. The 20-pounder rifle on the topgallant forecastle was also swung around to starboard and run out. After all the guns had been moved, the men were ordered to resume their stations as before directed. As soon as all were again quiet, the points in which the plumb-lines crossed the upper edge of the T-squares were marked at the same time; and the deflection of the plumb-line, read off from both squares, was found to be sixteen inches.

The work of the crew here terminated, and by the movement of the guns above mentioned a registered inclination was obtained, and data furnished by which the centre of gravity might be found.

The weight of each gun moved was taken, and the distance through which it had been moved in a transverse direction was then very carefully measured and recorded.

Thus ended the work on board the ship. The recorded draught of water at the time of the above experiment was, forward 11 feet 0 inches, aft 13 feet 6 inches.

Displacement to the above line in tons, 1010.84. Centre of buoyancy below water-line, 4 feet 6 inches. Centre of buoyancy above the lower

edge of the keel, 7 feet 6 inches. Metacentre above centre of buoyancy, 7 feet  $5\frac{1}{2}$  inches. Metacentre above lower edge of the keel, 14 feet  $11\frac{1}{2}$  inches.

The sum of the products of each weight, and the distance through which it was moved, was (in tons and feet) 199.32, and the deflection from the upright of the plumb-lines in 20 feet was 16 inches; denot-

ing by  $\phi$  the corresponding angle,  $\tan. \phi = \frac{1\frac{1}{3}}{20} = \frac{1}{15}$ ,  $\phi = 3^{\circ} 49' 21''$ .

Weight of nine-inch gun and carriage 10,437 pounds, moved 20.66 feet. Weight of eleven-inch gun and carriage 24,159 pounds, moved 7 feet. Weight of 20-pounder rifle and carriage 3,793 pounds, moved 3.635 feet.

$$GM = \frac{Pe}{W \tan. \phi} = \frac{199.32 \times 15}{1010.84} = 2.958 \text{ feet, centre of gravity below}$$

metacentre. The height of the centre of gravity above the lower edge of the keel 14.95 feet — 2.96 feet = 11.99 feet. The height of the centre of gravity below the mean load-line is, therefore, .26 =  $3\frac{1}{4}''$ . Relative stability or displacement, multiplied by the distance between the metacentre and centre of gravity  $1010.84 \times 2.96 = 2992.6864$ .

The first instance in which this experiment was tried, to determine the position of the centre of gravity of a ship experimentally, was on board H.B.M. Sloop *Scylla* and the *Rover*, of eighteen guns, in Portsmouth Harbor in May, 1830. The experiment was made by a Mr. Morgan, of the School of Naval Architects, at that time the foreman of the Portsmouth dockyard.

No other experiments are recorded from that time up to 1855 (excepting those made on the *Princeton* and *Somers*, before mentioned, in 1844, and found recorded in the *Franklin Institute Journal*), when, by the upsetting of the steam-transport *Perseverance* in the dock at Woolwich dockyard, the subject was brought under the serious consideration of naval architects. The determination of the metacentre and centre of gravity is now made for every ship added to the English Navy.

The labors of Mr. Froude and of other gentlemen who have devoted their attention to the subject of rolling of ships has resulted in the establishment of two great facts. The first of these is that the principal thing (although not the only one) which influences rolling is the distance between the centre of gravity of a ship and the *metacentre*; the second is that a ship rolling at sea is largely influenced by the period,

etc., of the waves she meets with. Experience confirms the accuracy of both of these deductions.

Ships which have a great distance between the centre of gravity and the metacentre are technically termed "stiff," and will spread a great amount of canvas, but they usually roll with violence.

On the other hand, ships which have a moderate distance between these points are not so "stiff," and roll moderately; while, if the distance is very short, they will be "crank," and liable, under certain circumstances, to upset.

Very respectfully,

Your Obedient Servant,

(Signed) T. D. WILSON, Naval Constructor U. S. Navy.

The reading of Naval Constructor T. D. Wilson's paper was followed, after some discussion, by a paper by Commodore F. A. Parker :

## THE "MONITOR" AND THE "MERRIMAC."

BY COMMODORE FOXHALL A. PARKER, U.S.N.

AT ten minutes before ten, on the morning of the 30th of January, 1862, an iron floating battery, designed for the Government of the United States by John Ericsson, and named, at his suggestion, the *Monitor*, was launched at Green Point, Long Island, and at three P.M., on the 25th of February, formally taken possession of by the Navy Department, and put in commission at the Navy Yard, New York.

On Thursday, the 6th of March, this novel *float*, concerning whose fate many gloomy predictions had been hazarded, left the Lower Bay in tow of the steamer *Seth Low*, and, with a fair wind and smooth sea, steered for Hampton Roads. Her "muster-roll," which may well be handed down through all time as a *roll of honor*, contained the following names :

John L. Worden, lieutenant commanding ; Samuel D. Greene, lieutenant and executive officer ; Louis M. Stodder, acting master ; John J. N. Webber, acting master ; George Frederickson, acting master's mate ; Daniel C. Logue, acting assistant surgeon ; W. F. Keeler, acting assistant surgeon ; Albin C. Stimers, inspector of machinery ; Isaac Newton, 1st assistant engineer ; Albert B. Campbell, 2d assistant engineer ; R. W. Hanus, 3d assistant engineer ; M. T. Sanstrom, 3d assistant engineer ; Daniel Toffey,

captain's clerk ; Richard Angier, quartermaster ; Hans Anderson, seaman ; Dorick Brinkman, carpenter's mate ; Anton Baston, seaman ; William Bryan, yeoman ; Joseph Crown, gunner's mate ; David Cudderback, captain's steward ; Thomas Carroll, 1st captain hold ; John P. Conkling, quarter gunner ; Thomas Carroll, 2d 1st class boy ; Anthony Connoly, seaman ; John Driscoll, 1st class fireman ; William Durst, coal-heaver ; John Garrety, 1st class fireman ; George S. Geer, 1st class fireman ; R. K. Hubbell, ship's steward ; Patrick Hannan, 1st class fireman ; Jesse M. Jones, surgeon's steward ; Thomas Joice, 1st class fireman ; Matthew Leonard, 1st class fireman ; Thomas Loughran, seaman ; Edward Moore, ward-room cook ; Lawrence Murray, ward-room steward ; Michael Mooney, coal-heaver ; John Mason, coal-heaver ; William Marion, seaman ; William H. Nichols, landsman ; Charles Peterson, scaman ; Christy Price, coal-heaver ; Robert Quinn, coal-heaver ; John Rooney, master-at-arms ; William Richardson, 1st class fireman ; Ellis Roberts, coal-heaver ; James Seevy, coal-heaver ; John Stocking, boatswain's mate ; Moses M. Stearns, quartermaster ; Charles F. Sylvester, seaman ; Peter Truscott, seaman ; Abraham Tester, 1st class fireman ; Thomas B. Viall, seaman ; Peter Williams, quartermaster ; Robert Williams, 1st class fireman ; Daniel Welch, seaman.

About noon, on the 7th, the wind freshened, and the sea began to rise, and by four in the afternoon was making a clean breach over the little *Monitor*, causing her to reel and stagger like a drunken man—now striking the pilot-house with such fearful force as to drive the helmsman from the wheel, now raising its foaming crest far above the tops of the smoke and blower-pipes, and deluging with water the deck below. A little later, and the drenched blower-bands begin to slip, the draught grows feeble, and the steam runs down ; then, with a sudden snap, the blower-bands part, and in an instant the fire and engine rooms are filled with gas. In vain do the engineers and firemen, led by the executive officer, rush to the post of danger and endeavor to repair the damage. A poison more deadly than that from the upas-tree forbids approach to the severed bands. With heroism unequalled, each, in turn, essays to reach them ; but, one by one, all fall senseless to the deck, and are borne on the shoulders of their sailor comrades to the upper air.

While this scene was being enacted in the engine-room, the steam pumps had ceased to work, and the berth-deck pump been found to be useless, while the water driven through the hawse-hole, through the lookout-holes in the turret, and over the tops of the smoke and blower-pipes, was gradually gaining upon the vessel and threatening to submerge her. Fortu-



nately, however, the wind was off the land, and Worden, cool and collected amid the menaced danger, had ordered the *Seth Low* to steer directly for the shore. By dark the sea became smooth, and at eight P.M., the engine being again in motion, and the steam-pumps rapidly freeing the ship of water, the *Monitor* was a second time headed for Hampton Roads.

The first watch passed pleasantly away, under a serene sky, while the silver moon looked benignantly down upon a band of mariners as hardy and daring as that which, leaving the shores of Spain four centuries before, had braved the trackless ocean in search of this very land, for whose defence these later mariners were now so resolutely pressing onward.

With the mid-watch the sea again rose, and dashed madly over pipes and turret, threatening a recurrence of the disaster of the previous day. The wheel-ropes, too, became jammed, so that, no longer governed by the rudder, the vessel yawed wildly to and fro, bringing a fearful strain upon the hawser by which she was towed, and upon which—now that her engine had nearly stopped—her safety mainly depended. To add to the horror of this anxious night, every few minutes, in response to the enquiries of the captain, came the dismal sound from below, “Blowers going slowly, sir, but can’t hold out much longer!”

Ere the rising of the sun, however, the waves had subsided, and when it set the *Monitor* was inside of Cape Henry, heading for Fortress Monroe. Through the providence of God, her officers and men were saved from shipwreck; and well might the lovers of freedom, everywhere on the habitable globe, rejoice at their salvation. The Genius of the Republic had a great work for them to perform on the morrow, for which the severe trial to brain and nerve to which they had been subjected on their adventurous passage was doubtless designed as a grim preparation.

For never were brain and nerve more needed than now—never arrival more timely than this! The *Cumberland* sunk, the *Congress* in flames, several transports destroyed, the *Minnesota* aground! Such was the tale, alike piteous for those who told and those who listened to it, which startled the ears of the iron pioneers as they entered the waters of the Chesapeake—a tale which, flashed across the wires, caused apprehension in every loyal heart from Maine to Virginia, from New York to California, for the safety of the capital, of Baltimore, of Mansfield’s army. What mighty issues, then, now depended upon the untried *Monitor* and her glorious crew! Perchance a nation’s weal or woe, liberty or slavery, republicanism or tyranny! But God is just; and amply did the vessel sustain her country’s honor, amply vindicate the judgment of the gifted Ericsson, in the conflict that ensued.

At nine o'clock that night Lieutenant-Commanding Worden reported his arrival at Hampton Roads to Captain Marston, the senior officer present; and, being directed to proceed to Newport News for the protection of the *Minnesota*, he availed himself of the services, as pilot, of Acting Master Samuel Howard, an earnest volunteer for this duty, and, continuing onward, anchored in close proximity to the stranded vessel a little after midnight. Just before he "came to," the *Congress* blew up with a terrific report, and, as the blazing fragments were thrown high in air, exhibited a spectacle of grandeur such as is rarely witnessed. The Confederates greeted it with loud huzzas, but the Unionists beheld it with feelings of shame and humiliation, and a vague fear of some dread disaster in the future. On the *Monitor* not a word was spoken; but each man registered a vow of vengeance, on the tablets of his heart, against the ruthless *Merrimac*.

Thus passed away the weary hours of the night, and when day dawned all eyes were directed toward Sewell's Point, in an eager endeavor to discover the number, disposition, and intention of the foe.

And first "loomed up," amid the mists of morning, the *Patrick Henry*, next the *Yorktown*, and finally the iron-plated ram herself, the formidable *Merrimac*, surrounded by several small tugs, and looking, with her arched back, like a huge tortoise. Her design was, evidently, to assume the offensive, and about half-past seven she was reported under way, with her consorts, steering for Newport News. At the same time the drums on the *Minnesota* and *Monitor* were heard loudly beating the call to quarters; and the gallant Worden, lifting his anchor, stood boldly toward his enemies, with the intention of engaging them at as great a distance as possible from the noble frigate, in whose defence it became clearly necessary to give battle now.

As he approached, the wooden vessels, scattering like a flock of frightened sea-gulls, took refuge behind the defences at Sewell's Point, and, alone and unaided, the *Merrimac* sullenly confronted her tiny antagonist. Then, turning head to tide and slowing her engine, she triced up her ports and commenced firing, while her crew gave vent to their enthusiasm by cheer after cheer, as they demanded to be taken into close action with what they derisively styled "a Yankee cheese-box upon a raft." And, in truth, the simile was not a bad one; nor was it to be wondered at that, calling to mind the havoc made on the previous day by their mammoth vessel, the *Merrimacs* should now look contemptuously down on the strange-looking craft which presumed to dispute their approach to what they had deemed their lawful prize, the helpless *Minnesota*.

On the other hand, the crew of the *Monitor* felt entire confidence in their officers, their vessel, and themselves, and well knew that, on this still Sabbath morning, from every temple throughout the North, every stately mansion, cot, and cottage—for the telegraph had spread far and wide the news of the impending battle—prayers were being offered up for their welfare. The married men thought of their wives and children, the single of their mothers and sweethearts; and, if anything further were needed to stimulate their patriotism and courage, there were the stars and stripes floating just awash from the mizzen peak of the *Cumberland*, telling how brave men had died rather than surrender.

Worden now steadily steered for the starboard bow of the *Merrimac*, on a course at right angles to her keel; and, when within a few yards of her, put his helm hard-a-starboard, and, in a clear, ringing voice that was distinctly heard by the enemy, gave the command—fire!

Scarcely had the word escaped his lips when the muzzle of an 11-inch Dahlgren was seen protruding from one of the ports of the turret, and, in a second after, Greene, who was deliberately sighting the piece, pulled the lock-string. "It did our hearts good," said an old tar who had escaped the carnage on board the *Congress*, and who, with many of his shipmates, was an eye-witness of the fight—"it did our hearts good to see its flash and to hear the noise it made, and to know that the little *water-tank* was paying the rebs full interest on the debt we owed them."

The Confederates were not slow, however, in responding, both with great guns and musketry—the latter aimed at the lookout-holes in the pilot-house, with the view, no doubt, of disabling the commanding officer and helmsman; and the battle was thus fairly begun, each vessel, as she passed close aboard of her antagonist, delivering her fire and receiving a tremendous fire in return. It was an anxious moment with both Union and Confederate commanders: the one apprehensive that his turret, which had been hit twice, might be so deranged as to cease revolving; the other dreading, as he heard the huge missiles of his enemy rattling against the sides of his vessel, lest her armor should be pierced. As the iron-clads drew clear of each other, however, it became apparent that neither was injured in the least; and as, with confidence redoubled, Worden turned short round to renew the engagement, he found his adversary by no means disinclined to welcome him to close quarters. So at it again they went, side by side, and again the solid bolts glanced harmlessly from roof and tower and turret. For two hours the battle raged in this manner, the vessels almost touching each other, when the *Monitor*, finding her supply of shot in

the turret exhausted, hauled out of the action and ran into shoal water, where she remained while it was being replenished. This was a tedious operation, as each shot weighed one hundred and sixty-eight pounds, and had to be hoisted from below by hand, and occupied about twenty minutes, during all which time the Confederates, both afloat and ashore, believing the victory theirs, were loudly and wildly cheering.

Giving no heed, however, to their noisy vociferations, Worden coolly waited until his battery was reported "ready for action," when, observing that the *Merrimac* was bearing down upon the *Minnesota*, and had opened upon her with terrible effect, sending one shell through the boiler of a tug lashed alongside of her, and another fore-and-aft of her berth-deck, knocking four rooms into one and setting the ship on fire, he stood boldly across the assailant's bows; and the *Merrimac*s found, to their chagrin, the despised Yankee cheese-box intact, and once more interposed between the Confederate monster and its prey.

Judging the occasion favorable, Lieutenant Jones, the commanding officer of the *Merrimac*, determined to ram his saucy opponent, and, ordering four bells to be rung, dashed ahead at full speed, with the hope of hitting her amidships; but, by a skilful movement of his helm, Worden avoided the direct blow, and the *Monitor*, being struck obliquely on the starboard quarter, bounded away from her enemy without receiving the slightest injury.

The contact of the vessels was brief, but before they separated Greene had planted a shot full and fair in the roof of the *Merrimac*, which "stripped off the iron freely," and for a moment it was thought by the officers and crew of the *Minnesota*—anxious spectators, as we may well conceive, of this novel combat, upon whose issue the fate of their own ship depended—that the leviathan had received her quietus; for she turned her head quickly toward Norfolk, while Worden, close at her heels, steered across her stern, and endeavored to cripple her screw.

The excitement now among the lookers-on at Newport News and Fortress Monroe no language can describe. "She is whipped! she is whipped!" they cry. "Hurrah for the little *Monitor*." But suddenly their voices are hushed, and each man holds his breath; for here the *Merrimac* comes once more—a goodly sight to see, with all her banners flying—steering straight for the "little, submerged propeller." Again the vessels graze each other in passing, again the eleven-inch gun plays upon the *Merrimac*, while shot, shell, and canister in return are concentrated upon the pilot-house and turret of the *Monitor*. Thus the fight continued for another hour without any obvious advantage to either combatant, when a

shell, striking the pilot-house of the *Monitor*, fractured one of the great iron logs—nine by twelve inches—of which it was composed, and, filling Worden's face and eyes with powder, utterly blinded and in a degree stunned him. Deprived of sight for ever, as he supposed, and writhing in agony, this brave officer lost not his self-possession for an instant. His force of character and high professional training nobly sustained him; and, like Regulus amid the tortures of the Carthaginians, his thoughts were not of himself, but for his country. Believing his vessel seriously injured—for the top of the pilot-house had been partially lifted off by the concussion—he ordered the helmsman to sheer off into shoal water, and then, feeling faint, groped his way to the foot of the ladder leading to the berth-deck, and sent for Lieutenant Greene. "I found him," says Greene in a letter written just after the action, "leaning against the ladder, as noble a specimen of a man as ever breathed; his face black with iron and powder, and his sight apparently gone. He told me in a calm, quiet voice that the pilot-house was damaged, and that I must take command. I led him to his cabin, and laid him down upon a sofa, and then hastened to take my place beside the helmsman, while the gun-captains continued to fight the guns, under the supervision of Chief-Engineer Stimers, who was revolving the turret."

Finding the injury to the vessel less severe than his commander had supposed, Lieutenant Greene ordered her head to be again turned towards the *Merrimac*, which was now, for a second time, keeping up a deadly fire on the *Minnesota*. As the *Monitor* turned, however, so did the *Merrimac*, and, to the surprise of all not on board of her, she steamed at full speed for Norfolk. Yet, expecting her each instant to turn upon her pursuer, the Unionists were silent until they saw her wholly leaving the battle-field and seeking shelter under the Confederate batteries, thus, by all the laws of war, acknowledging herself vanquished. Then a shout of exultation arose, from sailor and soldier alike, extending from Fortress Monroe to Newport News, which shook the very heavens above. Right had, once more in the world's history, triumphed over wrong! And the dead of the *Congress* and *Cumberland*, whose bodies were lying stark and stiff upon the banks of the James or in its bed, had not died in vain; for to the injuries inflicted upon the *Merrimac* by their well-directed broadsides, on the bloody 8th of March, was due, in some measure, it has been credibly asserted, the great victory of the following day.

The political significance of this victory can hardly be over-estimated. It produced an immediate and marked effect upon our diplomatic relations with England and Europe, whose rulers, restored to their senses

by this "latest Yankee notion," began now to look upon the United States as a formidable naval power.

What the wounds of the *Merrimac* really were we shall perhaps never know ; but that they were serious none can doubt. For Lieutenant Catesby Jones was an officer of acknowledged capacity, bravery, and experience, who must have well understood that fealty to the cause which he had espoused required him to retain the offensive as long as it was possible to do so. He would, therefore, never have retired from the fight while a hope remained to him of winning it.

As the little *Monitor*, very properly, gave up the pursuit of the foe—for, with the vast interests depending upon her safety, her rôle was purely defensive—and, with the proud banner of freedom flying from her flag-staff, once more took her place alongside the *Minnesota*, all hearts were raised in thankfulness to God for his manifold and great mercies. And all over the land for many, many months the story was told of how Ericsson planned and how Worden and his gallant men fought the famous *Monitor*. God's blessings on them all ! May a grateful country never suffer their memories to grow cold, and may their names, inseparably connected with some of the darkest and yet most glorious days of the Republic, be mentioned with reverence by our children's children.

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Commander F. V. McNAIR, U.S.N., in the Chair.

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OUR FLEET MANŒUVRES IN THE BAY OF FLORIDA, AND THE NAVY OF THE FUTURE.

BY COMMODORE FOXHALL A. PARKER, U.S.N.

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CIRCUMSTANCES having made it necessary for our Government, at the commencement of the present year, to assemble a fleet in the waters of Florida, the Hon. Secretary of the Navy thought the occasion favorable for the instruction of its officers in the various branches of their profession, and especially in naval tactics, that part of it to which enlightened Europe had given most attention, America and Asia least; and it seeming but reasonable that the author of a theory to be practically tested should be permitted to test it himself, provided he desired so to do, I, who had drawn up both the tactics and the tactical signal-book, was detailed for this service, and, on the 16th of January, reported at Key West to Rear-Admiral Case, as "Chief of Staff of the united fleets under his command."

It being found that the collective fleet would not be ready for manœuvring before the 1st of February—some of its vessels ordered from distant stations not having yet reported—the intervening time was passed in boat, great-gun, howitzer, and infantry exercises; and, on the afternoon of the 20th of January, a force of seventeen hundred blue-jackets and marines was thrown ashore on the south beach of Key West, formed in line of battle, and advanced in this order through a dense

chaparral to the lighthouse, distant a half-mile from the landing, whence, after a brigade dress-parade, it was marched in column of companies, right in front, to the Government store-house wharf, which had been designated as the place of embarkation. Taking into consideration the fact that at least one-half of the men were greenhorns, recently shipped, the affair was an exceedingly creditable one. There was neither straggling nor drunkenness; and, although the irregular swaying of the bayonets on the march betrayed the recruit, yet the manual of arms and the various changes of formation were executed with a precision and style which reflected the highest credit upon the young drill-officers, all of whom, with three or four exceptions, were graduates of the Naval Academy.

The howitzer-firing from the boats, however, on this occasion, was neither rapid nor well sustained, nor was the howitzer manipulated afloat as dexterously as it should have been. Ashore it appeared to better advantage, yet neither afloat nor ashore did this truly sailor arm compare favorably with the infantry.

Of the boat exercises in fleet manœuvres, the less said the better. They were decidedly a failure, and showed clearly how little importance had been attached to the study of fleet tactics by the navy generally.

On the 31st of January the rear-admiral commanding issued the following order:

The North Atlantic fleet is hereby separated into divisions as follows:

VAN, OR RIGHT DIVISION.—1. *Congress*; 2. *Ticonderoga*; 3. *Canandaigua*; 4. *Fortune*.

CENTRE DIVISION.—5. *Colorado*; 6. *Wachusett*; 7. *Shenandoah*; 8. *Wyoming*.

REAR, OR LEFT DIVISION.—9. *Lancaster*; 10. *Alaska*; 11. *Kansas*; 12. *Franklin*.

RESERVE DIVISION.—Monitors and torpedo vessels.

The senior officer of each division will command it, and will wear a division flag at his main. He will lead his division when the right is in front, and bring up the rear with the left in front. He will repeat the Admiral's signals, and, when all the vessels of his command have answered *his* signal, will hoist an answering pennant as an indication to the Admiral that the command are prepared to obey it. When all the divisional officers have hoisted their answering pennants, and the Admiral is ready, he will haul down his signal; the divisional officers haul down *their* signals and *answering pennants at the same instant*, and the signal is executed.

From the moment of sailing, each vessel will keep her distinguishing



pennant hoisted until she comes to anchor, when she will haul it down.

When signal 413—*Get under way*—is hoisted with the preparatory over it, and answered in the manner prescribed above, it will be hauled down, when each vessel will heave in to a short stay, and hoist her distinguishing pennant. So soon as all have their distinguishing pennants flying, signal 413—*Get under way*—will be made by the Admiral, and when replied to as above directed, and the Admiral is ready, will be hauled down. *All now weigh together.*

When signal 224—*Anchor*—is hoisted, with the preparatory over it, and properly answered, it will be hauled down. At this instant the fleet will slow to three knots.

The Admiral will next hoist signal 224—*Anchor*—and the moment it is mast-headed each vessel will stop her engine (without waiting for a signal from divisional officers), letting go her anchor the moment it is hauled down.

When the signal is made to “get under way,” the fleet will move out in “columns of vessels” with the van leading, unless another formation be signalled.

If not otherwise directed, vessels will “come to” with their starboard anchors.

All courses signalled are magnetic. Tactical signals at night will be made with Coston lights, and the moment of execution denoted by the discharge of a gun.

In conclusion, the Commander-in-chief calls particular attention to the “Explanation,” U. S. Navy Signal-Book, Naval Tactics, 1874, whose precepts must be rigidly adhered to by Commanding Officers.

A. LUDLOW CASE,

Rear-Admiral U.S.N.

Commanding U. S. Naval Force, North Atlantic Station.

Flagship *Walash*, 1st Rate, Key West, Fla., Jan. 31, 1874.

On the 3d of February the fleet (the reserve excepted), which had been lying in irregular order off Key West, shifted its berth to the “outer buoy,” near Sand Key light, where it anchored in columns of vessels abreast by divisions, in natural order, heading south, the van division, commanded by Captain Rhind, being on the right. At daylight on the following morning general signal was made to get under way, and as no formation had been prescribed, and the vessels were then heading S.S.W., the van division moved forward, while the centre and rear divi-

sions obliqued to the right, until in the van's wake, when they steered S.S.W., thus forming column of vessels, which formation the fleet preserved very badly during the day, coming to anchor at night in line off buoy No. 9, Dry Tortugas, by a movement analogous to the right into line of the army, the vessels heading N.N.W., and bearing from each other, reciprocally, E.N.E. and W.S.W., the *Congress*, flagship of the van division, having anchored first and furthest to the N'd and E'd.

At eight A.M., on the 5th, the fleet weighed, and, forming column of vessels, followed the *Congress* through the passage between the Dry Tortugas and the Rebecca Shoal into Florida Bay. The direction of the head of the column was several times changed during the day, and at six P.M. the signal "Forward into line—left oblique!" was made, followed shortly afterwards by the signal "Anchor!"

On the 6th we moved to the eastward, and anchored a tug at the distance of twenty-five miles southeast from Key West, in which vicinity we remained for more than three weeks, in the almost daily exercise of fleet manœuvres. These consisted of the various line, column, and echelon formations laid down in the tactics, and in passing from one to the other, the column varying from single vessel to division front, the echelon being single and double, natural and inverted, and the line either single or double; the fleet moving alternately by the front, flank, and rear. After a few days' exercise, the various movements were performed with exactness, though with a slowness that was disheartening, since the greatest speed that could be maintained by the fleet *as a unit* was four and a half knots an hour.\*

As our anchorage was exposed to winds from the northwest, which, during the winter months, sometimes sweep with great violence over the Bay of Florida, the fleet always came to at night in columns of vessels abreast by divisions, heading east, and in this order, on February 9th and 10th, it rode out a northwest gale, without the slightest apprehension being felt on the part of the commander-in-chief for the safety of any of his

\* It must be remembered that several of these vessels had been long in commission, and were almost "broken down" in boilers and engines; yet they formed part of a force that did not number one too many for the service that might have been required of it, and their speed could not have been exceeded by the fleet without abandoning them as prizes to the enemy, had we been called upon to meet one.

Out of our whole force of wooden and iron vessels, not more than eight could have maintained a speed of six and a half knots, and not more than six a speed of eight knots an hour.

The tugs *Pinta* and *Fortune*, and the little steamer *Dispatch*, are, of course, not included in this summing up.

command, since, being in echelon so long as the wind blew, no vessel could drive on the hawse of another.

On the 20th and 24th insts. the fleet, steaming in column of vessels (close order) at the rate of four knots an hour, was exercised in firing at a target, distant eight hundred yards; and on the 25th some exceedingly interesting experiments were made with spar torpedoes, each vessel exploding one or more of these, filled with from 80 to 150 pounds of powder, under or near a floating raft constructed of casks and spars.

On the 26th and 27th the fleet, in columns of vessels, abreast by divisions, was exercised principally in changing direction without altering formation, and on the afternoon of the latter day, the vessels being in column of divisions, with the van leading, and flagships on the left, heading east, and the Admiral desiring to anchor for a few hours for the purpose of communicating with the shore, and afterward to proceed west to the Dry Tortugas, from which direction the tide was then setting, signal was made to the van division, *By the left flank!* to the centre division, *Star!* to the rear division, *Forward into line—right oblique!* So soon as the rear of the van division was clear of the left of the centre, signals were made to that division, *By the right flank!* *Dress on centre division!* By the time these were executed the rear division had gained its place, and, the whole fleet being now in line, under the *Brooklyn's* distinguishing pennant was hoisted 267: "Fleet—from the right and left of—on the vessel whose distinguishing pennant is shown above this signal, form double echelon inverted."

The moment this signal came down the wings moved forward simultaneously and formed a right angle with each other, of which the *Brooklyn*, of course, was the apex.

In this formation the fleet anchored, and, swinging head to tide, found itself, upon weighing anchor at eight P.M., in double echelon (natural order), with the *Brooklyn*, carrying her guide-lights, leading and steering west. Midway between the two columns, on a line with the fifth vessel of each, was the *Wabash*, with her tenders, the *Dispatch* and *Pinta*, on either quarter.

During the night the vessels kept their stations perfectly. Certainly in unity and strength the fleet had gained greatly since the day when it had feebly groped its way out of the harbor of Key West, and, at irregular intervals and in straggling groups, made its way to the islands, whither in perfect order it was now returning.

At six A.M. signal was made to the divisional commanders to bear up for the anchorage previously assigned to them at the Tortugas, and the fleet manœuvres here ended.

A week later, and the reserve division of monitors was exercised for two days in squadron evolutions, and, contrary to what was expected, it manœuvred admirably; its speed, however, being limited to that which the slowest one of its number could maintain for any length of time, was but four knots an hour.

The distances and intervals of the vessels were remarkably well kept, and all but the *Mahopac*, which was evidently out of trim, steered well. The wind was light from the S'd and E'd during both days' evolutions, and on the first day the water was smooth. On the morning of the second a heavy sea was rolling in upon the Florida reef, on the outside edge of which we were, but by noon it had subsided to a gentle swell. Table A shows the relative turning power of the monitors, moving at the rate of  $4\frac{1}{2}$  knots an hour, with light wind and smooth sea; Table B their greatest attainable speed under the most favorable conditions of wind and weather.

TABLE A.

Names.	Rate.	Tons.	Full cir. to stb'd.	Full cir. to port.
Saugus.....	4	550	3 min. 00 sec.	4 min. 00 sec.
Manhattan.....	4	550	6 min. 49 sec.	4 min. 45 sec.
Ajax.....	4	550	7 min. 10 sec.	7 min. 15 sec.
Mahopac.....	4	550	6 min. 49 sec.	7 min. 59 sec.
Dictator.....	2	1,750	7 min. 54 sec.	8 min. 30 sec.

TABLE E.

Names.	Rate.	Tons.	Speed in knots.
Dictator.....	2	1,750	10.50
Saugus.....	4	550	6.00
Ajax.....	4	550	5.75
Manhattan.....	* 4	550	5.50
Mahopac.....	4	550	4.75

And now the "great drill," as the New York *Herald* had styled our exercises, being ended, what was the lesson it had taught? That a naval force, no matter of what elements composed, possessed but little strength unless properly organized and thoroughly exercised in tactical manœuvres, every officer who had witnessed our evolutions was willing to admit; but, apart from all this, it became painfully apparent to us that the vessels before us were in no respect worthy of a great nation like our own; for what could be more lamentable—what more painful to one who loved his country and his profession—than to see a fleet armed with smooth-bore guns, requiring close quarters for their development, moving at the rate of four and a half knots an hour? What inferior force could it overtake,

or what superior one escape from, of any of the great naval powers of the earth? Did it rely, in the latter case, upon its spar torpedoes for defence, what Don Quizote of an admiral was going to run upon them, when, having "the legs" of his adversary, he could concentrate upon his van or rear or upon one of his flanks, and, choosing his distance, coolly cut him to pieces with his artillery?

And, in truth, what reliance could be placed upon our torpedo system afloat for either offence or defence?

After many days' preparation, seven of the eighteen torpedoes used on the 25th of February had failed to explode, while of those that did explode not more than four were submerged under the target.

If, then, on a beautiful, calm day, with nothing to disquiet us, such was the result, what would have happened had the fleet at the time been exposed to the disturbing influences of an enemy's shot and shell? Take, for example, the *Wabash*, whose battery consists of forty-four nine-inch guns. Now, while she is approaching an enemy (supposing such a thing possible) with the design of torpedoing him, she will either be using her artillery or not using it.

In the latter case her enemy, having simply a target to fire at, would riddle her completely, and cut all her torpedo-gear away before she could get within a hundred yards of him.

In the former, how, in the name of practical common sense, is the operator at the electric battery, amid the confusion and din of battle, and the smoke of his own guns, to tell the instant to "close the circuit"? For he has but an instant, remember, and no more. If, however, the object struck is itself to close the circuit, how are you to be assured that, after the *mêlée* has once commenced, this object will not be one of your own vessels?

The *Franklin*, the *Colorado*, and the *Lancaster*, leading their respective columns, and the *Wabash* in the centre of the fleet, looked warlike and formidable indeed, with their powerful batteries, as artillery ships; but with their booms rigged out as torpedo vessels they were simply ridiculous. "But," remarks the torpedo officer of the *Wabash*, in his official report of March 9—which is little more than an apology for the many failures of February 25—"to say that it is useless for these old wooden ships to even try to use torpedoes or have them is, in my opinion, a mistake; for, if they ever can get alongside of vessels of superior force and speed, either by surprising them at anchor in the night or in any other way, they can destroy these vessels with torpedoes when it could be accomplished in no other possible manner."

The plain answer to this is that men-of-war do not suffer themselves to be surprised at night by *large bodies moving slowly*. The proper way to attack a vessel lying at anchor is with small boats fitted with torpedoes, as Cushing attacked the *Albemarle*; for if you run at her with your own vessel, and her commanding officer be not a fool, you will probably find yourself journeying toward the stars long before your pole can be brought into requisition; since in this torpedo warfare on soundings the advantage is decidedly with the defence, and it is not to be supposed that a vessel would remain long at anchor without surrounding herself with floating or submerged torpedoes, or a cordon of boats fitted with torpedoes, inside of which it would be impossible for a large vessel to penetrate. Or, if without torpedoes, her captain might not unwisely follow the example of one of our old officers of farming propensities, who, being obliged to remain many weeks at anchor off our southern coast during the civil war, quietly fenced himself in, and then, taking care that the gate of his sea-yard was closed at sunset, he slept peacefully every night, undisturbed in the slightest degree by torpedo visions.

The exercise of the torpedo in Florida Bay was of great service to us, however, since for the intelligent use of any weapon it is as important to know what cannot as what can be effected by it. It is one thing to promise great results on paper, and another to obtain them in actual practice; and it is clear to my mind now that, rigged out on a pole attached to a large vessel not possessing very great speed and turning power, the torpedo is alike harmless to friend and foe.

Nevertheless, for our long line of seaboard the torpedo is invaluable, and the submarine mine of the engineer, supported by forts, and aided, as it would be in time of war, by monitors, tugs, and launches, has almost hermetically sealed our harbors to a hostile fleet, while a rigid blockade of any of them would be next to an impossibility, harassed incessantly, as the blockading force would be, by improvised rams and torpedo-boats, and by infernal machines of every conceivable device and construction.

It is true that the blockading admiral, supposing him to be a man of energy and resolution, would endeavor to overcome the torpedo with the torpedo, the mine with the countermine; yet, taking into consideration the ingenuity and enterprise of our people, and the disadvantage under which both armies and fleets operate at a distance from their base of supplies, the defeat of the blockaders might be relied upon, I think, with almost absolute certainty.

Shall we, then, because secure in a great degree from the attacks of hostile fleets upon our shores, conclude with Mr. Boutwell that ships of

war may be dispensed with, and let our vessels rot alongside of decaying wharves?

Is the great Republic so beloved by all mankind that its citizens are safe in every land and its merchantmen on every sea?

We know that such is not the case, and surely all experience should teach us that nothing is so galling to a gallant nation as to be obliged to submit to insult because utterly unprepared to resent it. Unfortunately for the peace-makers, the millennium has not yet come, and whatever may be the indications of it in the heavens above, there are none whatever on the earth below. Nation is still rising against nation. Europe is a vast military camp, while the fleets of the great naval powers surpass all that the world has yet seen of mighty armaments upon the deep. Turkey, with fifteen iron-clads, forty-four screw-frigates, and a disciplined army, is not dead yet; China, with her vast hordes, imports modern artillery and improved rifles; Japan, destined to bear the same relation to Asia that England bears to Europe, has one or more dock-yards and an iron-clad squadron. What, then, is there in the condition of any of the four quarters of the globe to lead to the belief that wars in the future will be less frequent than in the past? At the risk of being accused of intellectual blindness, I emphatically reply, nothing whatever. I am forced, then, to the conviction that, for the maintenance of our national dignity at home and abroad, the protection of our commerce upon the high seas and our citizens in foreign lands, a sea-going fleet is absolute necessary for us—not a large fleet like that of England, but one which shall be complete in itself, and serve as a safe nucleus to rally around when the hour of trial comes. Let us consider now of what elements this fleet should be composed.

If the object to be kept in view were simply the encountering of a hostile force at sea, the ram would alone, in my opinion, suffice for our purpose, fully convinced as I am that, for fleet-fighting, it is the most terrible engine of war that a navy can possess. The fire of artillery may be withstood, the contact of the torpedo guarded against; but that there is no withstanding the shock of the steam-ram the battle of Lissa, the sinking of the *Cumberland*, and daily collisions on the ocean bear witness. For attacking forts, however, guns must be brought into play; and for creeping stealthily upon a large vessel at night, in thick weather or amid the smoke of battle, there is nothing equal to the low torpedo-boat; consequently, to be prepared for all the service that may be expected of it, the fleet of to-morrow must consist of rams, torpedo-boats, and artillery-vessels, all of which should be steamers of great

speed, having auxiliary sail power, and, if not propelled by twin-screws, some mechanical contrivance to enable them to turn short around with celerity; for turning power is essential to every man-of-war, and especially so to a ram, which must always keep her head turned towards the enemy. In storms the dependence of these steamers for safety should be on their engines, and if never required to make sail with the wind forward of the beam, their masts might be telescopic (as proposed by Rear-Admiral Boggs some years since), and their spars and sails so light as to be easily handled and sent below; so that an artillery-vessel would have nothing but her lower masts, and a ram and torpedo-vessel nothing at all, left standing above decks when steaming head to wind or going into action. All that I have said above refers to the fighting-vessel. For cutting up an enemy's commerce ships of the *Alabama* and *Shenandoah* type will be required, having a long-range pivot gun forward, two steam torpedo-cutters, and a Gatling battery, and every admiral in time of war should be supplied with a number of extraordinarily fast steamers to carry despatches and act as lookouts.

At present our vessels are adapted to the days of Paul Hoste rather than to the age of steam, loaded down as they are with immense spars and rigging, which, in a general action, would infallibly be shot away, and, trailing after them, foul their screws, thus rendering them utterly helpless; for woe be to that vessel, in future naval battles, whose propeller refuses to turn after the *mêlée* commences. Not many minutes can elapse before an enemy will be upon her, steaming at full speed, and, striking her in a vital part, send her to the bottom. It becomes, therefore, all important that the motive power of a steamer should be protected from injury, and certainly nothing could more imperil it than the masts and rigging as at present arranged.

At first sight it might seem a very expensive matter to keep up a purely steam marine; but when the high price now paid for *surplus* masts, spars, rigging, and cordage is deducted from the bill, I think it will be found that an efficient steam navy can be maintained at a cost but little exceeding that of our present nondescript one. I know that our Benbows of the present day, young as well as old, will cavil at this; for with them not to "talk rope" is not to be a seaman. These men still delight in dissertations upon the hauling down of a jib and the brailing up of a spanker, and dwell fondly upon the legends of the good old times when, however potent cotton might be on land, flax was certainly king upon the sea; but the great majority of naval officers are, I am sure, looking forward to a higher order of things, and will agree with me in



the opinion that the tar of the past, although a glorious fellow in his day, it would by no means be desirable to resurrect for the navy of the future.

A ram should be purely a ram, a torpedo-boat be restricted to the use of torpedoes, while an artillery-vessel, for offence and defence, should place all her reliance upon her battery, not turning out of her way to seek an opportunity for ramming, though not, of course, failing to take advantage of one, should it chance to offer.

For the man who has several weapons to choose from may hesitate, in action, which to avail himself of, while he who has but one will be quite sure to use that one effectively.

Whether or not our artillery-ships should be iron-clad is a vexatious and much-mooted question; but as the duel between iron-plating and artillery has already resulted in favor of the latter, if we may believe the reports of experiments in England and Germany; as powder is still being improved, so that, without greater strain upon the gun, it will exert more force upon the projectile; and as the ram and torpedo have no more respect for the costly iron-clad than the comparatively cheap wooden vessel, I should prefer converting our iron into guns rather than into armor. As to what these guns shall be, whether rifled or smooth bored, our able Chief of Ordnance is a most competent judge. By the world generally the former is considered *in every respect* superior to the latter, yet I confess to not being entirely convinced of the justness of the decision.

I was for a long time intimately associated with the late lamented Admiral Dahlgren, who, without disparagement to any, I may safely say was the greatest ordnance officer our navy has yet produced, and up to the day of his death he was firmly persuaded that for "close action"—and no naval battle has ever yet been decided at long range—the smooth-bore possessed decided advantages over the rifle. In the experiments initiated by him against iron-plating at 400 yards, while the rifle bolt went through the target at every discharge, the spherical projectile fell dead apparently at its base for three or four or five fires; but then, suddenly following the report of the smooth-bore, came a crashing sound, and it was found that the target had been shaken to pieces. It must be borne in mind that these trials were made against plating of less than half the thickness of that now used in England, and, therefore, do not afford a fair test of the relative merits of the two guns at this time; but I submit that recent experiments on the other side of the water have not been exhaustive in this regard, and are, therefore, neither satisfactory nor conclusive.

Placed side by side, with the full power of each developed against targets at short range, the gun which shall be found to have produced the greatest effect after twelve rounds have been fired in quick succession will, it appears to me, be the best for general purposes, whatever may be the merits of the other for special service; for in assembling vessels to attack forts or fleets you could in one fire have the concentrated effect of these twelve rounds many times repeated. In saying this let it not be understood that I am an advocate of the smooth-bore; on the contrary, all that I have read of late inclines me to prefer the rifle, and that which has most influenced me in its favor is a remark of Captain Jeffers, that from it you "get greater explosive effect for same weight"; but I do think that, before substituting one system of armament for another, we should test the matter *ourselves* to the "bitter end," and I trust that Congress will see the wisdom of making a liberal appropriation for this purpose.

As to the calibre of the guns, notwithstanding what has been said to the contrary in an exceedingly forcible prize essay, which has met with general favor in England, I espouse the American idea—"the bigger the better"; depend upon it, with Yankees to serve them, the shot of mammoth guns will not be thrown away. They have a saying "out West" that it is "bad manners to draw a pistol unless you intend to use it"; and, though it may not be ill-mannered, it is certainly unwise to hit a ship at all unless you do her some damage, for men get a contempt for that which does not hurt when it strikes them. With a fleet composed of the three classes referred to above, an admiral, informed by his lookouts of the approach of an enemy, would signal such a formation as he should deem best, always, however, keeping his artillery in the centre of the fleet, and his rams nearest to the enemy, and well in hand, in readiness to begin the attack. No order of battle could be laid down which would suit every occasion, and the effect of adopting any one order as absolute would be to give your enemy the advantage of knowing how he should find you, and laying his plans accordingly, while you would be left in doubt up to the last moment as to what his method of attack or defence would be. A fleet should be so drilled as to be enabled to assume any formation with readiness, and it should be *a unit of force acting under one head*. Nothing could be more fatal to us than the acceptance of the idea that it may be separated into groups, each group being, to some extent, independent of the other.

For at sea, as on the land, "war is nothing more than the art of concentrating a greater force than the enemy upon a given point," and Com-

mander Noel's plan of battle would simply afford one's adversary, in my opinion, a chance of surrounding his detached groups one after the other with a superior force, and thus whipping the whole fleet in detail.

I may remark here that in our new tactical signal-book the signal "From the centre of threes, fours, fives, etc., form double echelon" (natural or inverted), affords us the means of throwing our whole fleet, or any division or squadron of it, into groups offensive or defensive of any required depth, each group, however, being closely supported by all the others.

Opening the ball with artillery-vessels "passing each other, at a combined speed of twenty knots," could only result in one of those indecisive actions which every commander-in-chief should aim to avoid; for three-fourths of the projectiles fired would fall into the sea, while the smoke of the guns on both sides would so obscure the vision as to render the attack of the rams of no avail.

In my judgment, the rams should begin the action by charging the enemy, and throwing him into confusion or bringing him to a stand; then the artillery-vessels would open with some effect, and the torpedo-boats, under cover of their fire, proceed stealthily but swiftly to complete the work of devastation inaugurated by the charge.

After charging through the enemy, the rams should reform and charge back, or, if unable to do this, pass around his fleet, attacking everything in the way, and, after regaining their own lines, take their position with the reserve, in readiness to act with it when the "supreme moment," as the French term that instant when victory or defeat hangs in the balance, has arrived. This is the time, too, to "put in" every boat fitted with torpedoes that the condition of the sea will permit to be lowered.

It would seem useless, perhaps, for us to talk of the assembling of fleets when our flag scarcely floats from the mast-head of a merchantman upon the sea, and the city of New York, our commercial metropolis, seems so far indifferent to the national misfortune as actually to take pride in the number of foreign steamers which daily leave her wharves; yet I cannot but believe that the great Republic will awaken from her lethargy ere long, and once more put forth her strength upon the deep.

When that day comes, when our commerce is again extended to the remotest corners of the earth, I have faith that a navy will be created for its protection worthy of a great people, whose fleets some of you, gentlemen, will be called upon to command.

This you can prepare yourselves to do intelligently only by devoting yourselves zealously to the study of your profession; and let me advise

you, above all else, to read diligently the naval history of the past and the present, and to imitate Nelson in his close study of naval tactics ; for depend upon it that in future naval battles, other things being equal, victory will belong to that fleet which is most skilfully manœuvred.

In conclusion, let me repeat what I have so often said before—namely, that a man-of-war, *without speed and turning power*, is as useless as “a painted ship upon a painted ocean,” no matter what her armament or armor ; and let me beg of you, in opposition to the doctrine of dividing fleets into independent detachments, to adopt for your motto : *The ships of our Union and the union of our ships : may they be like our States, “one and inseparable.”*

## DISCUSSION.

COMMANDER TERRY. Has not the plan of separating the vessels of a fleet into groups been adopted in the French navy?

COMMODORE PARKER. Any number of vessels may be called a group; but the *peloton*, an assemblage of four vessels, to which the English have given the distinctive name of group, was suggested by Admiral Willaume, of the French navy. I do not object to groups, but to *detached* groups, acting independently of each other.

REAR-ADMIRAL RODGERS. Was not this plan adopted at Key West?

COMMODORE PARKER. At Key West the vessels were separated into groups, in close supporting distance of each other.

COMMANDER FARQUHAR. Supposing that sails and spars are eventually done away with, how will signals be made—above all, in action? Will a commander-in-chief be obliged to rely entirely on the hand-flag?

COMMODORE PARKER. It will be easy to signal from a flag-pole before going into action. After once getting into action, I consider it useless to signal at all, except to the reserve; the plan of battle should be fully understood before going into action.

REAR-ADMIRAL RODGERS. It was stated in the article that the maximum speed attained by the fleet during the manœuvres was four and a half knots. Was the result due to the slowness of the ships, or was it the fault of the commanding officers?

COMMODORE PARKER. I believe it was entirely owing to the slowness of the vessels. In making the passage to the Bay of Florida signal was made to keep the speed up to five knots. The *Shanadooh* signalled that it was utterly impossible to do it. The best that the *Wobush* could do was six and a half knots. The *Franklin* could be forced up to nine, but could not keep up more than seven.

REAR-ADMIRAL RODGERS. I am loath to believe that the maximum speed of any fleet of the United States navy is only four and a half knots. I have commanded several of the vessels that have lately been assembled at Key West, and their speed was certainly much greater than four and a half knots. I cannot allow the statement to go out to the world without expressing my doubt about it. In regard to the use of steam, I agree with the views of Commodore Parker.

COMMODORE PARKER. It is impossible to judge of the speed of a fleet by what can be done by single or detached vessels. All the vessels of a fleet must be possessed of great and permanent speed, or else the faster vessels must reduce their rate of speed to conform to that of the slower ones.

LIEUTENANT MCLEAN. I have known the *Shenandoah* to make twelve knots when in good condition. As to doing away with sails, I think it would be very unwise. I have seen a steamer scudding before the wind under reefed topsails, her propeller being almost all the time two-thirds out of water. She would have been in a rather bad situation without her topsails.

COMMANDER MCNAIR. I am sure I have seen times when reefed topsails were very useful. I think it would be unwise to abandon the use of sails entirely.

COMMODORE PARKER. In all my experience I have never seen such a storm as would have made it necessary for a steamer, not borne down by the pressure of the wind on her masts, spars, and rigging, to scud, especially if she were provided with a suitable drag. I would use sails merely as auxiliaries of steam.

CHIEF-ENGINEER BAKER. The low rate of speed of the fleet assembled at Key West was owing to peculiar circumstances. Much of the machinery built during the late war by inexperienced contractors, at a time when the best material could not always be obtained, had deteriorated even from its original condition by the effects of wear and decay. When the *Shenandoah*, unable at the Key West fleet manœuvres to make five knots, was new, she was a twelve-knot ship, but her boilers have been worn out in long service. The vessels of the United States navy will in future be able to keep up a greater speed than four and a half knots.

It may be of interest to the Institute to know that one of the vessels lately built by the Navy Department, the *Svatava*, now employed in the expedition for observing the transit of Venus, has attained a speed of twelve knots, with only eight of her ten boilers in use. This performance was under steam alone, uninfluenced by wind and sea.

A vote of thanks was then tendered to Commodore Parker.

The chair was resumed by Rear Admiral Rodgers, but, there being no further business, the meeting adjourned.

## DISCUSSION OF THE PAPER READ BY LIEUT. COLLINS (No. 6).

COMMODORE RODGERS. Mr. Chairman, the labors of my brother officers in this and in other expeditions for the same purpose have reflected great credit upon the service. I am proud to mention that in the course of a recent conversation with a gentleman who is perhaps the greatest mathematician in this country, he remarked that the naval officers connected with the surveying expeditions across the Isthmus of Darien had rendered their names immortal; that the canal would without doubt be constructed eventually; and that the names of Selfridge, Lull, Shufeldt, and others, would be for ever remembered with gratitude and respect. He attributed much of the success of these officers to the excellent education that many of them had received at the Naval Academy.

I think the time has arrived for naval officers to manifest an interest in the great improvements and scientific investigations that are now continually going on.

COMMODORE F. A. PARKER. Mr. Chairman, I think it would be interesting to the members of the Institute to learn how it is proposed to avoid or overcome the obstacle presented by the bar at the mouth of the Atrato River, on which there are, I believe, only three or four feet of water.

LIEUTENANT COLLINS. It has been suggested to close up all the mouths of the delta except three, and in this manner increase the depth of water on the bar.

REAR-ADMIRAL JOHN L. WORDEN. I think the idea a good one. The great force thus added to the current would doubtless in time cut a sufficient channel through the bar.

COMMODORE RODGERS. Even if that plan should fail, the difficulty could be overcome by constructing a side canal similar to the one proposed at the delta of the Mississippi River.

COMMANDER GREER. What is the width of the bar?

LIEUTENANT COLLINS. The width of the bar is about half a mile. After passing the bar, the water is from twenty-five to twenty-eight feet in depth. The river is about two thousand feet in width, and has a good broad channel, even in the dry season. The canal route proposed by Commander Selfridge is about twenty-eight miles in length, and will require three miles of tunnelling. The entire cost is estimated at \$56,000,000.

COMMANDER GREER. What was the cost of the Suez Canal?

COMMANDER FARQUHAR. The total cost was about \$80,000,000; there are, however, no locks in the Suez Canal.

On motion of REAR-ADMIRAL WORDEN, the thanks of the Institute were tendered to Lieutenant Collins for his very interesting paper.

The Institute then went into executive session.



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VOLUME II.

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*For the year 1877.*

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# CONSTITUTION.

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## TITLE.

ARTICLE I. The Organization shall be known as the “*United States Naval Institute.*”

## OBJECT.

ART. II. Its object shall be the advancement of professional and scientific knowledge in the Navy.

## ORGANIZATION AND OFFICERS.

ART. III. 1. The officers and the permanent committees of the Society shall include:

A President.

Vice-Presidents.

A Secretary.

A Corresponding Secretary. } Executive Committee.

A Treasurer.

A Committee on Publications.

Corresponding Secretaries for Stations.

2. Special committees may at any time be appointed by a majority vote of the Society to consider questions not properly under the cognizance of the Standing Committees.

3. There shall be a Vice-President and Corresponding Secretary in each squadron, and at each shore station, who shall be chosen to hold office for one year, by the members of the Society on the station.

## MEMBERSHIP.

ART. IV. 1. The Institute shall consist of members, honorary members, and associates.

2. All officers of the Navy, Marine Corps, and of the Academic Staff of the

Naval Academy, shall be entitled to become members without ballot, on payment of initiation fee and dues to the Treasurer, or the Corresponding Secretary on the station.

3. Honorary members shall be selected from distinguished Naval and Military officers and from eminent men of learning in civil life; provided that the number of such members shall in no case exceed thirty.

4. Associates shall be chosen from persons connected with the Military and Naval professions, and from persons in civil life who may be interested in the objects that it is the design of the Institute to advance.

5. Honorary members and associates shall be elected as follows: Nominations shall be made in writing to the Executive Committee, and such nominations, with the name of the member making them, shall be entered on the minutes of the committee. At the succeeding meeting of the Institute the committee shall report. If their report be favorable, a majority of the members present shall decide the election; but, if unfavorable, a two-thirds vote shall be required to elect the candidate. Two members of the Executive Committee shall constitute a quorum for carrying out the requirements of this section.

6. The annual assessment for a member shall be five dollars, and for an associate three dollars, payable upon joining the Institute, and on the 1st day of each succeeding January.

7. Membership shall only be forfeited in cases where the recommendation of the Executive Committee, supported by a two-thirds vote of the Society, shall so determine.

## NOMINATIONS AND ELECTIONS.

ART. V. 1. There shall be a meeting of the Society on the second Thursday in January of each year, at which all officers shall be chosen, except those provided for in ART. III, Sec. 3.

2. Members not in attendance may vote by proxy at such elections, as well as upon questions relating to the Constitution and By-Laws; but vote by proxy will only be allowed in the two cases herein specified. Honorary members and associates will not be allowed to vote on any question.

3. A majority of votes recorded shall determine choice.

4. Members elected to the position of Officers of the Society will assume their duties as soon as notified.

5. Vacancies may be temporarily filled by the Executive Committee, but regular nominations and elections shall follow as soon as practicable.

6. All voting for officers shall be by ballot in session of the Society.

## DUTIES OF OFFICERS.

ART. VI. 1. The President, or, in his absence, the Vice-President, or in the absence of both, a member of the Executive Committee, will preside in Executive Session.

2. The transaction of all financial, executive, or administrative business, in which latter shall be included censorship of papers offered for presentation to the Society, shall be in the hands of the Executive Committee. The Committee will determine for itself its routine of business and form of record.

3. The Secretary shall keep a register of the members, a copy of the Constitution and By-Laws, in which he shall note all changes, a journal of the proceedings of the Society, a separate record of the proceedings of the Executive Committee, and a file book in which the reports of committees, &c., shall be entered. These books shall be at all times in readiness for inspection. Papers offered by members unable to be present, if accepted by the Executive Committee, shall be read by the Secretary. He shall give due notice of all meetings of the Society, and shall have control of the Stenographer and copyists employed to prepare records of proceedings.

4. The Corresponding Secretary shall attend to all correspondence and keep a record thereof.

5. The Treasurer, under the direction of the Executive Committee, shall be the disbursing officer. He shall keep a receipt and expenditure book, and an account current with each member. He will submit his books for examination whenever asked for.

6. The Committee on Publications shall have charge of the printing and publication of all papers and proceedings of the Society.

7. Corresponding Secretaries of stations shall keep the Institute, through its Corresponding Secretary, advised of new members, and of all matters of interest, and shall attend to the collection and transmission to the Treasurer of the dues of members.

## MEETINGS.

ART. VII. 1. There shall be a meeting of the Society on the second Thursday of each month for the discussion of professional and scientific subjects.

2. Special meetings may be called by the Secretary, at the request of one or more of the general officers, or of standing or special Committees.

3. A stenographer shall be employed to keep the record of all proceedings of regular meetings.

4. Annually, or as much oftener as the Executive Committee may decide, a record of papers read before the Society and the discussions growing out of them,

shall be published in pamphlet form. Papers on intricate technical subjects may be published as a part of the proceedings of the Society without being publicly read, if in the opinion of the Executive Committee the subject to which they relate be not of a character to be appreciated on merely casual investigation.

#### AMENDMENTS.

ART. VIII. No addition or amendment to the Constitution and By-Laws shall be made without the assent of two-thirds the members voting. Notice of proposed changes or additions shall be given by the Secretary at least one month before action is taken upon them.

## BY-LAWS.

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**ARTICLE I.** The rules of the United States House of Representatives shall, in so far as applicable, govern the parliamentary proceedings of the Society.

**ART. II.** 1. At both regular and stated meetings the routine of business shall be as follows.

2. At executive meetings, the President, or, in his absence, the Vice-President, or, in the absence of both, a member of the Executive Committee, will call the meeting to order and occupy the chair during the session; in the absence of these, the Society will appoint a chairman.

3. At meetings for presentation of papers and discussion, the Society will be called to order as above provided, and a chairman will be appointed by the presiding officer, reference being had to the subject about to be discussed, and an expert in the specialty to which it relates selected.

4. At regular meetings, after the presentation of the paper of the evening, or on the termination of the arguments made by members appointed to, or voluntarily appearing to enter into formal discussion, the chairman will make such review of the paper as he may deem proper. Informal discussion will then be in order, each speaker being allowed not exceeding ten minutes in the aggregate, unless by special permission of the Society. The author of the paper will in conclusion be allowed such time in making a résumé of the discussion as he may deem necessary. The discussion ended, the Chairman will close the proceedings with such remarks as he may be pleased to offer.

5. At the close of the concluding remarks of the Chairman, the Society will go into Executive Session, as hereinbefore provided, for the transaction of business, as follows:

1. Stated business, if there shall be any to be considered.
2. Unfinished business taken up.
3. Reports of Officers or Committees.
4. Applications for membership reported.
5. Correspondence read.
6. Miscellaneous business transacted.
7. New business introduced.
8. Adjournment.



THE RECORD  
OF THE  
UNITED STATES NAVAL INSTITUTE.

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Vol. II.

1875.

No. 1.

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U. S. NAVAL ACADEMY, ANNAPOLIS.

APRIL 8, 1875.

Commander WM. T. SAMPSON in the Chair.

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The Secretary read the following letter from

LIEUTENANT J. FORSYTH MEIGS,

ON THE VELOCITY OF THE WIND.

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I beg to enclose herewith a record of observations made by myself on board the United States Steamer Omaha, Captain P. C. Johnson Commanding, of the relative speeds of this ship and of the propelling wind upon various points of sailing; and of the speeds, dimensions, &c., of waves.

The velocities of winds and waves are in knots, of 6086 feet to the mile, per hour; the dimensions of waves are in feet; the rules for log-books have been followed in noting the "state of sea"; the small letter *s* under the letter denoting the state of the sea denotes that the sea was probably caused by the *same* wind that is noted in its proper column, the letter *o* that it was probably caused by some *other* wind; in the column for heel or roll, the letters *h*, *s* and *p* signify *heel*, *starboard*, and *port* respectively.

The instrument used in determining the velocity of the wind is a small wheel-anemometer, made by Nigretti and Zambra of London. It has given every proof of accuracy and durability. A spirit level, bent to a radius of five inches, was used to determine the roll and heel. In making observations for the velocity of the wind, the anemometer was always held for one minute in the air current, well clear of every thing, while the log was being hove. All other observations, for

dimensions of waves, &c., were made, as nearly as possible, at the same time. The observed velocity of the wind is corrected by means of a table for the solution of right triangles.

The observations cover a time from October until the following May. The ship's draft, when the record was begun, was 14 feet, 6 inches forward, and 17 feet, 2 inches aft; when it was concluded, the draft was 13 feet forward, and 16 feet, 10 inches aft. The ship received on board no large supply of coal or provisions during this time.

## RESUMÉ.

The figures, as tabulated, appearing somewhat voluminous, I have added the following résumé. Always calling the speed of the wind 100, we have :

POINT OF SAILING.	Number of Observations.	Number representing ship's speed.
Close-hauled .....	26	62.6
One-half, one, and one and a half points free.....	7	74.3
Wind abeam.....	4	77.5
One, two, and three points abaft beam.....	6	76.3
Broad, and three points on quarter.....	6	56.3
One and two points on quarter.....	11	46.9
Wind dead aft.....	13	39.4

The difference between the last two is 7.5 per cent., which is very nearly the increased distance that a ship must sail, if she hauls up  $1\frac{1}{2}$  points so as to fill all her sails, when her port is dead to leeward, thus showing, if the figures are reliable, that nothing is gained in point of time, by thus hauling a ship up.

The observations on the close hauled point of sailing are the most numerous; and, as they do not enable one to perceive any order or sequence, as arranged according to the speed of the ship, they are re-arranged below according to the velocities of the wind.

	True velocity of wind.	Number representing speed of ship when speed of wind=100.	Difference.	N/C	True velocity of wind.	Number representing speed of ship when velocity of wind=100.	Difference.
1	4.2	47	38	14	10.7	80	
2	4.9	46	39	15	11.7	68	17
3	5.8	61	21	16	12.	75	10
4	5.9	67	18	17	12.6	41	44
5	6.7	78	7	18	12.7	63	22
6	7.3	78	7	19	13.8	50	35
7	8.3	84	1	20	13.9	54	31
8	8.6	61	23	21	14.9	50	35
9	9.	77	8	22	16.	43	42
10	9.3	64	21	23	16.2	30	55
11	9.5	88	Mean of 11,	24	17.4	40	45
12	9.9	87	12, 13, 14, is	25	19.1	34	51
13	10.1	84	85.	26	22.3	37	48

This table would appear to show that a speed of wind of about 10 or 11 miles per hour is, for the wind, what may be termed its most

record of observations to determine the relation between the velocities of wind and ship, dimensions and velocities of waves, roll of ship, &c. made on board the U. S. Ship Omaha, CAPT. P. C. JOHNSON, Commanding, by LIEUT. MEIGS, U. S. Navy.

DATE.	Point of sailing.	SAIL SET.	of ship per hour	WIND.		SEA.					Remarks.			
				hour shown by	velocity of wind.	ave from crest to	ave from crest to	ave from crest to	ave from crest to	ave from crest to		ave from crest to		
"	"	"	6.	4	6.2	7.3	10	200	6°	10s	10s	complete oscillation (or port) roll again.		
"	"	"	6.	4	7.7	8.9	10	200	6°	10s	10s	complete oscillation (or port) roll again.		
"	"	"	6.	3	7.3	8.5	9	200	5°	13	9s	10s	4°S-10°P 5°P-10°S	
"	"	"	3.	1	1.6	2.7	7	50	16°	5s	6	10s	6°P-8°S 8°	
"	"	"	10.	5	9.6	13.4	7	50	16°	5s	6	10s	6°P-8°S 8°	
"	"	"	4.4	3	2.8	5.3	7	50	16°	5s	6	10s	6°P-8°S 8°	
"	"	"	2.	2	2.1	3.5	9	25°	4°	9s	17	10°	10s	10s
"	"	"	2.	2	3.1	5.2	12	106	22°	6s	10	5°	10s	10s
"	"	"	5.7	4	3.9	7.9	11	106	22°	6s	10	5°	10s	10s
"	"	"	1.5	1-2	2.2	3.4	4	106	22°	6s	10	5°	10s	10s
"	"	"	3.	3	3.3	5.8	5	60	9°	7s	6	3°	10s	10s
"	"	"	9.5	4	8.5	16.4	4	70	7°	7s	6	3°	10s	10s
"	"	"	3.7	4	4.1	7.5	4	70	7°	7s	6	3°	10s	10s
"	"	"	4.	2	3.4	7.1	4	70	7°	7s	6	3°	10s	10s
"	"	"	5.	4	4.8	9.4	6	60	11°	11°	11°	11°	10s	10s
"	"	"	6.	6	12	17.5	6	60	11°	11°	11°	11°	10s	10s
"	"	"	8.	6	7.3	11.7	6	40	16°	6°	6°	6°	10s	10s
"	"	"	10.	6	10.8	20.	6	40	16°	6°	6°	6°	10s	10s
"	"	"	2.4	4	4.9	7.3	5	100	6°	6s	9	5°	10s	10s
"	"	"	5.	3	4.4	9.3	5	100	6°	6s	9	5°	10s	10s
"	"	"	5.25	4	7.5	12.7	4	70	11°	9s	5	5°	10s	10s
"	"	"	6.	4	8.	13.9	5	60	9°	3°	3°	3°	10s	10s
"	"	"	10.	6	10.5	20.3	9	140	10°	9°	9°	9°	10s	10s
"	"	"	2.	2	4.7	7.2	2	30	8°	5°	4	11°	11s	11s
"	"	"	2.5	2	4.3	6.8	2	30	8°	5°	4	11°	11s	11s
"	"	"	3.5	2	4.5	8.	5	50	6°	6°	9	5°	10s	10s
"	"	"	3.7	2	7.	10.7	5	50	6°	6°	9	5°	10s	10s
"	"	"	3.7	1	5.8	9.6	5	100	6°	6°	9	5°	10s	10s
"	"	"	3.9	3	5.4	9.5	5	100	6°	6°	9	5°	10s	10s
"	"	"	4.	4	7.1	11.1	4	110	4°	6s	11	11°	10s	10s
"	"	"	4.25	4	6.3	10.5	4	110	4°	6s	11	11°	10s	10s
"	"	"	4.35	4	5.7	9.9	4	110	4°	6s	11	11°	10s	10s
"	"	"	4.25	5	6.5	11.25	4	110	4°	6s	11	11°	10s	10s
"	"	"	4.75	4	6.5	11.25	4	110	4°	6s	11	11°	10s	10s
"	"	"	5.	3-4	9.7	15.7	3-4	88	5°	4°	8°	8°	10s	10s
"	"	"	6.5	6	8.4	14.9	6	88	5°	4°	8°	8°	10s	10s

dimensions of waves, &c., were made, as nearly as possible, at the same time. The observed velocity of the wind is corrected by means of a table for the solution of right triangles.

The observations cover a time from October until the following May. The ship's draft, when the record was begun, was 14 feet, 6 inches forward, and 17 feet, 2 inches aft; when it was concluded, the draft was 13 feet forward, and 16 feet, 10 inches aft. The ship received on board no large supply of coal or provisions during this time.

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The difference between the last two is 7.5 per cent., which is very nearly the increased distance that a ship must sail, if she hauls up  $1\frac{1}{2}$  points so as to fill all her sails, when her port is dead to leeward, thus showing, if the figures are reliable, that nothing is gained in point of time, by thus hauling a ship up.

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13	10.1	84	85.	26	22.3	37	48

This table would appear to show that a speed of wind of about 10 or 11 miles per hour is, for the wind, what may be termed its most





economical speed; the percentage velocity of the ship becoming less, unsteadily but perceptibly, as the wind varies from this velocity in either direction.

#### THE DRAG OF THE SCREW WHEN UN-COUPLED.

The mean of eleven (11) observations with the screw down, and either turning or not turning, gives the ship's velocity as 44.8 per cent. of that of the wind; and the mean of ten (10) observations (this particular number having been selected because no greater one could be had where the similarity of condition of wind, sea, &c., would give a good comparison,) with the screw up, gives the ship's velocity as 50.6 per cent. of that of the wind. Thus showing a loss of 5.8 per cent. of speed when the screw is down—this would be .29 knot at a speed of 5 knots. The screw was always un-coupled when it was down, and would begin to turn at a speed of from 4 to 5 knots, and would continue to turn at a lower speed when started.





THE RECORD  
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U. S. NAVAL ACADEMY, ANNAPOLIS,  
DECEMBER 9, 1875.

Commander N. H. FARQUHAR in the Chair.

In the absence of the Secretary, Chief Engineer Baker read the following paper on

THE INTEROCEANIC CANAL,  
BY LIEUTENANT FREDERICK COLLINS.

Some two years since, I had the honor to read before the Naval Institute, a paper in which I attempted to present a comprehensive view of the Interoceanic Canal question, as it then appeared in the light of the latest reliable information.

Since that time important additions to our knowledge concerning two proposed routes have been made, and my duty as a member of the Institute requires that I should acquaint it with the facts. It will not, however, be necessary that I should speak of the Panama route, since you will doubtless receive information concerning the results of the survey of that line by Commander Lull, from other sources.

I will therefore confine myself to a description of the route by way of the Atrato and Napipi rivers, giving you the information acquired by an expedition under my command that made a careful survey of that route during the winter just past.

For a general description of the country in which this proposed route lies, I would refer to my previous paper. I wish now merely to describe its physical features, and to discuss briefly the question of its adaptability to the construction of a ship canal.

At the time of the reading of that paper, our knowledge of the country in the vicinity of the Napipi, was confined to observations made from the river beds. All our surveys had been made in the

beds of streams, and in projecting a canal line, it was assumed that the country for half a mile or so back from the river, was the same as it appeared on the banks. More intimate knowledge shows such a supposition to be erroneous. The country that, from the river, had appeared to be flat, was found to be covered with a network of hills.

This fact is of great importance as showing the difficulty of acquiring information concerning the character of those regions. It also shows how easily experienced men, anxious only to learn the truth, may be deceived, and it enables us to enunciate the general rule that favorable reports concerning any route, not substantiated by the results of actual survey over the ground itself, are worthy of little consideration.

In saying this, I do not by any means wish to be understood as depreciating the value of surveys made in the beds of streams. On the contrary I accord to such surveys great value, and believe that all preliminary reconnoissances, in such a country as Darien at least, should always be so made.

But a most important distinction must be made in estimating the value of the results so obtained. And for this reason; a survey in the bed of a stream, naturally shows the *lowest possible profile* within the region that the stream and its tributaries drain. If, therefore, such a survey shows an *unfavorable* profile, the question of the possibility of finding a *favorable* one anywhere within those limits must be regarded as conclusively settled in the *negative*.

But—and mark the difference—if such a survey shows a *favorable* profile, the question of the adaptability of the line is by no means to be regarded as settled in the *affirmative*. No ship canal can follow the windings of a mountain stream, and before any accurate estimate can be formed of the character of the line of the canal, that line itself must be carefully surveyed from end to end.

The principles then to be borne in mind when called upon to judge of the value of explorations are these:—*unfavorable* reports founded upon reliable surveys in the beds of streams may be accepted without hesitation; *favorable* reports with such foundation can be regarded only as indicating the desirability of a more careful examination before judgment can be formed as to the merits of the route.

Furthermore, let me say that, reports of favorable routes on the authority of “old Spanish maps and documents,” or from “conversations with the Natives,” or of passes in the Cordilleras seen from either shore; or of low land seen from a height, or while passing up or down

rivers; or of passes determined by the temperature of boiling water or the velocity of streams—all such reports, I say, need no longer agitate the geographical and commercial worlds—they may be set down at once as a snare and a delusion.

Applying these principles to the results of the surveys of the past six years, we find that from the surveys in the beds of streams the various routes that have been from time to time proposed between the Panama railroad and the Napipi river (with the exception of the Truando route which has not been examined since Niehler's survey,) have been pronounced unfavorable; and such unfavorable verdicts may be accepted without hesitation.

From a similar examination the Napipi route was pronounced favorable. This result should have been accepted simply as indicating the desirability of further surveys; it was altogether wrong to suppose that sufficient data had been acquired to justify the preparation of estimates of cost. The additional examination that has since been made has shown the character of the country to be essentially different from what we had been led by the previous surveys to suppose.

This route still remains, however, even with all its disadvantages, the most favorable one south of Panama, at least. The fact that it is so poorly suited to the purpose, is a sufficient index to the character of the others.

But let me proceed with a description of the country in that vicinity, which was my avowed purpose when I set out, but to which I have been long in coming.

Our survey followed the left or northern side of the valley of the Napipi, from the Atrato to the junction of the Doguado. At this point the line crossed the Napipi and followed the valley of the Doguado till opposite Chiri-Chiri Bay, when it struck across the "divide" and descended to the Pacific, in the valley of the Chiri-Chiri River.

In reference to the general topographical character of this region, I may say that our observations on the main line of survey, and in extended reconnoissances, showed its physical features to be wonderfully systematic. From the main divide, which skirts closely the Pacific coast, come down, to the eastward, long spurs or ridges that form the divides between the various western tributaries to the Atrato. These ridges send off to the northward and southward smaller spurs and these divide again and again, till the whole country is overspread with ranges of hills, running the one into the other, like the veins on a leaf. A detached hill is rarely to be found.

The crests of these hills, are usually very narrow and their sides descend abruptly—often precipitously. These crests rising and falling with gentle slopes, always afford good ground for walking. On this account they are used for roads or trails almost exclusively by the natives, they having long ago learned that the longer way round, with a good road, is a surer way home than the shorter, which, cutting across the ridges, presents a succession of steep and slippery hillsides. They thus practically exemplify our proverb, even if they do not put it into words.

Immediately along the line of survey, the country naturally divides itself into four divisions, as regards its topographical features. First, there exists from the banks of the Atrato, for some five miles to the westward, a flat, swampy region of a lower average level than the banks of the adjacent streams. During the wet seasons, this region is frequently inundated to a considerable depth. During the dry seasons its more elevated portions become sufficiently dry to be passable, but those of a lower level always remain open water swamps or miry morasses.

This portion of the route is in fact the delta of the Napipi, since it is bounded to the westward and northward by a second mouth of that river called the *Braso Muriel*, while a third mouth, the Palmerito, flows through its central part. It includes, in the portion near the Atrato, two large *cieneegas* or lagoons, which during the wet months, are shallow lakes, but which become more or less dried up as the rain lessens.

The second topographical section extends from the Braso Muriel some six miles to the westward. It is characterized by the extension of the spurs of the divide between the Napipi and Opogado rivers to the very banks of the former, rendering it necessary to cross them continually with the survey. Extended reconnoissances were made to determine the practicability of flanking these hills by a detour to the northward, but in almost every case they were found to increase in altitude as they receded from the river, proving to be parts of the system just described, rather than detached hills that might have been flanked.

When, therefore, these hills butted on the river, there was no course left but to cross them, and our line through this section shows a succession of steep hills, the highest being 253 feet in elevation.

The third topographical section extends from the western limit of the second, to the point at which the projected canal crosses the Napi-

pi, near the junction of the Doguado and Meriudo rivers. In this section, the spurs or ridges generally terminate at a thousand or fifteen hundred feet back from the river, and it was accordingly found possible to avoid them by keeping the line well down to the southward. Our profile, therefore, of this section shows level or gently undulating ground, with no elevations of any considerable magnitude.

This section, in common with all except the first, is well covered with heavy timber, which appears wherever the ground loses its swampy character.

The fourth topographical section extends from the point of crossing the Napipi, to the Pacific ocean. It is characterized by being extremely broken, and by the great height of its ridges as compared with those of other sections.

For the greater part of this section the line lies in the valley of the Doguado. The distance between that river and the Meriudo is so small, and the divide between them so high, that the spurs extend almost invariably directly to the river banks. A line of survey carried up the valley anywhere except in the river bed, must cross these spurs continually.

In this section the main dividing ridge between the valley of the Atrato and the Pacific slope is found. It was crossed at an altitude of 778 feet, and so steeply does its western slope descend that the crest of the divide is only 7,000 feet in direct horizontal distance from the beach. The tunnel required for passing under this ridge is three and one half miles in length.

The direct distance from the Pacific at Chiri-Chiri Bay to the Atrato, is but about 28 miles, but the introduction of the curves, necessary to follow the best ground, increases the actual length of the canal to thirty and one quarter miles.

From the data acquired by the last expedition, I have calculated the probable cost of a canal by this route, according to the general plan proposed by Commander Thos. O. Selfridge. This plan, in its essential features, is to follow the left bank of the Napipi for about 20 miles, to its junction with the Doguado. At that point the canal is to cross the Napipi by a dam of sufficient height, and then to follow the valley of the Doguado, till the cutting becomes too deep to continue an open cut. A tunnel will then be resorted to, to carry the canal under the dividing ridge, and bring it out on the Pacific, at Chiri-Chiri Bay.

In the plan on which the following estimates have been founded the summit level has been placed at 143 feet above mean tide, and 12

locks with a lift of 10.3 feet each on the Atlantic side, and 10 locks with a lift of 14.9 feet each on the Pacific side will be required.

The Canal is to be fed at the summit from the Napipi river with its tributaries, the Doguado and Meriudo, as well as from the next river to the southward, the *Ouia*, for which purpose an aqueduct three and two-tenths miles long is necessary.

The estimates include all the works supposed to be necessary to the successful operation of the Canal, and for its preservation and protection from accident, by floods or otherwise.

The following dimensions have been assumed as best suited to meet the requirements of the case:

Width at bottom,	72 feet.
"    at water surface in earth,	150 "
"            "            rock,	98 "
Slope of sides in earth cuttings,	1½ to 1.
"            "            rock            "            below water,	½ to 1.
"            "            "            "            above      "	¼ to 1.
Width of top of embankment,	9 feet.
Slope of embankment, exterior	2 to 1.
"            "            interior	1½ to 1.
Width of "bench" (at ten feet above water)	9 feet.
Width of locks inside,	60 "
Length of locks between mitre-sills,	400 "

For the tunnel calculations have been made with several different forms and dimensions. In the estimates given below, a tunnel 60 feet wide at water surface, with 30 feet depth of water\* and 86 feet height above water, has been allowed for. If a tunnel 70 feet wide should be considered necessary, the cost would be increased by about three and a half millions of dollars. In order to be on the safe side it has been assumed that the tunnel would require lining throughout with an arch of masonry.

The following prices have been allowed in computing the cost of the various portions of the work.

Excavation in earth,	33 cts. per cubic yard.
"            "            rock,	1.25 to 1.50 per cubic yard.
"            of tunnel,	5.35 " "
Arched lining of tunnel,	20.00 " "
Dredging,	50 cts " "

\* 28 feet is the *minimum* depth of water in any part of the Canal.

Hydraulic concrete for Locks, Culverts, Dams, &c., \$7.00 to \$8.00 per cubic yard.

As close a calculation of the amount of work of every kind, as is possible with the data at hand, has been made, and the cost calculated at the above prices with the following result:

#### ESTIMATED COST OF CANAL.

Excavation and Embankment,	\$28,697,398
Tunnel,	33,241,923
Locks,	5,049,214
Culverts,	3,031,405
Side Drains,	2,449,953
Dam for crossing the Napipi,	616,057
Aqueduct for feeding Canal from Rio Cuia,	548,726
Diversion of rivers,	1,670,159
Grubbing and Clearing,	191,900
Breakwaters at Chiri-Chiri Bay,	2,613,000
Improvements at mouth of Atrato,	817,780
Light house at each terminus,	60,000
	<hr/>
	78,557,515
Add 25 per cent. for contingencies,	19,639,379
	<hr/>
Total estimated cost,	\$98,196,895

Without entering into any comparison of this canal route, with others that have been proposed, I present the following as the chief advantages and disadvantages of the Napipi route, according to the best of my judgment.

#### ADVANTAGES.

1. Shortness of artificial channel required.
2. Good Harbors. That on the Atlantic side is all that could be desired, while at the Pacific terminus there is deep water with good holding ground, and the region is seldom visited by violent gales.
3. The cutting mainly in rock or stiff, tenacious clays. In such materials the amount of excavation can be reduced to a minimum; the clay will form stable embankments, and its impervious character will greatly reduce losses from leakage and filtration.
4. Proximity of the heaviest work to the Pacific, rendering transportation of labor, "plant" and supplies inexpensive.

5. The greater part of the work to be performed lies in a healthy region (for the tropics).

6. Abundance of good timber for construction.

7. Absence of high winds along the line of the canal. Transit would be greatly impeded in a canal lying through a region of violent winds.

8. Freedom from liability to terrestrial convulsions of a nature likely to interfere with the permanency of the canal works.

9. Absence of large streams, or of deep valleys to be crossed at a high elevation.

10. Friendly attitude of the inhabitants.

11. Fertility of the soil. With proper management, the country in the vicinity of the line could be made to produce the greater part of the supplies required by the laborers.

#### DISADVANTAGES.

1. The necessity of resorting to a tunnel. This, while it is no doubt practicable, involves great expense in construction, uncertainty in estimate of cost, and a probable increase in the difficulties attending transit, especially for large ships.

2. The steep descent of the Pacific slope, requiring the grouping of a large number of locks, and consequently increasing the liability to accident to the works.

3. Very heavy cuttings required in the valleys of the Doguado and Chiri-Chiri.

4. Limited water supply during dry seasons.

5. Liability to damage to the works from sudden floods. It is believed that this contingency is well guarded against, yet the liability to sudden and violent floods in a hilly country, subject to excessive rains, cannot be overlooked.

6. Excessive rains likely to wash away embankments, while in course of construction, and to interfere generally with the progress of the work.

7. Shortness and uncertainty of the yearly periods well suited to the work of construction.

8. Undeveloped state of the country and scarcity of native labor.

9. Remoteness from the great commercial centres of the world.

The above are all that have occurred to me, with what attention I have been able to give the subject. Those accustomed to the contem-



plation and execution of great engineering schemes will doubtless see many more on both sides, while it is quite certain that, in the actual execution of the work, many complications and contingencies will arise that the best minds will now be unable to foresee. \*

In concluding this paper, it may not be inappropriate to present my views as to what general conclusions may be drawn from the results of the long series of explorations that have been perseveringly carried on during the past six years.

The main fact to be deduced is that the construction of a ship canal between the Atlantic and Pacific Oceans is to be a work of truly Herculean proportions; a work involving the expenditure of much time and treasure in its execution, and demanding the exhibition of as great engineering skill as has been put forth in any work as yet accomplished by man.

The dreamy hope, that has existed since the days when Columbus searched in vain for a natural strait, that somewhere among the gloomy fastnesses of the isthmus there might be found a spot so exactly suited to the purpose that the construction of an artificial channel would be an easy task, must be regarded as forever dispelled.

Nature has not been so kind as to leave the gateway open, and when man shall essay the task, he must be prepared to find his highest faculties and greatest energies taxed to their uttermost.

In fact, in view of the difficulty of constructing a canal, it does not appear to me improbable that the question of transit will be finally solved by resort to some form of marine railway, by means of which ships with cargoes intact shall be hauled overland from one sea and launched to continue their voyages upon the other. Such a project is by no means new, but the inherent difficulties which it presents have caused it to be kept in the background, so long as any chance of finding a place well suited to the purposes of a canal existed.

But with the demonstration of the magnitude of the Canal project, and the recent improvements in the raising of ships, and in mechanical appliances generally, it is likely to assume greater importance. I have recently been informed that certain parties in New York are taking the matter into serious consideration, and, if they will be able to insure the safety of ships while in transit, their project may be as likely to meet with favor as that of a canal involving locks, dams or viaducts and tunnels, or other difficult engineering works.

The question as to which route presents the most favorable conditions to the construction, maintenance and successful operation of a

ship canal involves so many considerations as to make its solution a matter of extreme difficulty. Without entering into any discussion of the relative merits of each, I will say that, taking everything into consideration, and after careful deliberation, I am perfectly well satisfied that the Nicaragua route presents more favorable, and fewer unfavorable conditions than any of the others. The fact that this route is open to serious objection only goes to prove the remarks just made concerning the inherent magnitude of the projected task.

I believe that the construction of a successful ship canal through the isthmus of Nicaragua will be one of the most difficult enterprises that man has ever yet undertaken. Still I am confident that it will be less difficult there than elsewhere, and, with time, money, and the highest order of engineering talent, it cannot be regarded otherwise than as perfectly practicable.

In regard to the possibility that a better route than any that has been examined may have been overlooked I would say that the explorations have been so conducted as to preclude such a possibility.

In a country as densely wooded as is the one in question it is practically impossible to cover every square mile of it with lines of survey; hence there will always be left a chance for interested parties to declare that, had the last explorers gone a little farther to the north, or a little farther to the south, they would have found the exact spot desired. But the fact that the survey of the bed of a stream is fully competent to decide the unfavorable character of all the region drained by that stream and its tributaries, has already been dwelt upon. It is therefore easy to see that, when all the principal water courses have thus been followed up with unfavorable results, further search is not only unnecessary, but positively absurd.

I am aware of the fact that certain persons are loudly proclaiming that the United States are politically opposed to the opening of a canal, and that all these explorations have been instituted for the purpose, and carried out with the idea, of demonstrating the impracticability of such an undertaking.

I do not propose to enter into any controversy with persons capable of conceiving and publicly proclaiming such idiotic notions. The good faith of the government and the honor of its officers cannot need to be vindicated to its own citizens. And if people can be found elsewhere sufficiently simple to pin their faith to visionary enthusiasts or unprincipled adventurers, in preference to accepting the statements of responsible officers whose very position guarantees absolute truthfulness, we can well afford to let them do so.

Further surveys will greatly add to our knowledge of the topography of the various regions, and in the interest of geographical science it is to be hoped they will soon be made. But they can only result in demonstrating the general correctness of the conclusions already drawn, and those who embark in them with any other hope will find, in the end, that they have parted with their money to no other purpose than the demonstration of their own foolishness.

In a word, it may be said that no reasonable doubt can now exist that the data necessary to a determination of the most favorable place for the connection of the oceans by a ship canal have been secured.

COMMANDER FARQUHAR stated that he was very sorry that Lieut. Collins was not present himself, in order to answer some very interesting questions which would most probably have been asked by some of the members. He himself, he said, was of the opinion that the great difficulty in regard to the building of the canal, was the estimating of the cost of the work. It being proposed that the lowest depth of water in the canal should be twenty-six feet, he did not see how any reliable estimate of the cost of the simple excavation could be made. Should rock in large quantities be encountered during the process, the expense would be, of course, greatly increased. So little was known of the nature of the country, that no guarantee could be given that such a contingency might not arise.

He was attached to surveying expeditions across the Isthmus of Tehuantepec, some years ago, and it was while on that duty that he had come to the conclusion that it was next to an impossibility to make, with any degree of certainty, an estimate of the cost of the work. Lieut. Collins, himself, he continued, in an article read before this Institute, about a year ago, estimated the cost of this Canal to be fifty millions of dollars; now, in his last paper, which has just been read before the Institute, he says that it will cost over ninety millions of dollars. Another great difficulty, would be to get from the tunnel, which is twenty-five hundred feet above the level, to the Pacific. The idea of having twelve locks, in such a short distance, with a fall of over two hundred feet each, was an almost impracticable undertaking. The only way that he could see of arriving at any conclusion in regard to the cost of the canal was to compare it with other works of a like character. The Suez Canal cost about eight hundred thousand dollars a mile. It was to be remembered however that it was built almost entirely by forced labor, and that the country

through which it runs is perfectly level, and the soil entirely free from rock. The country across the Isthmus of Darien offered no such advantages. Labor would be very high. Taking these facts into consideration, and acting upon them as a basis for an estimate, the members of the Institute might be able to form some little idea of how vast was the undertaking, and what tremendous expense it involved.

REAR ADMIRAL RODGERS moved that the thanks of the Institute be tendered to LIEUT. COLLINS for the great service he had rendered to science in his thorough description of the topographical and geographical nature of the country across the Isthmus of Darien.

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MARCH 9, 1876.

Professor N. M. TERRY in the Chair.

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THE TACTICS OF SUBMARINE TELEGRAPH WORK.

BY PASSED ASSISTANT ENGINEER THOS. W. RAE.

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This title has been chosen to define precisely the scope of the paper. No industrial enterprise exacts of its votaries from inception to completion, wider and more thorough knowledge of their respective specialties, than does the uniting of distant countries by telegraph cable. The statistician, hydrographer, physicist, manufacturer and seaman must all do their utmost possible to avert from the project the disaster that any miscalculation, careless reconnoissance, clumsy workmanship, or inadequate equipment will loudly invite. So much is comprehended in the phrase Submarine Telegraph Work, that in a limited article it will be impossible to dispose of more than a single branch of the subject, with any degree of completeness. To elect this branch is then the question, and, considering each in turn, the choice naturally falls on that of which least has hitherto been said.

The function of the hydrographer in cable-work is not different from what it is in connection with other undertakings, the electrician's researches are clearly and learnedly set forth in various published works upon the subject; but the processes of the factory, the routine of laying the finished cable, both of which exhibit how far practical restraints modify abstract theoretical conclusions — these are unknown, and their importance demands honorable recognition in the group of technisms already specified. It is not he who dreams of the possible utilization of some one of nature's forces, whom posterity will enshrine, but rather he who impresses and disciplines this force until it seems to have no purpose but to do man's bidding. Some pre-historic Chinese experimenter and Hero of Alexandria, no doubt

did boil water, and drive curious toys thereby, but until Newcomen drained the Cornish mines with it, the Steam Engine cannot be said to have had an existence. Motion under electrical influence has been recognized as far back as natural philosophers have recorded their investigations, and many, among whom Schilling, Gauss and Weber are notable, have considered its application to telegraphy: but until Cooke, Wheatstone, Steinheil and Morse had patiently and unremittingly sought for and found a way around this obstacle, had neutralized that incompatible quality, had simplified and cheapened apparatus and material until suitable for common use—the Electric Telegraph had no real life. Who first conceived the idea of crossing the ocean with a telegraph cable, cannot be named, but they who did it first are subjects of history; and the aim of this article is to tell the methods and devices resorted to by these adventurous and ingenious spirits and their successors, which gave birth to Ocean Telegraphy and have so developed it that the laying of a new cable excites little more notice than the passage of a mail steamer.

Having said thus much to illustrate the propriety of the caption, it may be of interest to glance at considerations which influence the putting down of a telegraph cable as a commercial enterprise. The reproach of mad speculation, that not without show of justice was urged against the originators of the first scheme for spanning the Atlantic, has, in these latter days, quite lost point. The undertakings have been uniformly successful, and the close scrutiny so long maintained of the conditions under which cables work remuneratively, has embodied a system of principles by which one may very closely predicate the result of a scheme of this nature. While the thoughtful cannot but be impressed with the boldness and faith of those who hazarded their fortunes on the success of a cable of unprecedented length across the only guessed-at bed of a stormy ocean, it must be understood that they did not argue from incomplete or insufficient premises—for, as early as 1851, France and England were in electrical communication underneath the Channel; and two years later, England and Belgium, under the German Ocean. Then Scotland and Ireland were united, next England and Holland, and during this same time Prince Edward's Island was connected with the main land, and a short cable put down in the Baltic Sea, between Korsøe on the Island of Zealand, and Vyberg. The cables of the Black Sea followed, and were a great advance upon preceding ones, not only as regards length, which was all together three hundred and fifty miles, but also on account of nearly

half the circuit's being of that rarely satisfactory type of cable, viz. unarmored, except at the shore-ends. This line connected Varna, Balaklava and Constantinople, and was an outgrowth of the Crimean war. Europe and Africa were next united, first by cables from Spezzia to Corsica and Sardinia, one hundred and twenty miles in total length, and later, after repeated disasters, by a line from Cape Spartivento to Bona, near Tunis, one hundred and twenty-five miles long.

During this time a second attempt to span the Gulf of St. Lawrence proved successful; and in 1857, Sardinia, Malta and Corfu were joined by cables of an aggregate length of seven hundred and seventy miles. It must not be supposed that the foregoing list is a series of unbroken successes. No less than seven failures occurred in the few schemes mentioned; but they only served to stimulate to greater effort the undaunted Newall, who planned and executed all but one of them. The projectors of the Atlantic cable did not then plunge into the enterprise blindfold, and their experience, combined with all that preceded and all that has followed it for a guide, has made investment in submarine telegraphs as legitimate and conservative a venture as buying Government bonds. Regarded commercially the question is as follows:

The foreign commerce of the regions which it is proposed to unite amounts to a certain sum annually, and use of telegraph facilities bears a definite ratio to that amount, as established by many years' observation. A cable of given dimensions—which are limited by length of route, and depth of water—can transmit but so many words a minute. May it then be reasonably expected that the charge per word which will be paid without demur, and which statistics prove to stand in a specific ratio to the interests involved, will pay the expenses of maintenance, and yield stockholders satisfactory dividends, besides accumulating a fund for making good the casualties from which no line is absolutely safe? It is readily seen from the foregoing that about the most important factor in the calculation is the size of the cable which it is practicable to lay, and, as this depends upon careful survey of the route under consideration, the cost of thus much of the enterprise is literally cast upon the waters, in hope of return after certain days.

The experience upon which these remarks are based was acquired from Florida to Guiana, through the Greater and Lesser Antilles, and across the Caribbean Sea, embracing a variety of ocean bed which perhaps no other equal portion of the globe can show, and for this reason peculiarly full of interest. It is needless here to touch upon the subject of deep-sea soundings, for its latest development may be learned from

the recent valuable reports of the Hydrographic Office, where they are thoroughly and accurately described—and moreover the depth of the ocean has little influence one way or another, in laying a telegraph cable across it. The consideration that really weighs, and which must be most carefully studied, is the nature of the land beneath rather than the depth of water above it. It is a noticeable fact, and one for which there is ample explanation, that the ocean bed at great depths does not present the same asperities of surface encountered on dry land. There are elevations and depressions, hills and valleys—even mountain chains in some localities,—but whether from the constant attrition of currents, or the superincumbent weight of water under which they were first thrown up by interior forces, the abruptness which characterizes similar features on dry land does not appear. A recognition of this fact reduces greatly the labor of sounding in mid-ocean, and it is only on approaching land, that more frequent and precise casts are necessary. On the undulating bottom, and in the undisturbed water of lower depths, a cable is practically indestructible, but when pendent between rocky ridges or swayed by currents across the face of a submarine precipice, its rapid destruction is inevitable.

In the open sea only enough soundings need be taken to give a profile sufficiently accurate to reveal the per centum of “slack,” as it is termed, which must be allowed at each point of the route to insure the cable’s lying entirely upon the bottom without strain nor yet undue waste. But as the depth lessens, and the cable leaves the region of perpetual calm for that of currents and waves, no method of observation should be neglected; the soundings should be taken as frequently as possible, the lead and specimen cups closely scrutinized, and the nearing shore carefully scanned, so that by noting the direction of mountain ranges—if such be the nature of the coast—the slope of their sides, the direction and succession of intersecting valleys—an analogue may be obtained of the blind region undergoing exploration. This proceeding will be found of great service—it hints at formations which are often discovered upon actual trial, furnishing in this way a guiding hypothesis for the accurate survey of the landings upon which, as much as upon anything else, the success of a cable, as a piece of engineering, depends. The route chosen for the landing must be retired as far from marine highways and anchorages, and in as deep water as possible—for the size, weight and cost of the cable are vastly increased amid surroundings where damage from the grounding of a ship or the dragging of an anchor is possible. It is worth while to devote time and



labor to the finding of a secure path for the shore-end of a cable, and to insure that it be laid therein. If the course be sinuous, or attended with abrupt declivities, the trouble of establishing a base line on the shore and erecting beacons at its extremities sufficiently prominent to be visible from any point of the route will be fully repaid, not only at the first laying but in possible future repairing operations. This work done—the quantity, type and dimensions of the cable may be settled upon, and an opinion formed of the feasibility of the scheme. The insulated conductor of all cables is now-a-days substantially the same. Calculation, experiment and, what is better yet, prolonged use have pronounced a loosely laid strand of seven copper wires, whose circumscribing cylinder has a diameter of about 0.15 inches, to be the best for general purposes, and the best dielectric for this strand to be layers of gutta percha closely adhering to the wire and to each other, until its diameter amounts to 0.3 or 0.4 inches. The difference in modern cables lies principally in their armor, which depends almost entirely upon the depth of water in which they are laid. The deep-sea type must be able to sustain its own length for at least the greatest depth along its route, and a large factor of safety is employed to give security in case of unforeseen strains. The weight of average deep-sea cable is between one and two tons per mile. A serving of twisted hemp is interposed between the conductor and its armor to prevent the latter's cutting into the former, and damaging the insulation. Outside the iron armor most modern cables have another serving of yarns, which is the nucleus of a coating of tar and silica that in many cases saves the armor from rapid corrosion. The first cable uniting Cuba and Florida failed for this reason; it lay across patches of a peculiar red mud, presumably oxide of iron, which completely destroyed the wire covering, and this being gone, the Gulf current soon severed the conductor. Some cables include several separate conductors, which, while enlarging the capacity for business, so increase its bulk, that the expedient is only permissible in short circuits. The conductor is made from the purest Lake Superior copper, whose resistance to the passage of currents is least of any of the useful metals, and which, measured in the British Association units or ohms, ranges from four to five per knot.

The reason for employing a twisted strand instead of a single wire is that it may not be parted within the dielectric, by the strain to which the method of putting on the armor renders it liable. Economy of labor and material prescribe that the latter shall be put on in the same manner that wire rope is made, and the elasticity of such a fabrication

necessitates an equally elastic conductor. While it is eminently desirable that the conductor should offer a minimum resistance to current electricity—it is even more necessary that the dielectric should offer the maximum opposition to its escape, and this too is measured in similar units. The ordinary insulation demanded by modern contracts is 300,000,000 ohms per knot, at 75° Fah., because the insulating power of gutta percha varies considerably with pressure and temperature. Another quality exists upon which the rapidity of signalling depends to a very great extent, and which thus far has proved the most obstinate of drawbacks: it is called electro-static or inductive capacity and is measured as readily as resistance, but in other units. The British Association unit of capacity is termed a farad, and each knot of the average deep-sea cable contains about one-third of a farad. The less this quantity is, the greater the speed of signalling, and, as it varies with the material and thickness of the insulator, much research has been lavished upon the subject, which has only resulted in a return to first principles. India-rubber has hardly more than half the inductive capacity of gutta percha, but has not made a good record for durability. It is employed in the cable connecting Toulon and Algiers, but its use has been abandoned in later constructions.

Mathematical reasoning has established that the thickness of dielectric must be about one-third the diameter of conductor, for the most rapid signalling, but, as this would bring into dangerous prominence the unavoidable imperfections of the former, the practice is largely in excess of this proportion. The tests then, to which a cable under construction is subject, are as follows:

The iron wire of the armor, which is sometimes procured already coated with zinc, and sometimes so treated in the cable factory, is subjected to periodical tests for tensile strength, ordinarily, once every week, which are carefully recorded. The specific conductivity of the copper wire is determined by comparison with established standards, and it is then laid into strands, (by machinery similar to that employed in making wire rope) about two nautical miles in length, and wound upon huge wooden reels and rolled away to be covered with gutta percha. This process is one of the arcana of the craft and guarded with jealous care. In general terms it consists in drawing the strand through tanks of molten gutta percha and passing it through metal dies, which are kept well lubricated and cold enough to prevent adhesion. After becoming hard it goes through a bath of fluid known as Chatterton's compound, and while yet warm receives another layer

of gutta percha applied in the same manner as before. This compound is the only thing that experience has shown to be thoroughly efficacious and reliable for intimately uniting gutta percha, and its use entails the payment of a heavy royalty. The West India cables date every misfortune from the substitution of another material in their construction, which, while it met fully all factory tests, could not resist the vicissitudes of climate. The delay caused by the making anew of faulty joints lost the expedition the best season for laying, and misfortunes followed thick and fast.

Some fifteen days after the core has been formed in the manner described, the large wooden reels upon which are wound the two-mile lengths, are immersed in tanks, heated by steam to a temperature of 75° Fah., and the first complete electrical test is applied. The principal instruments used are the astatic galvanometer, the ordinary resistance coils and the condenser, all of which are mounted on a large slab covered with ebonite and sustained by piers of solid masonry. This secures freedom from tremors and thorough insulation of the apparatus, indispensable requisites for accurate tests.

The battery cells are upon platforms suspended by cords and links of India rubber, ebonite, or other insulating material, from the ceiling; which effectually precludes loss of current in their vicinity. The shape in which this record is kept is shown in Form I.

A brief notice of these columns may be necessary at this juncture. The first three explain themselves, but the four succeeding contain records from which the degree of insulation can be estimated.

The core, having its distant end insulated, is charged with the entire battery, and, after a few seconds, the galvanometer is momentarily introduced between battery and coil, and the deflection noted. It is then cut out, and at the expiration of one minute the coil is discharged through the galvanometer and the deflection again observed. It will be found to be less than the first deflection and indicates the rate of loss of charge in one minute, which measures the perfection of the insulation. The ninth column contains a record of "copper-resistance," as it is termed in shop parlance, of the coil, which is obtained by the arrangement familiarly known as the bridge. The practice is to use a single cell in this test. The entries in the right hand and last column are for the purpose of estimating that very variable quantity, the strength of the battery. The method is to charge the condenser with one cell in good condition, and discharge it through the galvanometer (and whatever additional resistance may prove necessary)—noting

carefully the deflection. Then charge the condenser with the whole battery and discharge as before. The deflection will rarely be found to be that due to the increased number of cells, and the last divided by the first will represent the number of standard cells to which the testing battery is equivalent. By the term "Constant" is meant the deflection of the galvanometer needle, produced by sending the current of one cell through a definite resistance, commonly one million ohms, which serves as a criterion for estimating other resistances.

The expressions "I. Lead" and "C. Leads" indicate insulation and the copper-resistance of the leads, which must be estimated for the reason that the core under investigation is usually removed some distance from the batteries and instruments, and must be connected with them by wires, known as *leads*, whose various resistances must be noted and separated from those that are being sought.

Form I. CORE AT 75° Fah.

No.	Length.	Weight.	Charge.	N	Disch.	Charge.	P	Disch.	I	C R	Min.

Form II. SERVED CORE.

No.	Length.	G. P. R. per knot at 75°	Charge.	N	Disch.	Charge.	P	Disch.	I	C. R.	Temperature. Cable.	Coil.

Condenser 1.  
10.  
200.  
Constant.  
I. Lead.  
C. Leads.

FORM III. CABLE TEST.

No. of Sec- tion.	Length.	Charge.	N	Disch.	Charge.	P	Disch.	Deflec. after 1 min.	C R	Rev's of Mach.	Temperature Cable.	Coil.	Last coil in cir- cuit.

Condenser 1.  
10.  
200.  
Constant.  
I. Lead.  
C. Leads.

It was once deemed necessary to test cables under a pressure of many atmospheres, and again in a vacuum, in order to rupture bubbles of air which might be confined in the dielectric; but this is now no longer the practice.

The warm bath and accompanying test being finished, the core is passed through a machine which serves it with wet hemp, and, for

fear that it may have received some mechanical injury in the process, it is again subjected to tests whose results are recorded in very similar form to the last (see Form II.); the only exception being that the insulation is obtained by the method of deflection and expressed in actual units of resistance.

The remote end of the coil being carefully insulated, it is charged with the full battery, and the galvanometer interposed between battery and cable. The only path in which a current could establish itself is through the dielectric, and the deflection of the galvanometer needle by this current, compared with its deflection through the specific resistance—in short with the constant of the galvanometer,—affords a means of expressing the resistance of the insulator to the passage of current in conventional units. If the reel of “served core,” as it is now called, is satisfactory, it is immediately joined to its predecessor, which is perhaps already receiving its iron armor, and being coiled away in large water-tight iron tanks of great capacity. Each machine has its own tank, and the cable made by it constitutes a section. The process of jointing is one of greatest nicety and involves every possible precaution. The several wires of the copper conductor are made one, by solder, and an accurately fitting scarf is formed between the two ends to be united. This is served with fine wire and further secured by solder, and, ultimately, gutta percha is drawn over the union and the ends worked and kneaded imperviously together, using the patent compound of Chatterton with lavish hand. So much trouble was encountered at these points in the earlier cables that the safeguards resorted to are most stringent. Contracts generally permit a joint to have as little as one-third the insulation of other portions of the core, but a skilful manipulator will cause them even to exceed it.

The mode of testing is to immerse the joint, after cooling it thoroughly in ice, in a carefully insulated vessel of water, and, having insulated the remote end of the cable, charge it for a brief period of time. The vessel of water contains a sort of collecting plate, which is in communication with a condenser, and whatever charge percolates through the joint into the water is stored up in the condenser. After a suitable interval the condenser is discharged through the galvanometer, and the deflection noted. The same steps are then taken with a similar length of core which includes no joint, and a comparison of the deflections obtained reveals the ratio between insulation of joint and of core. A separate record of these tests is kept, each joint specified by a number, and its distance from the beginning of the cable noted.

The name of the person who made it is also entered, in order to fix the responsibility of failure, should it occur. The hemp serving is then carefully laid around the jointed core, and it passes through the machine, which applies the armor without further manipulation. The position of the joint is indicated upon the finished cable by a leather tag. The only subsequent test which is taken is that of the finished sections in the tanks. It occurs every noon at the dinner hour, when the machines stop, which in motion would interfere with the observation, and is substantially the same as the preceding. The form of record is appended. (See Form III.)

The finished cable, passing from the machine to the tanks, envelopes a drum of known circumference whose revolutions are recorded, and inspection of these dials discloses the amount completed each day. Five or six miles is the capacity per diem of the average machine. It is customary, during the process of construction of a cable, to send daily from the works to the office of the engineer, sheets drawn up in the following manner. (See Forms A, B, and C.) By reference to these he can give instant information to curious directors and stockholders *in esse* and *in posse*. The tabular forms are substantially the same, and are exhibits of all the results of the tests applied at different stages of the construction. Form A. is an abstract from the record of observation upon "core at 75," as it is familiarly called. Form B. is the same for the "served core." The weight which is noted in Form A., as a useful factor in the electrical calculation, is omitted after the serving has been applied.

"Actual Resistance" is substituted for "Total Conductivity," the one being the reciprocal of the other, and the resistance of the insulator per knot is calculated, by means of established tables, from its actual temperature, which for the "served core" may be anything. Form C. introduces quantity of finished cable, and takes note of the temperature of the dry tank in which it is being coiled, as well as of that portion of "served core," which is still in electrical connection with it, but has not yet gone through the machine which applies the armor. The resistance of the insulator for the whole length of cable in circuit is recorded, and, at first glance, seems an incongruity, as it reduces as the cable grows. Reflection shows that as no insulation is so perfect as to entirely obstruct escape, the greater length affords more avenues of exit, and two miles of similarly insulated wire offer only half the resistance of one mile. The resistance of conductor, however, varies in direct ratio to the length.



## Tests applied to Cable.

## SECTION

DATE.	Time.	No. of Coil at end of Circuit.	Yards.	N. Miles.	Revs.	N. Miles.	Temperature			Total Resistance.	Conductor.	Insulator.				Induction.			REMARKS.					
							Cable.	Core.	Mean.			Total Resistance.	Per Nautical mile.	Constant of Inst.	No. of Stand-ard Cells.	Deflection at per 1 min. Neg.	Resistance of whole length.	Per N. mile.		Resistance reduced to 75°.	Discharge from Condenser.	Discharge from Cable.	Percentage at per 1 min.	Capacity per ter 1 min.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

The final step of the process is to cover the armored cable with a mixture of tar and silica, as previously described, and it is then ready for shipment. This operation may go on as soon as any section of the cable is completed. It is drawn through a machine which roughly serves it with yarn, and at the same time pours upon it the molten mixture which is shaped and hardened by a die through which the cable passes.

Stowing it on shipboard is carried on in the following manner: The more tanks the vessel has the better, not only for preserving the trim while paying out, but also for convenience in "turning over" cable, as the phrase is, when it is necessary to cut out a failing joint or a local fault. These tanks are water-tight, made of boiler iron, of as great size as the beam and depth of hold will allow, and firmly secured to the ship's keelsons. In the centre of each is a conical chamber equal in height to the tank, four or five feet diameter at top, and seven or eight at the bottom. The interior workmanship of tank and cone is as smoothly finished as possible, to guard against any hitch in paying out. Above each tank, during the process of stowing, a peculiar reel is placed, which draws the cable from the factory tanks through as many guide pulleys as may be necessary, and delivers it to the men stowing it below. All large cable-works endeavor to establish themselves on the banks of navigable streams, so that the risk incurred by their perishable





Fig. II.

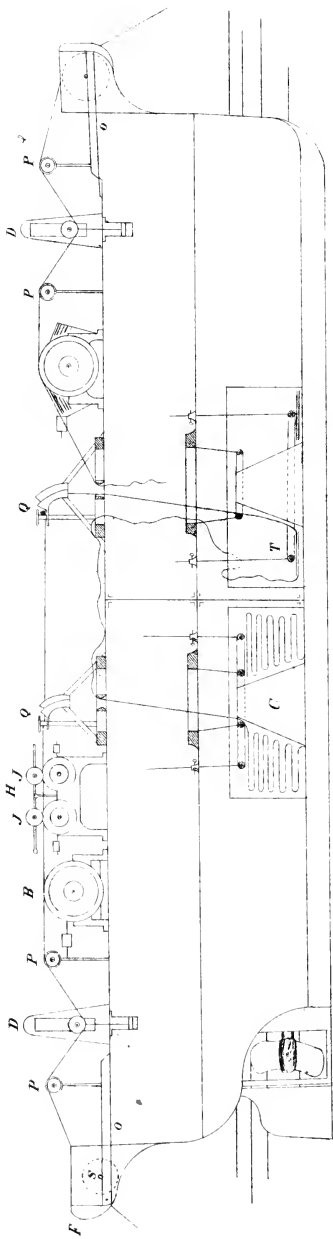
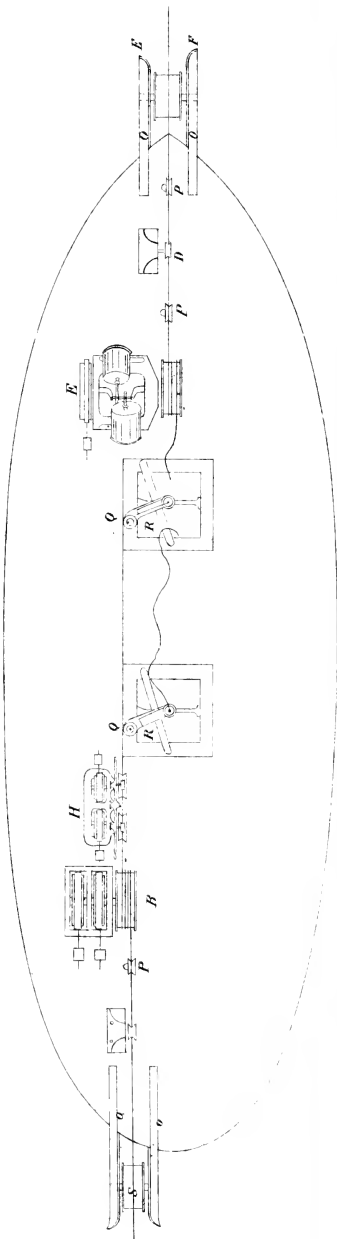


Fig. III.



staple in passing from factory to ship may be reduced to a minimum. This status facilitates immensely the coiling down. One of the little machines alluded to—which consists of little more than a wheel with an acutely angular groove scored in its face, driven by an ordinary hoisting engine—will enable skilful men to coil down a couple of miles per hour without much difficulty. The cable lies in this narrow groove, pressed down into it by what is called a jockey wheel riding on top, thus creating adhesion enough to let the grooved wheel haul along the cable at its own velocity. The cable-end, having come on board, is passed down into and over the edge of the tank—to be accessible for testing purposes. While the stowing goes on, this end is carefully insulated so that a continuous charge may be kept on the cable, the escape of which through the galvanometer would indicate to the observer the occurrence of any injury to the dielectric. The coiling is from the periphery to the centre of the tank, and from right to left, to insure its paying out naturally. And as each layer, termed a flake in shop parlance, is completed, the cable must cross it to reach the starting of the next flake, as in the sketch, Fig. I. This naturally produces inequalities in the surface, which are remedied by the introduction of battens between the flakes, radiating from cone to periphery of tank. Whitewash is liberally used to prevent the adhesion of the tar and silica coating of adjacent parts. While the coiling down is going on, there is time for a glance on deck, at the assemblage of machinery there collected. Substantially it is but an apparatus for picking-up and paying-out cable, but its accessories are numerous. Two meagre views of the deck will assist description, and they are given herewith. See Figs. II & III.

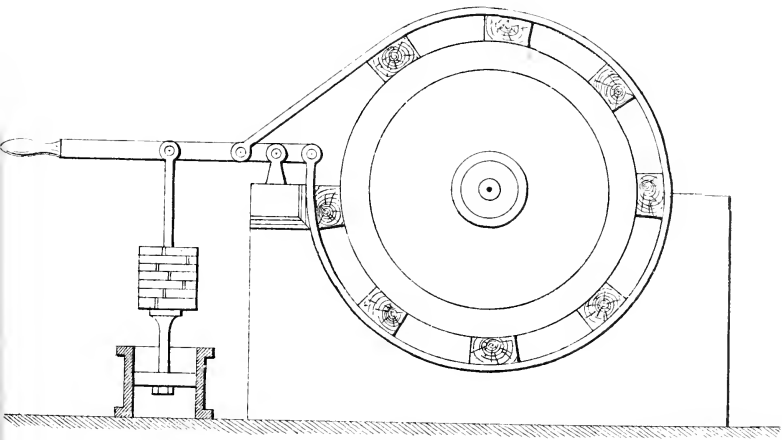
At bow and stern are heavy outriggers, marked O, which carry strong flanged sheaves designated by S. These sheaves have curved guards attached, which permit the cable or grappling rope to trend in any direction, without subjecting it to sharp bends or obstructing its motion in or out, as the case may be. A practical caution is well introduced at this point, viz., to avoid the not uncommon blunder of keeping these curved guards concentric with the sheaves above the level of the outriggers. With the cable or grappling rope trending athwart-ship it is very apt, when bow or stern sinks in a sea-way, to slip up the curved guard and, remaining there, when the vessel rises to the next wave, cause damage to apparatus and cable. The next piece of mechanism which invites attention is the dynamometer lettered D, for measuring the strain upon the cable or grappling rope at each

instant. Two elevated pulleys, P. P., stand at equal distances from a standard in which a carriage bearing another grooved pulley has vertical motion. The cable passes over the fixed pulleys, and under the movable one which plays the part of a rider to it. Weights are attached to the riding pulley, and its motion is steadied by connecting to it a loose piston which traverses a vertical cylinder beneath the standard, filled with oil or water. The nearer the cable approaches the line joining the vertices of the fixed pulleys, the greater will be the strain upon it, and, knowing the distance apart of the latter, and the weight of the riding pulley with its attachments, the strain corresponding to a given amount of vertical motion, may be readily calculated. Scales are constructed in this manner, and it is better that the motion of the riding pulley should be perpendicular to the line uniting the fixed pulleys.

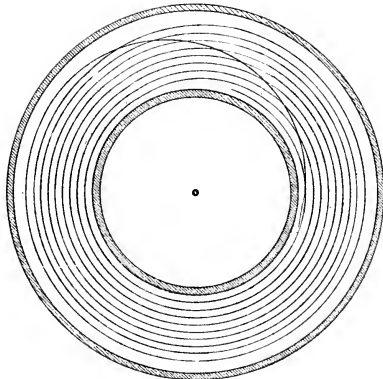
The brake, Fig. IV, next demands notice, and consists of a heavy drum about which several turns of the cable are taken, thus obtaining the proper degree of adhesion. The first turn of cable is deflected, after completing one circuit of the drum, by a device styled a "plough edge," making room for the succeeding turn, and thereby preventing fouling. The shaft which carries the drum has also upon it several heavy, broad-faced wheels which the brake blocks press against. These are commonly of elm, and attached to a belt of iron encircling the wheel in manner of the appended sketch.

The wheel turns in the direction indicated by the arrow, and if the levers are weighted too heavily, the adhesion between blocks and wheel face causes the lever to lift; thus bringing the distance upon it, between the points of attachment of the brake band, to some extent into its circumference, and the lengthening it thus undergoes releases the wheel. Notwithstanding that excess of motion in the lever is controlled by loose pistons working in cylinders filled with liquid, which terminate the rods that depend from the levers and bear the weights, the action of this arrangement is often found to be too sudden and extreme, and the following device has proved a remedy, viz. dividing the brake band and attaching the adjacent ends to a common axis in the frame which supports the wheels directly opposite the fulcrum of the lever. The faces of the wheels are in the shape of an extremely obtuse angle, apex upward, to prevent lateral motion of the blocks. It is almost needless to say that the brake wheels must be immersed in tanks of water with provision for changing it often. The apparatus marked H is a dependency which fulfils precisely the same office as a man easing a taut rope by rendering it around a belaying pin. To secure adhesion to

*Fig. A.*



*Fig. 1.*





the drum, the cable must be kept moderately taut behind it, and the holding-back machine does this.

The cable lies in acutely angular grooves upon the faces of wheels which have a common axis with small brake wheels. Upon the cable ride weighted jockey wheels, marked J, which crowd it down until sufficient adhesion is secured, and the cable feels the influence of the brakes.

In the centre of every hatch is a species of hawse pipe, which serves to guide the cable to the upper deck, and Q designates a quadrantal cast-iron trough, which leads the cable from the hatch pipe into the way which extends from the forward tank to the paying-out machinery. This may or may not be provided with rollers to ease along the cable. In the tank are seen a couple of iron rings of different diameters, one of which is capable of adjustment at any point between the top and bottom of tank.

The smaller one generally encircles the cone just below its top, and is about a foot greater in diameter, and the larger one whose diameter is about half that of the tank, follows down the cable as it diminishes. The purpose of this "crinoline," as it is called, is to confine the rapidly moving cable close to the cone, and thus add to the safety of the men, who must remain in the tank during the laying, to remove the battens used in stowing the cable, and carefully guard against twists and kinks. The crinoline rings and hatch pipes are fitted with movable openings, which readily permit the cable's being withdrawn in the perilous operation of changing tanks. The picking-up machinery varies little from the foregoing.

A large strong drum fitted with powerful brakes, and driven by well-sized engines, is its general description. Its remoteness from the main boilers of the ship generally necessitates a separate one for hoisting purposes, but this is not always the case. The chief desiderata are that all drums, sheaves and guide pulleys have liberal width of face, for the reason that, besides having to afford room for two parts of cable—as when a hight is hauled aboard—they must occasionally contain chains and hawsers for springs and other purposes (a group of three sheaves at the bow would at times be a great advantage); that the "balks," as the timbers supporting the bow and stern sheaves are called, have numerous heavy ring bolts for the attachment of selvage stoppers, which are used to hold the cable when necessary to remove it from the drums for any purpose: that one or more counters be attached to each drum to register its revolutions, and that in every tank, and convenient to the paying-out machine, engine-room signals be put up, to strike in event

of a threatened fouling of the cable. A spacious, convenient, and well-lighted chart-room on deck is indispensable, for the ship's position must be plotted continually, and the per centum of slack cable regulated by the probable depth of water there. The testing room must also be convenient, spacious and well appointed. It would be impossible in the limits of this article to specify its equipment, but it is much the same as that of the test-room of a factory. The astatic is replaced by the marine galvanometer, whose heavy turret of soft iron and controlling magnet guards it against terrestrial disturbance as perfectly as the double attachment of the needle does against the oscillations and shock of waves. In extreme cases it is well to substitute a strand of silk floss for the slender fibre which supports the needle. Resistance coils and a condenser also form part, and with batteries for ship and shore use, insulated wire, instruments for telegraphing, coupling screws, various implements, tabular forms and stationery, the list is complete. The special equipment of a cable-ship consists of grappling rope, grapnels, chains, huts of corrugated iron for erecting over the shore-ends when they are in isolated regions, as is generally the case, tools and material for jointing and splicing, picks and shovels for trenching, buoys and anchors of all sizes, small brakes and sheaves, for boat and barge use, and last, but by no means least, a steam-launch.

Imagine a ship thus loaded, fitted and equipped, *en route* for the initial point of the cable route. This in itself is a matter for deliberation, and the choice is influenced by prevailing currents and probable weather. With a cable perfect as regards insulation and external condition—which reduces vastly the chance of sudden stoppage—it is best to run with wind and tide; and even if local faults are suspected which may develop under pressure, or if the cable has been deranged in the tank by stress of weather, making it likely that the vessel may have to stop and remain hanging by it, while faults are cut out or a "foul flake" cleared, it is still better to run so that wind or tide will conduce to keep the ship pointed on her course, instead of swinging her back over the cable put down and subjecting it to risk of rupture across some sharp edged rock.

The surveillance maintained day and night in the factory is not altogether relaxed on shipboard. The cable tanks are kept filled with water, if weather will permit, and daily tests of insulation and continuity taken. Few tests are permissible on shipboard, but these serve to demonstrate the condition of the dielectric, and the fact that the conductor is unbroken, and are the only absolutely important ones. Hav-



ing reached the initial point of the route the vessel chooses suitable anchorage while the shore end is put down. This type of cable has not been specially described, and it may not be amiss to do it here. Its weight ranges from twelve to thirty tons per mile, and is given by additional armor, each layer of wire being of larger size than the preceding one. This is used where anchors may be dropped or vessels ground upon it. The end may be made fast to a boat which is either towed or warped ashore, and, as it proceeds, the cable is lighted out of the ship and kept from sinking by boats which slip under it whenever the bight gets too heavy for the predecessor, or, if this is not practicable, a measured quantity is put in a barge or lighter, which is towed from shore to ship.

The coast of Guiana presents as great difficulties to this operation as can be imagined, and they were overcome as follows in laying the line from Trinidad to Demerara. The shallow sea whose greatest depth was not sixty fathoms, in the whole route of three hundred miles, precluded the laying of heavy cable into deep water, and it was considered unjustifiable to carry it beyond fifteen fathoms which was not found within eighteen miles from land. The ship having been lightened in every way that ingenuity could suggest, proceeded to the selected spot, and, having attached a buoy and anchor to the cable end, and having sealed it up, let it go, and steamed in-shore in a making spring tide. The sea bottom of all this region is a soft silt washed down by the great rivers of that coast, and a ship may ground with impunity; so she kept on till the water began to shoal, when preparation was made to buoy and let go the cable end. The moment bottom was touched, the buoy was dropped, the cable cut and sealed up as rapidly as possible, and thrown after it, while the ship backed out of a nest which the turning tide was quickly preparing for her. There remained one and a half miles to overcome ere solid ground was reached, and the next step was to load a flat-bottomed scow, which was fitted with mast and sail, with the needed quantity of cable, and again to run for shore in a favoring breeze, throwing over the bights by hand. When bottom was touched, three quarters of a mile interposed between cable end and shore, of a mud too thick and tenacious for boats to move in, and too liquid to support a man's weight. The method then employed was to send from shore a grappling rope, make it fast to the cable end, and forcibly haul it through the mud. Two hundred and fifty convicts, in charge of keepers, performed this feat, either pulling on shore or lighting the cable and grappling rope along through the mud, in which

they sustained themselves by lying on floats of plank placed beneath their arms. A striking converse to this occurs in the Franco-American cable where it touches at St. Pierre. The steep sides of the island offered no natural path to the cable ends, which are therefore embedded in a trench cut in solid rock, and covered with hydraulic cement.

The "shore end" and "intermediate" cable—which are united by splicing to each the proper end of a "taper," as it is termed, made in the factory for the purpose—being disposed of, the "deep sea" cable in the various tanks is joined together, and to the "intermediate," by means of another "taper," and the laying may at once commence.

The process of "joining up," includes the making of the electrical connection already described, and the splicing together of the iron armor. The latter process is quite like splicing an ordinary iron rope. Strands in one end are unlaidd, and their places supplied with strands extending from the other end. A certain alternation is observed in this, and every pair of strands is butted as far as possible from the adjacent pair. The butted ends are strongly served with wire prepared for the purpose, and the entire splice, which may be from five to ten fathoms long, is served with tarred rope yarn. Provision has meantime been made on shore for the electrical test, which is kept up during the laying, and conducted as follows:

Insulation and continuity is all that is needed, and to exhibit these at every instant on shipboard, the cable end on shore is connected to one pole of a condenser, between whose other pole and the earth a speaking instrument is interposed. The same arrangement is made with the end on shipboard, with the addition of putting the full testing battery in communication with the cable through the galvanometer, which consequently exhibits a permanent deflection. The amount of this deflection measures the insulation—the sudden disappearance of the light from the scale, indicates a fault for which the ship must be stopped, and the defective spot cut out. Reflection will suggest that the conductor might be parted within the dielectric, without especially disturbing the deflection, and this danger is guarded against by the transmission of signals between ship and shore, every five minutes. This does not at all interfere with the permanent charge, the method of connection making it possible to cause waves of current to pulsate through the conductor without any electricity leaving or entering it. Strict record is kept of "continuity signals," and of the deflection which naturally increases as the cable gradually changes its dry tank for the deep sea. A reference to the distance paid out, however, renders it

easily reducible to a certain deflection per knot, which is the basis of comparison.

The routine on deck consists in noting the quantity of cable paid out, and comparing it with the distance made by the ship, as deduced from the patent log, at brief intervals. The route must be shown by a vessel leading the cable ship, as the varying mass of metal on board the latter so effectually deranges the compasses that not the slightest dependence can be placed upon them. The navigator, therefore, has little more to do than to determine from the ship's position by dead reckoning, and the profile along the adopted course, what may be the inclination of the bottom with the surface of the sea, and thus estimate the suitable quantity of slack cable. The average allowance is fifteen per cent. and it is regulated by the brakes which are weighted at will. A practical caution comes in very properly at this point, which is to avoid loading the brakes with reference to maximum speed of cable—as when the stern of the vessel rises in a sea way. If this be done, the brake drum will actually stop when the stern settles down in the trough of the sea, and the cable be subjected to great risk of snapping. One of the most delicate operations of laying, is, on having finished one tank, to commence laying from another. It must be borne in mind that the bottom end of the first is connected to the top end of the second and the bight lies along the deck between them. It passes within the crinoline and hatch pipe of the empty tank, from which it must be extricated with unerring certainty, at the critical moment, and the bight carefully handled, to prevent kinks and to guide it safely from tank to paying-out machinery. Just before this event occurs, men are stationed at the hatch, along the bight, at the brakes, and stoppers are loosely applied for emergencies. The ship is stopped, and while drifting on, the transference is accomplished.

In the event of a fault passing overboard, which is indicated by the galvanometer, the ship is instantly stopped and the distance of the fault measured. If the interruption be a failure of continuity, the distance away of the rupture may be measured by means of the recorded capacity, per knot, of the cable. Note the deflection caused by the discharge from a condenser of known capacity, and compare with it the deflection caused by a discharge from the cable, with the same battery and interval of time. If the dielectric be perforated, the distance away of the "earth," (as it is called) thus formed, may be found by measuring the resistance of the conductor to the point, by means of the "bridge" and referring it to the known resistance per knot. This

point determined, it is necessary to reel inboard again, and this is done by passing a spring from the picking-up machine, through the bow sheaves, and making it fast to the cable astern. The reeling-in proceeds till the spring feels the weight, when the cable is cut at the stern, and shortly comes on board over the bow, and is secured with stoppers as soon as the "fault" is recovered. After cutting out the defective portion, the end over the stern is brought round outside the ship, and in through the bow sheaves, and the joint and splice made. A hawser is then made fast to the bight and put about the drum, the strain is taken by the drum, the stoppers are loosed, and the bight lowered by the drum till well below the hull and screw, the hawser is cut and the cable once more hangs from the stern of the ship, which proceeds on its course. This operation is most hazardous, and attempting it in a rough sea lost both the lines from Jamaica to Aspinwall and Porto Rico. A perfect cable ship should be made after the pattern of our "double-enders," with feathering paddles, and capable of picking up or paying out at either end. The landing of the cable end is only a repetition of the work at the starting point.

Final tests, however, are made of gutta-percha and copper resistance which are materially changed for the better, by the low temperature and great pressure to which it is subjected. The Atlantic cable reduced its copper resistance six per cent. after laying, and increased its insulation nearly eight-fold. An apparatus which has a most important office here comes into play and demands brief notice. It is the lightning arrester, which consists generally of a pair of metal plates, bristling with points, and in near contiguity yet not touching. The cable conductor is attached to one, while the other connects by an ample earth wire with the ground. The air line is attached to the same plate as the cable, by means of an extremely fine wire which conducts low tension currents well enough, but fuses at the attempted passage of an intense charge. If lightning strikes the air line, instead of entering the cable and bursting through the dielectric to earth, it is checked by the melting of the fine wire, and, leaping across the small interval between the contiguous plates, finds ready escape to earth.

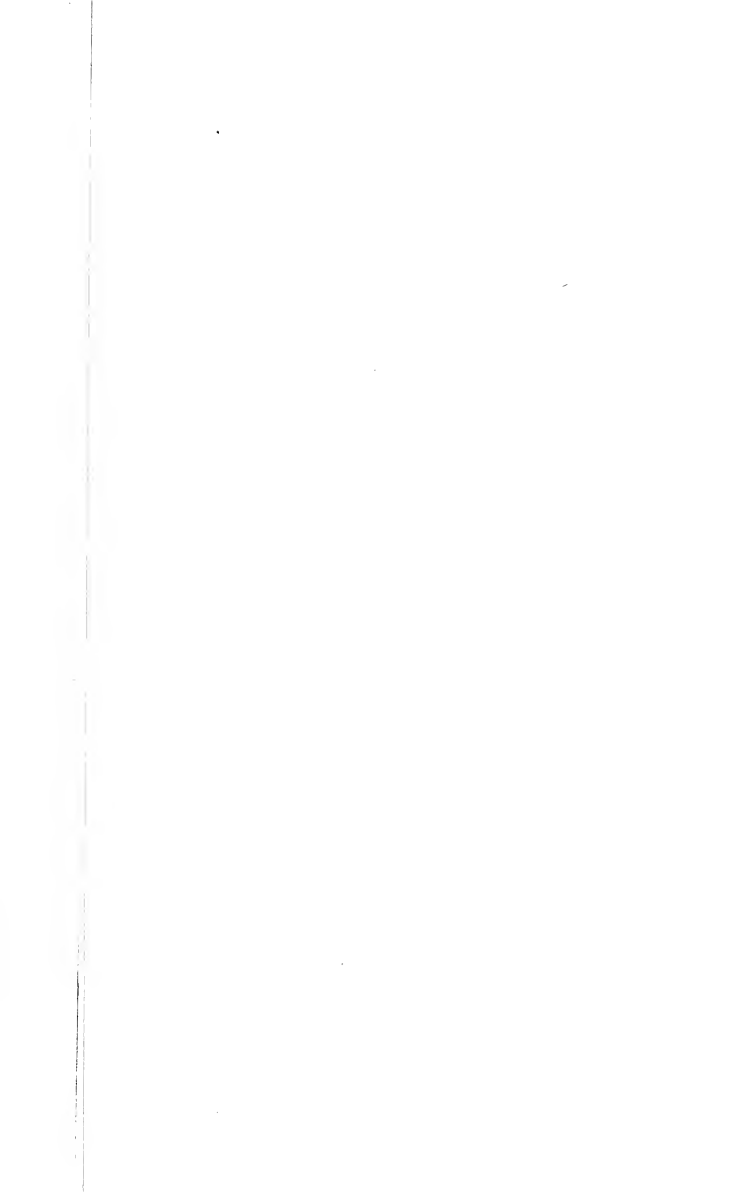
The grappling for a cable is so purely a tentative process, that it is impossible to enunciate any general rules. The major part of the work is to acquire an idea of the bottom, and to determine upon the proper implements and manœuvres. These settled, the end is well nigh reached. The apparatus consists of grapnels, whose pattern is rather a matter of caprice, chains of different sizes and lengths, and a rope made especially

for the purpose, of wire and tarred hemp. Shackles and swivels of an especial pattern are also employed. The rope possesses immense strength and just the proper buoyancy; wire rope being too dead and inert, and hemp, of sufficient strength, offering too great a frontage to the current. In grappling within sight of fixed points, the search may proceed at all times—always working down wind or tide. Let there be no doubt of being well above the cable before the grapnel is let go, and that there is enough rope out. Generally speaking, the more chain that is interposed between grapnel and rope the better, as it keeps the former down to its work. Away from definite points of reference, buoys may be anchored, and their positions determined as a substitute, but they rarely watch long, and the best method seems to be to move toward position, with the hope of being on it at a convenient hour for a good observation, and to so forecast that the termination of a drag shall fall in a time suitable for another, and in this manner make it possible to plot the approximate drift of the ship. It saves going over explored ground. The grappling rope leads through the forward dynamometer to the picking-up machine, and the indications of the former are carefully watched—any sudden increase of strain denoting that the ship is brought up by something which must be investigated, ere the work can proceed. The tremor of the rope also reveals much to an experienced touch. In deep water to attempt to drag otherwise than with the current is futile. It was supposed that twin screws would prove of great advantage to cable ships in this respect, but experience has not so demonstrated. Even with a slender rope, the centre of pressure of current, upon the rope and ship combined, falls far below the hull, when the depth of water is great, and although twin screws may lay the ship's stern across the current, the general drift is not appreciably altered. In all cases the use of engine power in dragging is to be discouraged, if any other expedient can be found; the risk of severing the cable is very great. Underrunning is resorted to reluctantly: with uniform bottom it may be carried on successfully, but the impossibility of ensuring that the ship keep directly over the cable, involves the risk of snapping it around or under some projecting rock, which it may encircle.

Work of the kind just described is necessitated by accident in laying or by the interruption of an established cable, and in the latter case is preceded by careful tests from both ends. The distance to the escape is best found by means of the "bridge" and the recorded resistance of the conductor: if the conductor alone be broken, the capacity

test will locate it. Other tests are prescribed, but are of doubtful utility, although the house over the end of a telegraph cable ought to afford nearly as great facilities for testing as does a factory. While the grappling is going on, a speaking instrument is connected with the cable end, and a constant watch kept upon it for news of the success of the search. This enables the ship, after having brought the cable to the surface, to know beyond the shadow of doubt on which hand the interruption lies. As regards the method of signalling; in long circuits, this is effected by means of the mirror instrument, which deflects a pencil of light upon a screen, moving it right and left, as currents come and go around the magnet. A perverse influence, called induction, makes itself so palpable on long circuits that the difficulty of signalling is great and speed is impossible. Analogy is often the best explanation, and an elastic tube of India rubber, traversed by a current of water, affords a capital one. Imagine such a tube conveying signals by the dropping of definite quantities of water out of its remote end—the amount being regulated by opening and closing a valve at the other. The pressure of the current distends the tube, and the closing of the valve does not instantly check the escape at the far end, for it is prolonged by the contraction of the tube, and in the case of rapid signalling would extend into the succeeding discharge effectually obliterating all distinctness. In this manner does the slow discharge from a cable militate against speedy communication. To send a signal through the Atlantic cable and to leave it clear for a succeeding one requires six or seven seconds, and as this would prescribe the speed for all instruments whose indicators must move from and return to a certain fixed point under each electrical influence—as is the case with land lines—it became necessary to surmount this obstacle. The mirror instrument does not surmount but evades it, in that its motion to right and left need not be referred to any zero point but only to its predecessor, thus enabling one signal to tread upon the heels of another. The light wanders aimlessly all over the scale to a casual observer; but the trained eye interprets every movement with ease.

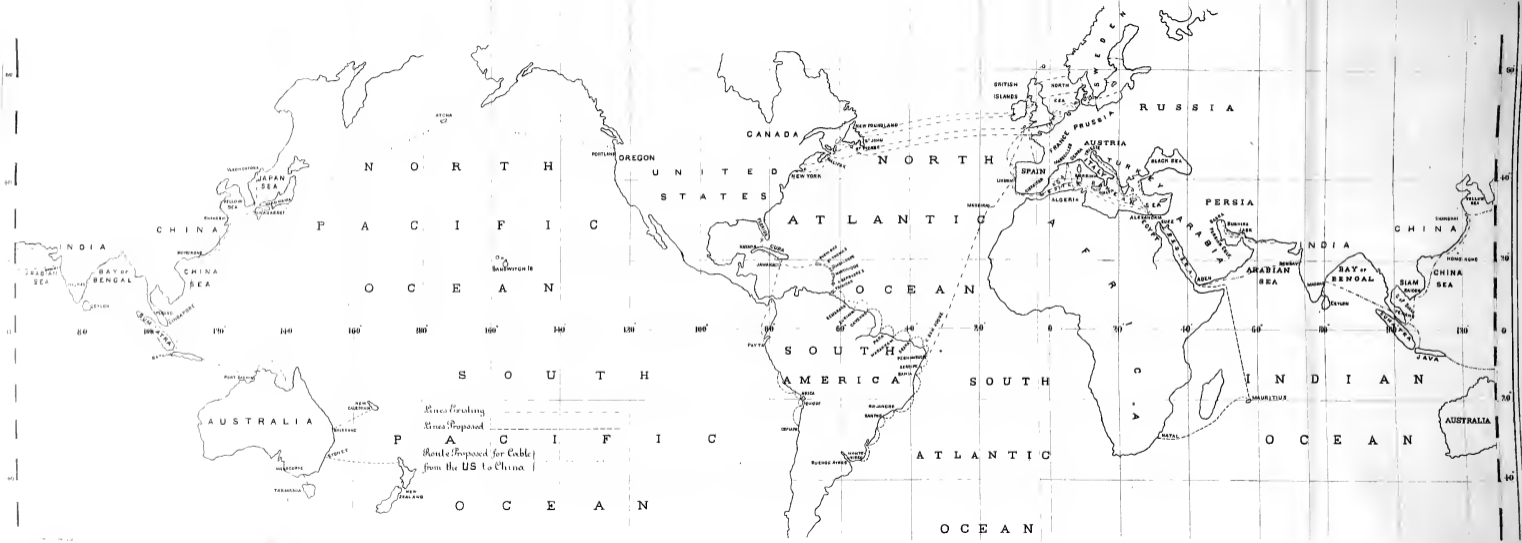
The accompanying map shows all existing and contemplated submarine telegraphs which have developed from the petty germ sown less than forty years ago in the English Channel. "Lines proposed," are so rapidly merging into "lines existing," that the geographer is allowed no respite in revising its charts. The one shown needs no explanation, but may suggest the question—"why should the proposed line between the United States and China follow the remote course it



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does, instead of touching at so noted a port of call as the Sandwich Islands?" The reason is that the indicated direction is approximately the arc of a great circle and reduces the quantity of cable necessary; also, that the depth of the central Pacific is as great, or greater, than any sea of the globe. While depth does not materially enhance the difficulty of laying a cable, it increases vastly the labor of repairing one; and as this necessity is always possible, it has influence in the selection of a route. The commercial and technical aspects of such enterprizes are as full of interest as they are various. The astronomer and geographer fix localities by the tenuous filament, and the minister in his cabinet handles fleets and armies at the very antipodes; but there is yet a broader view of their influence which it is impossible to overlook. It is a grand thought to the alien that it will bear his appeal from the uttermost parts of the earth to his own people, and speed back the words that secure him safety and comfort; it has yet a nobler mission. Ethnologists declare that race peculiarities are the outgrowth of climate, soil and diet, which in numberless generations have evolved a type; that the remote and less accessible regions exhibit typical traits in marked distinctness; while rivers or other natural highways help to obliterate them by facilitating association, exchange of product, intermarriage, and other modifying influences. Is it far fetched to draw a parallel between the material and immaterial, and urge that these highways of thought are tending to assimilate mankind; to subdue ignorant envy and hatred; soften natural asperities; broaden, liberalize, and mould the creature into some semblance of that Creator to whom time and space are as nothing?



THE RECORD  
OF THE  
UNITED STATES NAVAL INSTITUTE.

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No. 4.

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U. S. NAVAL ACADEMY, ANNAPOLIS,

APRIL 13, 1876.

Commander EDWARD TERRY in the Chair.

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TWO LESSONS FROM THE FUTURE.

BY LIEUT. T. B. M. MASON, U. S. N.

ESSAYONS.

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GENTLEMEN :

The two letters which I propose to submit to your consideration this evening will, I hope, explain themselves. As you will see by the dates, they are supposed to be written in the future, and are merely conjectures as to the probable results of possible events. They are supposed to be written by an officer—in the first holding the rank of Lieutenant, in the second, after a lapse of nearly a third of a century, that of Rear-Admiral. The friend in the first place holding the rank of Lieutenant, in the second, having for many years retired to the quiet of civil life.

SAN BOLO, DONLAND, JULY 4th, 1880.

DEAR FRIEND :

This is a melancholy way to spend the anniversary of our independence, I being at this moment anything but independent. I was sent here, a month ago, with about one hundred other officers, to rusticate until peace is declared, as there are no means of exchanging us. We

are on parole and allowed to wander within the military limits of this place.

As you were a spectator, and an actor, at the battle of the 8th of May, off Cady, it is unnecessary for me to recount to you more than the part taken by our ship. You know I was aboard the Franklin, our crack big ship, bearing the flag of the Commander-in-chief. When the enemy hove in sight, we formed with the other ships in order of battle, and manœuvring for some time, came in contact with them. You know that they have vastly improved their navy, since '76, and brought against us a force of twelve large iron clads, carrying very heavy English guns and well manned; besides they had quite a number of small steamers fitted with heavy torpedoes. As soon as they were in range, we opened fire, but we might as well have been throwing peas at a stone wall, whereas we received a number of heavy shells, some passing through us and some bursting aboard of us; in a few minutes our engines were disabled; we tried to signal for assistance, but neither this signal nor any that we had made since the firing commenced, attracted the slightest attention; every body seemed to be looking out for themselves. At last a big fellow deliberately shoved his nose almost through us, and our ship went down in no time. I was picked up by lucky chance, and I think that I am the only one left to tell the story, from our vessel. The Trenton, which was on our quarter, did splendid service with her guns, but in the end they overpowered her. I saw the old Wabash sunk by a torpedo attached to a vessel very little larger than her own launch. I expect that your ship and the Marion were the only two that escaped.

This *is* a terrible lesson, or *ought* to be, to those who sent us to sea, in ships scarcely able to get out of their own way; some having just returned from foreign stations, in the most dilapidated condition possible to imagine; with inferior ordnance, with green crews in most of the ships, and last but not least, stands the fact that, we really knew nothing of naval tactics or of the peculiar qualities of our vessels necessary to make any tactics a success; not from any fault of our own, but because we had never been able to practice the theories, which were given us. The fact that our signals could not be seen, or understood, is also significant.

I hope that this will reach you in safety, as I have to send it in rather a roundabout way. I suppose that peace will soon be declared, and it probably will be, as our country is now in the condition of the snake in its hole, not to be attacked in its own lines but having no chance if

it comes out. We will probably, for the sake of our commerce and so forth, have to eat humble pie and talk small.

Let me hear from you.

Believe me your sincere friend,

THO'S NOSAM,

Lieut. U. S. N.

R. SREGOR,

Lieut. U. S. N.

Norfolk, Va.

FLAG-SHIP INDEPENDENCE,

HAMPTON ROADS,

June 30, 1906.

MY DEAR OLD FRIEND:

You have probably read in the papers non-professional accounts of our great victory off Hatteras. Knowing that you are with us in heart, if not in body, it appeared to me that you would be interested by a minute detail of the means by which our success has been brought about. You must know that we are not in the condition in which you left us, shortly after that terrible day off Cady. *You* thought that our game was up, *I* did not. I trusted to the common sense of our people at large, untrammelled by political influence. The present has proved me right. In "81" the reaction set in and we have been steadily improving until, without the expense of our branch in former years, we have to-day the finest fleet afloat.

Our opponents, on the contrary, have made little advance; you know their people tried to copy ours in the old days, and would not appropriate any more money for improvements. They had had no lesson like our Cady.

To begin with, I will take our ships, as without them the guns, ram bows, torpedoes &c., would be useless.

We have now three kinds of vessels. 1st, *The ships of the line*, divided into three classes and all resembling each other, in general outline. They are armored on the bows and in the wake of the engines, boilers, magazines and steering gear. Their engines are capable of driving them up to 16 knots. Their steering gear turns them, on an average, in the circumference of a circle whose radius is 300 yards. They are all provided with ram bows and carry improved spar torpedoes, on the bows and quarters. Each has also a defense against swing torpedoes forward and aft. They are armed as follows.

1st class.	{	America.	Two 15 inch rifles, firing 2000 lbs. steel projectiles, mounted on pivot carriages forward and aft on spar deck, with $\frac{3}{4}$ round fire.
		Independence.	
		Columbia.	
		Columbus.	
		Constitution.	
2d class.	{	Liberty.	Sixteen 12 in. rifles, firing 1000 lb. steel projectiles in broadside on gun deck.
		Hull.	
		Decatur.	
		Bainbridge.	
		Farragut.	
		Porter.	
3d class.	{	Dupont.	Same as 1st class but with only twelve 12 in. broadside.
		Essex.	
		Franklin.	
		Brooklyn.	
		Hartford.	
		Wabash.	
	{	Ironsides.	Two 12 inch rifles on pivots. Eight 12 inch rifles in broadside.

2d. *The cruisers*, of which there is a large number. These vessels, answering to the old corvettes, are used on foreign stations, and as a squadron of observation to be attached to the fleet. These vessels are unarmored, carry respectable batteries, and have great speed.

3d. *The rams and dispatch tugs*. I send you a drawing of both, which you will find in Plate I. marked Fig's 1 and 2. The rams are heavily armored, presenting the appearance, at a distance, of large turtles. This arrangement makes them almost invulnerable, as they are very low. They have ram bows of great strength, and provided with a submarine gun in the bow and on each quarter, and are capable of great speed. The dispatch tugs are very fast and have great power. Their engines &c., are protected with a turtle back like the rams. They are fitted with spar torpedoes to be used only if attacked, their duty being to carry messages and look out for "lame ducks."

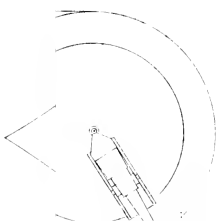
Having given you a general idea of our ships, I will describe this vessel on which I have the honor of hoisting my flag. She is of about 6,000 tons capacity, shorter and broader than our old ships. This form has been adopted to increase her turning power, which is an all important element for tactical purposes. She resembles, somewhat, in shape, those French vessels that we used to see up the Mediterranean in "70." I have attempted in my sketch, in Plate I, marked Fig. 3, to give you an idea of her and of the parts armored and those unarmored. The masts are steel and telescopic, as are also the lower and topsail yards. The rig is that of a barque. For action we telescope everything,



PLATE I.



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		Decatur.	
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		Porter.	
3d class.	{	Dupont.	Same as 1st class but with only twelve 12 in. broadside.
		Essex.	
		Franklin.	
		Brooklyn.	
		Hartford.	
		Wabash.	
			Two 12 inch rifles on pivots. Eight 12 inch rifles in broadside.
		Ironsides.	

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FIG. 1



FIG. 2

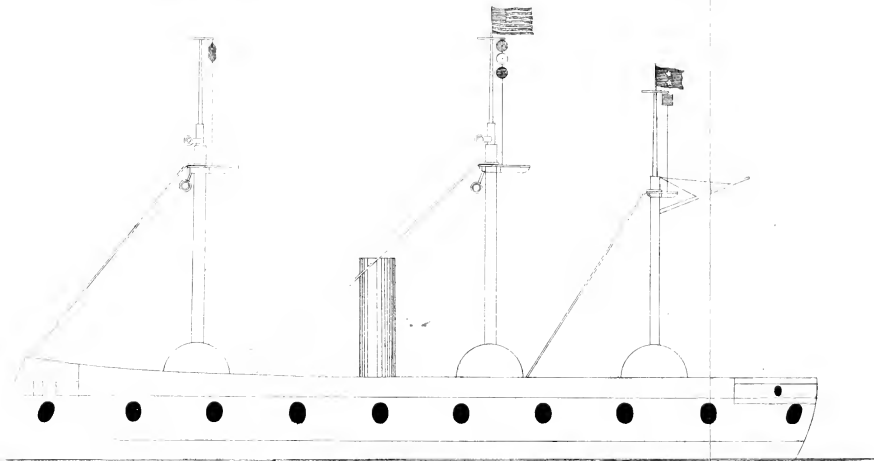
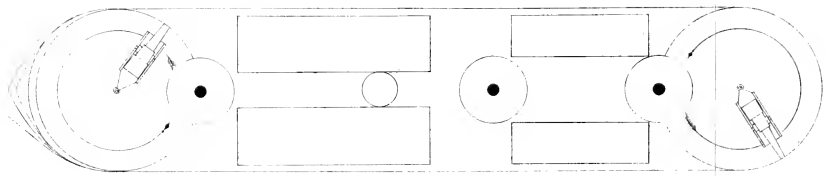


FIG. 3.



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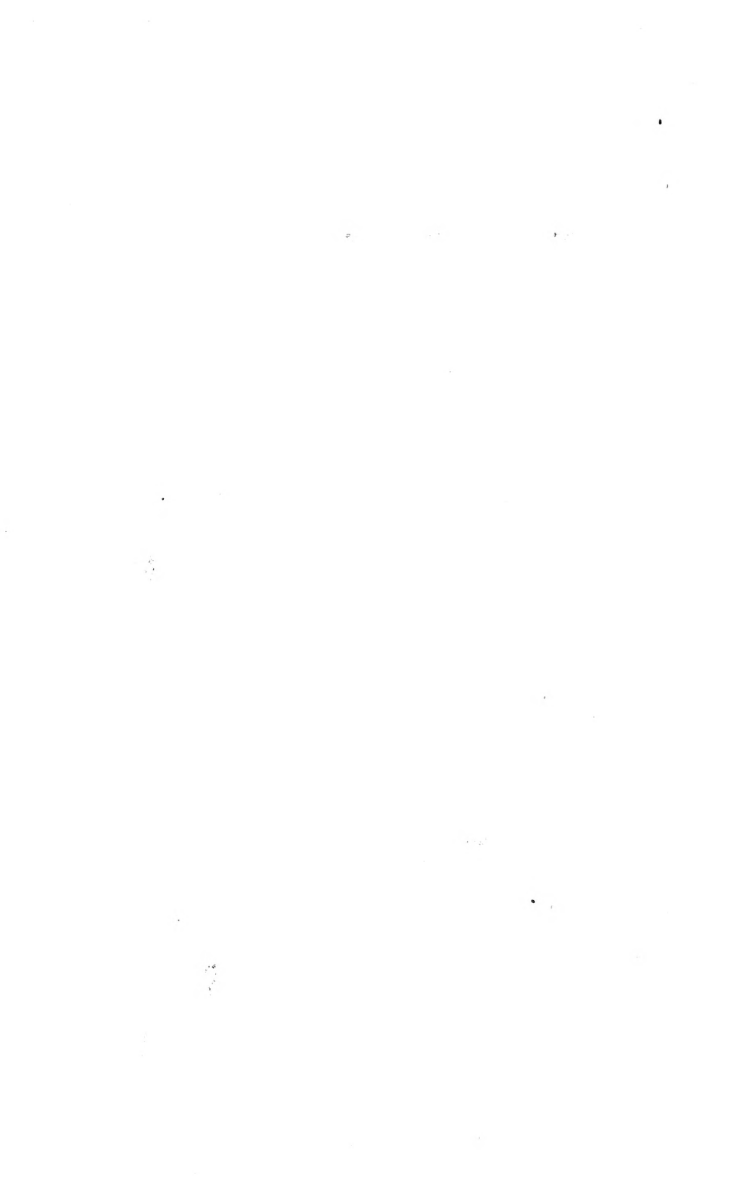
sending up light iron signal masts with four armed trucks. Around the foot of each mast is a little dome-shaped house, sufficiently strong to resist bullets and falling spars. The interior of these is more like a telegraph office than any part of an old man-of-war. In the forward one, in action, you would find the captain, the navigator, and the lieutenant in charge of the forward half of the guns. Telegraphs and speaking tubes connect this dome with the other ones and with the engine and steering rooms. There is also an indicator, showing the position of the helm, the motions of the engine, and the speed of the vessel, this last coming from the velocitometer, which is fitted in a tube, on each side of the ship, well below the water-line, so as to be out of the way of boats coming alongside, and of such like accidents. The gunnery lieutenant points and fires his guns and the forward torpedoes by means of electricity. As all the guns are worked by steam, and as the ranges, elevations and angles of concentration have been accurately ascertained, this is reduced to a nicety. The helm is worked by telegraph, the navigator being provided with an accurate table of helm angles for all, and under all circumstances of current and sea. The signals for the fore are worked from the rear part of this dome. In the main dome the signal officer is posted, and it is from this one that the flag-officer directs the motions of the fleet, or of his squadron. In the after dome the lieutenant in charge of the rear guns and torpedoes, the executive officer and the signal officer for the mizzen are stationed. The domes, as I said before, are so well connected with tubes, &c., that the different officers converse as if they were all in the same one. Besides the domes on the spar deck, there are steel turrets open at the top, to protect the men stationed at the bow and stern pivots from musketry fire. You will ask me what has become of my boats? They were left ashore, and in place of them we have four large bolsas spread on deck, ready for inflation and use, and capable of carrying all hands. On the gun deck, the forward and after guns are arranged to fire in broadside or directly ahead and astern. The carriages are worked and the guns loaded by steam, so that very few men are visible. The ammunition comes up from shutes, with self-closing tops, near the muzzle of each gun. On the berth deck we find the working people, well protected by the armor, a large fire brigade ready to proceed to any part of the ship with the best modern appliances for fighting that dangerous element, a large powder division ready to supply any amount of ammunition in very little time. Aft is the steering room. We do our steering by hydraulic power, so

that one man tends the whole affair under the direction of an officer, who watches the telegraph from the domes on deck. I send you a plan of the velocitometer, marked Fig. 4; it has been found of great use; it being very necessary to know the exact speed of the vessel at any moment through the water, whether in going ahead, turning or backing; it is only necessary to apply the correction to the given reading, for slip and friction, to attain the true velocity.

Our guns are all of the latest model, which has been adopted, after a long series of trials at Annapolis. The people growled a little at the necessary expense, but it was only necessary to say "Cady" to them, and the growling ceased; the pride of the American people had been touched and they were bound to come to the front. We have selected two calibres, the 15 and 12-inch—both very heavy, the 15 much more in comparison, as they are for the heaviest work. The 12 are lighter, so that we can carry a greater number of guns in broadside. What we have lost in individual penetration we have gained in aggregate when concentrated. Just think of a vessel that can throw 4000 lbs. from her bow, 12000 lbs. from her broadside, or 4000 lbs. from her stern, on a space twenty feet square. What would Nelson or Farragut have said of this in their days?

We have adopted the submarine gun, for torpedoing in the attack, and the electric spar torpedo for defense, both of the latest pattern, from Newport; which institution, like the Experimental battery, has had its vicissitudes.

Now that we have examined our inanimate material, let me say a word about our personnel. You will remember, that in "80" many resigned, and many poor fellows closed their final accounts at Cady. We were left nearly without officers and men. Something had to be done, and was done. The Naval Academy was thrown open to all, any boy properly authenticated who wanted to try could come, there was no limit except that of accommodation to the number in classes; but the course was most rigid, great weight being given to professional aptitude and officer-like qualities. From the graduating class of each year as many of the higher members as were required to fill up the deficiencies in the navy list were taken; the others were put in the naval reserve and sent as officers in the merchant service, every vessel having an American charter being forced to take so many; and every line carrying the U. S. mails (American line) was entirely officered by them. Those who elected and were found on examination to be qualified to become engineers went into that branch; those who elected the







marine corps and pay department (the latter having to give bonds) were allowed to follow their inclinations. Thus we have to-day a corps of thoroughly trained officers and a splendid reserve. The officers of the reserve do six months' service, every two years, for which they receive full pay.

Our apprentice system has supplied us with thoroughly well-fitted Americans for every branch required, and has also built up a reserve of long-service men, who, like the officers of the reserve, are at all times in training. In time of peace our first and second rates are used as school-ships in the large ports, equally distributed along the whole coast; their crews, not required for actual work on board ship, are temporarily employed at the yards and naval stations. The third rates are employed as a practice squadron for officers and men. The squadron of observation for the Fleet are employed as cruisers on the home station.

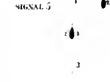
Every year the Fleet is assembled, at some rendezvous on the coast, for drill. The places of rendezvous and the time of rendezvousing are changed each time, so that, a war threatening, we can assemble without causing suspicion. These drills are carried on for instruction and improvement.

Commanding officers are rarely changed, so that they may become thoroughly acquainted with the ships that they command. Much time is devoted to individual ship and detached squadron movements, and all results are tabulated. Ships are turned, under all conditions that are liable to occur, and in all trims, so that separate tables may be obtained for future reference. A store squadron of fast steamers, to carry extra stores and coal, is requisitioned each year from the mail lines. Ships are kept fully coaled at all times.

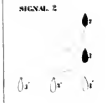
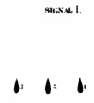
Our fleet is divided into squadrons of three vessels each, one of each class of the line. Two of these squadrons are commanded by rear-admirals and three by commodores, the commander-in-chief hoisting his flag aboard the ship of the commodore whose squadron is assigned to the centre. The flag ships receive the numbers from 1 to 5 in order of rank; this is also the number of the squadron. The other ships of each squadron are numbered, respectively, 12, 13, 22, 23, 32, 33, 42, 43, 52 and 53. The rams and tugs are divided amongst the squadrons. The flying squadron, commanded by a rear-admiral, and consisting of six corvettes, receives the numbers 6, 62, 63, 64, 65 and 66.

For squadrons there are six orders of steaming and six orders of battle. See plate II. The distance and interval, in order of steaming,

Squadron in 1<sup>st</sup> Order



Squadron in 1<sup>st</sup> Order.



SIGNAL 1



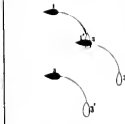
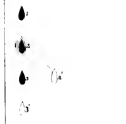
SIGNAL 1



SIGNAL 5

SIGNAL 6

Squadron in 2<sup>nd</sup> Order.



SIGNAL 2



SIGNAL 1

SIGNAL 1



SIGNAL 5

SIGNAL 1

SIGNAL 2

SIGNAL 3

SIGNAL 4

SIGNAL 6

Squadron in 3<sup>rd</sup> Order

SIGNAL 1

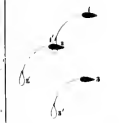
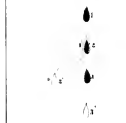
SIGNAL 2

SIGNAL 4

SIGNAL 5

SIGNAL 6

Squadron in 4<sup>th</sup> Order.



SIGNAL 3



SIGNAL 6

SIGNAL 1

SIGNAL 2

SIGNAL 3

SIGNAL 4

SIGNAL 5

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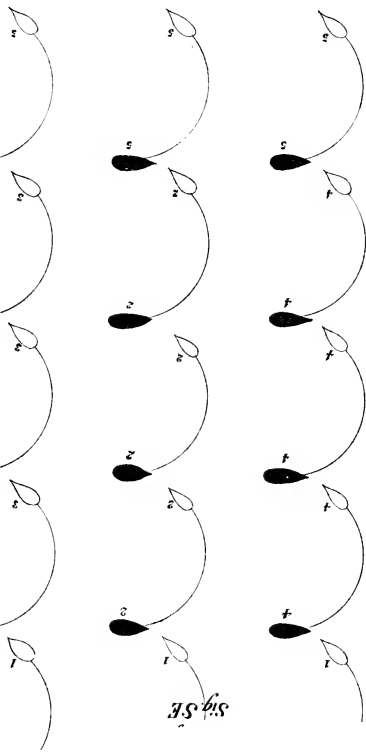
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is equal to the diameter of the average circle of turning; this is found by actual experiment, and is published in general orders. The distance and interval in battle is equal to the radius of the circle of turning. In the left-hand column you will find the six orders above mentioned. The parallel lines are equidistant, being placed one radius from each other. In the right-hand columns I have tabulated the five changes possible from any one of these given orders. Attached to each you will find its signal order, which I shall explain hereafter.

The squadrons, being thoroughly drilled, are united in fleet formation. There is one order of fleet steaming and one order of battle. The order of steaming is in three columns, fig. 5, plate III, the squadrons being formed in the following order: first squadron in 2nd order forming the centre; second squadron in 1st order forming the van; third squadron in 1st order forming the rear; fourth squadron in 2nd order forming the right; fifth squadron in 2nd order forming the left. You will see, by this arrangement, that the commander-in-chief is in the centre, where we have decided, by practice, that he should be, because he is safest there and because he can better observe and direct the movements. Also because if he were in the van in one formation, in the next he might be in the rear. The centre of each of the sides is occupied by a subordinate flag officer who, aspiring to higher honors, is at liberty to set an example of prowess.

I have also shown, in figure 1, several changes of direction. You will see that the order is not broken by any change; that the new course, with the exception of the wheel, is the only necessary signal to be made, the hauling down marking the moment of execution, and that the relative designations of Van, Rear, &c., change to correspond with the new position.

Fig. 2 represents the change from the order of steaming to the order of battle, executed at the hauling down of the battle signal on board No. 1, each squadron manœuvring as in squadron tactics. The order of battle, shown in Fig. 6, is very strong. Its principal qualities are an all-round fire, shown in Fig. 8, a wedge for the attack, and echelon for defense, close supporting distances, solidity and great mobility, the centre squadron forming a strong nucleus, and having its broadsides ready, in connection with the inner broadsides of the regular line, for any vessel that chooses to try the centre. I have essayed to show, by several diagrams, marked Fig. 3, the innumerable directions and fronts which may be taken up. The wheel is introduced to change front to intermediate points.



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The squadrons, being thoroughly drilled, are united in fleet formation. There is one order of fleet steaming and one order of battle. The order of steaming is in three columns, fig. 5, plate III, the squadrons being formed in the following order: first squadron in 2nd order forming the centre; second squadron in 1st order forming the van; third squadron in 1st order forming the rear; fourth squadron in 2nd order forming the right; fifth squadron in 2nd order forming the left. You will see, by this arrangement, that the commander-in-chief is in the centre, where we have decided, by practice, that he should be, because he is safest there and because he can better observe and direct the movements. Also because if he were in the van in one formation, in the next he might be in the rear. The centre of each of the sides is occupied by a subordinate flag officer who, aspiring to higher honors, is at liberty to set an example of prowess.

I have also shown, in figure 1, several changes of direction. You will see that the order is not broken by any change; that the new course, with the exception of the wheel, is the only necessary signal to be made, the hauling down marking the moment of execution, and that the relative designations of Van, Rear, &c., change to correspond with the new position.

Fig. 2 represents the change from the order of steaming to the order of battle, executed at the hauling down of the battle signal on board No. 1, each squadron manœuvring as in squadron tactics. The order of battle, shown in Fig. 6, is very strong. Its principal qualities are an all-round fire, shown in Fig. 8, a wedge for the attack, and echelon for defense, close supporting distances, solidity and great mobility, the centre squadron forming a strong nucleus, and having its broadsides ready, in connection with the inner broadsides of the regular line, for any vessel that chooses to try the centre. I have essayed to show, by several diagrams, marked Fig. 3, the innumerable directions and fronts which may be taken up. The wheel is introduced to change front to intermediate points.

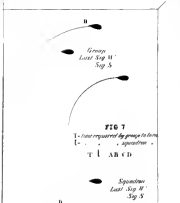
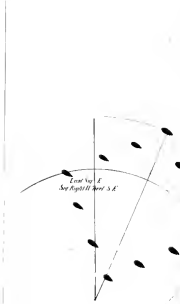
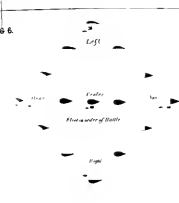
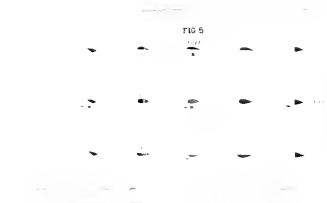
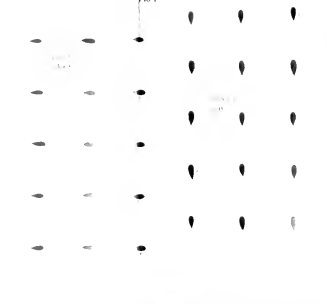
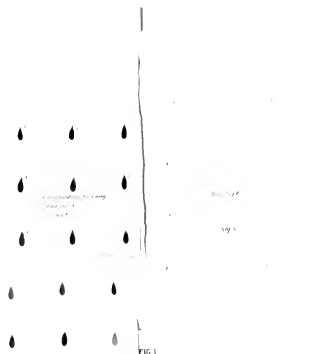


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FIG 100





I have shown you how we manœuvre, now let me tell you how we cause these manœuvres to be executed. We found that flags were unreliable in battle, and sought a substitute. The great objection to flags is that, in calms, they do not blow out, that they are not visible to windward or to leeward, and that they are constantly fouling. We have therefore adopted solid figures, such as balls, barrels, cones, and double cones, and a combination of the barrel and cone. These are made of colored bunting, spread on frames, which, when not in use are closed up like a Japanese lantern. Black has also been adopted as a signalling color, the shade of blue being slightly lightened. There are three sets of signals: Compass, Order and General.

In fig. 5, plate I, I have tried to depict them. First, for the cardinal points we use four balls, red, white, blue and black—for the quarter points a small black square, which, when hoisted uppermost, means  $\frac{1}{4}$  towards the lower point, in the middle  $\frac{1}{2}$  and under the second ball  $\frac{3}{4}$ . As most of the manœuvring signals are made by these, we hoist them at the main, if that be carried away, at the fore.

The order signals are hoisted at the main: they consist of the battle signal, a barrel with a cone at each end. This signifies that the fleet order of battle is to be formed, and everything gotten ready for action; and the squadron order signals, eight barrels differently colored hoisted at the mizzen, are intended as order signals to the squadron: at the fore under the battle signal, they have the signal significations of wheel, right about, left about, full speed, quick speed, common speed, cease firing and separate.

For general signals, to be hoisted at any mast, a series of cones, inverted cones, and double cones are substituted for the flags. The whistles are also used to mark the moment of execution of a preconcerted plan. The smoke stacks of all vessels are painted to show the squadron to which they belong. The admiral is often to assemble his officers for discussion and mutual improvement. A set of miniature block ships is provided, with a table-top arranged in squares, each officer manœuvring his own squadron or ships through each explanation, to make sure that every movement is understood. Any officer showing a dulness in comprehending movements or a lack of knowledge on any subject connected with tactics, should be relieved immediately. On the commanding officers depends the whole success of every movement, in these days where everything is reduced to a science, and a marplot is not to be tolerated. He may, by his ignorance or stubbornness, endanger the well being of the whole fleet. A commander must have

iron nerves, perfect judgment, a quick perception and complete knowledge of his profession. All must look to the commander-in-chief and obey him implicitly. The same rule must govern all inferiors. There must be no question nor doubt. In moments of emergency, the commander-in-chief will have been supposed to have given the necessary directions as to how it is to be met, and if he has not, captains may use their judgment. The commanders of the rams and tugs are to operate intelligently on their own hook, ramming and torpedoing whenever they get a chance and tugging whenever there is a necessity. They are to be young men of known coolness, intelligence, and good sense; every hope of advancement being open to them, if they are successful.

I have now brought you up to the period of our late battle, as far as improvements and inventions are concerned. I believe that I forgot to mention the telemeter, which has been so much improved, since your day, that it can be used in action, and the bearing vane, an instrument by which the bearing of any object may be measured instantaneously on the naval square; it is placed in the centre dome, all ranges being taken from and on the mainmast. Distances and intervals are measured from the same point.

On the 15th of May, the Vice-Admiral at New York received the following telegram.

WASHINGTON, May 15, 1906.

VICE-ADMIRAL WM. JONES, N. Y.

Fleet rendezvous at Hampton Roads, for exercise. Orders meet you there.

JOHN SMITH,  
Admiral of the Navy.

It had been previously concerted that, "for exercise" meant "for action." No suspicion was aroused by the telegram, which leaked into the papers as usual.

This telegram was promulgated the same day, to the commanders of squadrons and by them to the commanders of vessels. Accompanying it, in another enclosure, was the following confidential order:

All boats, light spars, extra rigging, clothing and small stores not absolutely necessary will be sent ashore. Every ship will take aboard her war allowance of coal and ammunition. Officers and men will send ashore all articles of clothing, mess furniture, &c., not absolutely necessary. All bulkheads will be taken down, and canvas ones rigged instead. Skylights, accommodation ladders and other such fixtures will also be gotten out of the ships. The bolsas will be gotten in work-

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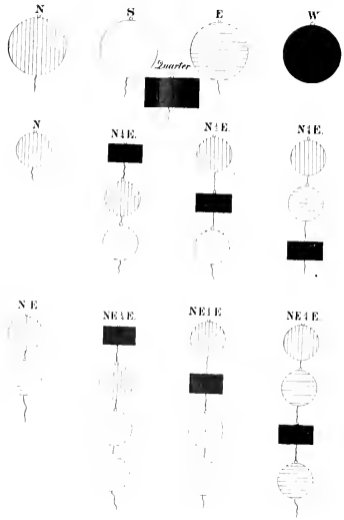
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Course Signals.



Note. For colors - Horizontal lines denote "Blue"  
Perpendicular "Red."

FIG. 5.

Slight steel signal mast, to be shipped on head of top - mast with four armed truck and staff & flag

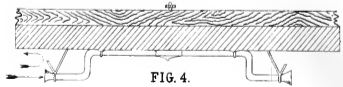
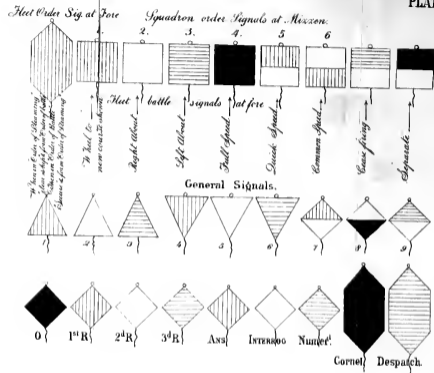
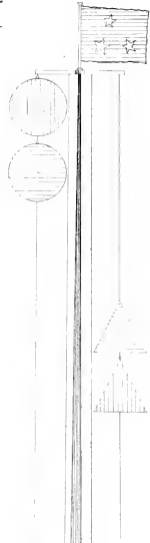


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ing order. Each ship will be allowed one whale boat. The fleet will meet at H. R. on the 1st of June.

WM. JONES,  
V. Admiral.

On the 1st of June the last vessel arrived at Hampton Hoards and a few days after we heard that war had been declared with Albinage to settle a long contested dispute. We found, at the rendezvous, six squadrons, besides a fleet of rams, tugs and store vessels—the latter furnished by the mail companies.

On the 1st of June the following general order was published.

G. O. No. 1.

FLAG-SHIP COLUMBIA,  
June 1st, 1906.

The interval and distance will be 300 yds. for order of battle. The speeds will be: Common 8 points, Quick 12, Full 15. The fleet will proceed to sea to-morrow 8 A. M. The squadrons will pass out in 2nd order in succession. Fleet order of steaming will be formed as soon as the rear is clear of the Capes. The order of daily exercise will be: at 8 A. M, signal exercise, at 10 A. M., pass to order of battle and manœuvre until 11.30. During the manœuvres the crew will be exercised at the guns, &c. At 1.30, commanders of vessels will repair aboard their squadron flag-ships for instruction, remaining for one hour. The fleet will be stopped for their going and coming. At 3, flag-officers will repair aboard the Commander-in-chief, in their tugs, for discussion and instruction. At the same hour the commanders of vessels will assemble their officers for the same purpose. The answer to a signal will be its repetition, in order to insure its being seen by all and thoroughly understood; great care must be taken to haul down together. This refers to Compass and Battle signals. General signals will be answered as provided for in the signal book. As soon as the general battle signal is hoisted, masts and yards will be telescoped, and every preparation made for battle; when it is hauled down the order of battle will be formed. Broadships will be preferred as the objective of firing. Concentration will be employed whenever practicable. The water line is the best place to aim at; especially for those ships which may be engaged on the side towards our own vessels. Rams and tugs will keep under cover, except when the former get a good opportunity to act; the latter will be on the lookout for disabled vessels, rendering them every assistance in keeping their position, or in taking off their

crews if in a sinking condition; they will only use their torpedoes when attacked. In passing an enemy, should the flag-officer in command of the exposed apex deem it expedient, he may form the 2nd order temporarily. The whistle will be used to signal a turn towards the enemy, then a charge at full speed. The first blast will be precautionary; the second one, for the execution of the plan. The flying squadron will be deployed when in steaming order, so as to preserve all points of the horizon, always placing themselves so as to communicate either directly or in succession with the fleet. As soon as the enemy is sighted they will assemble and remain under cover of the fleet. In action they will capture disabled vessels, assist our own disabled ones, and do such light fighting as may fall to them. The fleet of supply vessels shall follow the fleet, supplying it with coal and provisions whenever ordered by the commander-in-chief, at which times they will receive permanent invalids from the ships, supplying their places with men from their own crews, which have been increased for that purpose. In action they will keep well out of range, and will use every endeavor to escape if chased.

WM. JONES,  
V. Admiral.

You will see that this general order provided for nearly every emergency.

June 2d, according to order, we proceeded to sea, and cruised up and down the coast; each day rubbing off the rust that had accumulated since our last yearly drill. Our chief's plan soon became evident. He judged that our adversaries would come to us, and that their objective point would probably be their old favorite, the Chesapeake. This gave us several advantages; instead of pushing across the ocean we can employ our time in drilling, and we can keep our ships in the best trim by always being filled up with coal and ammunition. Should he try any other part of the coast we are sure that our coast defenses will keep him at bay until we reach him.

On the 18th of June, at sunrise, in about the latitude of Hatteras and about 50 miles from the Cape, the enemy was signalled heading N. W.—in all 18 large vessels. Our fleet was headed S. E., and the order of battle hoisted aboard the flagship. At 8 A. M. the enemy was 8 miles distant, and was forming in two divisions of groups abreast. Our battle signal came down and we immediately formed in order of battle heading S. E. At about 8.40 our leading vessels opened fire. The



shock was terrific. You know my ship led the van squadron. Our leading vessels opening with a concentrated fire on their leaders gradually changing to a broadside fire right abeam. Our firing was very rapid; it seemed as if our ships were always firing. The aim and accuracy was almost perfect. As the fleets advanced, our front overlapped them; they tried to break through us but the ordeal was too severe; only one vessel got as far as our interior, but the rams and reserve finished her; the rest were forced to swerve from their course and passed down our line, being rammed, jammed and torpedoed almost at will. As our left apex vessel reached what would have been nearly the position of their head, the first whistle was heard, soon followed by the others; we all turned toward the enemy, heading about N. E. Some of the remaining ships, of his shattered first line, tried to turn towards us, but our superior speed brought us round first and these poor fellows went down gallantly attempting to head to the foe; others seeing their hopeless condition, lying broadside to our ram-boys and rams, were forced to strike. It was while performing this turn, that the Brooklyn, the leading vessel of my squadron, was sent to the bottom by a Harvey. Her place was immediately supplied by the Hartford, from the centre. On getting clear of the first line, we were surprised to find the second heading for us, so that in the same day, we were to have a chance to try our system against both column and line of groups. All fire was reserved until we met; we were now going at the tremendous speed of 15 knots; we had therefore only time to deliver two broadsides in passing through, but were more fortunate with our rams. As before, the enemy saw the impossibility of breaking through us, divided like the earth before the plow, thus exposing to us the best position for ramming. After passing through, signal was made: Right about, and course S. W. when we changed the line again, this time getting it to greater advantage, as the remaining ships were attempting to re-form and meet us; but we had been too quick for them. This ended the battle, with the exception of a few individual sharp fights, where speed, superior metal and accuracy of fire finally gained the day. The enemy's loss was frightful; out of their 18 large ships 10 had been sunk by different means, and 7 captured; one had escaped when all was lost; this vessel and a few of the small fry are all that remain to them of that gallant squadron, once the ruler of the seas.

And now let us examine the results of this action, lasting in all just 35 minutes. We are now at the head of maritime nations in fact, as we have long been in reality; you know when they removed the

restrictions on ship building and ship buying, which occurred with the general reaction in sentiment after the battle of Cady, our merchant marine also took a great start, and to-day our ship-yards supply the world; the increase in wealth, to our people at large, would have paid for a hundred navies such as ours is to-day. Now, that we are able to guarantee perfect safety to our shipping, by our maritime supremacy, our ships will be in still greater demand. It is the old story about "Westward the star," &c. The truth of the matter is, that our large navy to-day does not cost our people, in proportion to their wealth, one hundredth what it did forty years ago; because with our commerce every other branch of industry has increased; we are now the great emporium instead of the great market; we are the bank instead of the borrower.

And thus, my old friend, I have drawn for you as vivid a picture of our success, its causes, and its results, as my poor pen can trace. History will polish off the rough edges of my narrative and, perhaps, gild them.

I send you some extracts, taken from various official reports, which will show you how some of our ideas and inventions have worked in practice.

FLAG-SHIP COLUMBIA,  
June 19th, 1906.

\* \* \* \* \*

The system of tactics worked beautifully, owing to the great mobility of our formation; we were enabled, at all times, to present a solid wedge to the enemy, which, moving at great speed, could not but break up his formations. The advantage of turning by ship, instead of by group, was shown by comparison in actual fight. The fears that some expressed, that our vessels were too close, proved themselves to be uncalled for. Our compactness was our strength. The shortness of duration of the action, 35 minutes, apparently incredible, was caused by the great speed at which we moved, and the immediate destruction dealt by our guns, rams and torpedoes. But few signals were made; these were, however, quickly answered and thoroughly understood. The whistle signal proved a success, as its shrill blast was heard above the bass notes of battle, with the greatest facility.

\* \* \* \* \*

WM. JONES,  
V. ADMIRAL.

JNO. SMITH,  
ADMIRAL OF THE NAVY.

FLAG-SHIP INDEPENDENCE,  
June 19th, 1906.

\* \* \* \* \*

We found our squadron movements of the greatest service; they are complete. We passed from one to another, as the front changed, without confusion, almost without knowing it. It was not found necessary, to form the 2nd order, as we passed. I enclose the report of Captain Sad of the late Brooklyn.

THO'S NOSAM,  
REAR ADMIRAL,  
COMMANDING 2nd SQUADRON.

WM. JONES,  
V. ADMIRAL.

U. S. SHIP HULL, 2nd CLASS,  
June 19th, 1906.

\* \* \* \* \*

We now noticed one of the enemy heading for us, evidently with the intention of ramming. He was approaching at an angle of about 30° with our keel. I let him come quite close, then sheered towards him and, as we ranged along side, gave him my forward guns and bow torpedo concentrated abreast his foremast, at about the water line. The effect was terrific. A hole about 25 feet square, into which the water rushed like a young Niagara, was the immediate effect. He sank, before he had passed us, and I am afraid, carried most of his people with him, as his boats must have been shattered, and could not have been lowered, in the short space of time before he went down.

JAS. BOWLINE,  
CAPT. COMD'G U. S. S. HULL,  
CHAS. BACKSTAY,  
COMMODORE COMD'G 5th SQUADRON.

U. S. S. FARRAGUT, 2nd C.,  
June 19th, 1906.

\* \* \* \* \*

It also becomes my painful duty to report the death of my commanding officer Capt. Toggle. The forward dome was struck by a heavy shell, which exploded in it, smashed it to pieces and killed all those stationed there. I immediately assumed command and with the second firing officer and second navigator, fought the ship through the rest of the action. It seems providential that we were not all to-

gether and that means had been provided to work the ship from any of the domes.

WM. CROSTREE,  
LIEUT. COMMANDER COMB'G  
U. S. S. FARRAGUT.

HENRY BLACKSTRAP,  
COMMODORE COM'G 4th SQUADRON.

U. S. MAIL STEAMER CITY OF NEW YORK,  
June 19th, 1906.

\*   \*   \*   \*   \*   \*   \*   \*

As soon as it was ascertained that the vessel was sinking, I called all hands on deck. The pumps were turned on the bolsas and they were ready by the time the men were up, which could not have been more than 30 seconds. We launched immediately and got clear of the ship just as she went down. The tug Relief came to our assistance and helped us get clear of the line. We then made sail and made the best of our way from the scene of action. The enemy, either from feelings of humanity, or, as we were hors-du-combat and could be easily picked up if they gained the victory, let us alone.

CHAS. SAD,  
CAPT. COMD'G LATE BROOKLYN.

THOS. NOSAM,  
REAR ADMIRAL COMD'G 2nd SQUADRON.

U. S. S. IRONSIDES, 3d CLASS.  
June 19th, 1906.

\*   \*   \*   \*   \*   \*   \*   \*

Finding that the engines would not turn I signalled for the tug Lively, which came on our starboard side; the Helper, seeing our condition, also came to us and placed herself on our port side. I sheered into the centre according to signal, the Porter taking our place in splendid shape. With the assistance of the two tugs I was enabled to keep my new place.

JAS. LUCKY,  
CAPT. COMD'G U. S. S. IRONSIDES.

JOE TOMPION,  
COMMODORE COMD'G 1st SQUADRON.

FLAG-SHIP COLUMBIA,  
June 19th, 1906.

\*   \*   \*   \*   \*   \*   \*   \*

The signals worked as had been anticipated. They were seen and

answered quickly. This has proved a triumph for our signals, as well as for our ships. The Farragut was the only vessel that lost a mast, and she, not being a flag-ship, was not in thus-wise injured. All arrangements had been made, however, if a flag-ship had lost a mast, to use the horn of the truck, toward the lost mast, of the next mast.

WM. JONES,  
V. ADMIRAL.

CHAS. BLUELIGHT,  
FLAG LIEUTENANT  
AND CHIEF SIGNAL OFFICER.

U. S. RAM LIGHTNING,  
June 19th, 1906.

\* \* \* \* \*

Just as she passed the Independence, under whose quarter I had been hovering, I made for her. She saw me, and, as I got within range, opened on me with all her guns. Thanks to our armor and its inclination, the shot glanced off of us in all directions. She then tried to sheer, but our great speed carried our bow into her in no time. I did not try to strike her in full broadside, as I was afraid of being carried down with her; but as we approached her I headed for her stern, and struck her in the wake of her mizzen rigging; just as we struck I discharged my bow submarine gun, whose projectile must have blown a large hole in her other quarter.

THOS. NOSAM,  
REAR-ADMIRAL COMD'G 2nd SQUADRON.

JOHN HOPE QUICKPROMOTION,  
LIEUT. COMD'G LIGHTNING.

U. S. RAM JAMMER,  
June 19th, 1906.

\* \* \* \* \*

Finding that she would pass before I could use my ram, I sheered and gave her my quarter submarine gun. The effect was not evident at first, as the wound was under water; and I was afraid that the shot had glanced under her bottom. I could not account for this as I had given elevation. She seemed to settle as I saw her last, however. I have since been told, by one of the prisoners, that one of their vessels had gone down in a vastly marvellous way, the projectile apparently coming from the bottom of the sea. They judged it to be some kind of fish torpedo.

CHAS. BACKSTAY,  
COMMODORE COMD'G 5th SQUADRON.

JAS. BETTERLUCK,  
LIEUT. COMD'G RAM JAMMER.

U. S. TUG ALERT,  
June 19th, 1906.

\* \* \* \* \*

The enemy's vessel approached, evidently with the intention of running me down. We were almost bow to bow: I sheered slightly to starboard as he was almost on me, and as I passed gave him my quarter spar torpedo on the bluff of his bow. I could have taken my little vessel into his hold without any difficulty through the hole that we had made.

JIM CRICKET,  
THOS. NOSAM, MASTER COMD'G ALERT.  
REAR-ADMIRAL COMD'G 2nd SQUADRON.

These extracts close my account. This battle has been to me a double victory, a victory in fact and a victory of theory. You will remember that, at one of our monthly meetings of the Naval Institute, when you and I were young lieutenants, I proposed some of the ideas which you see to-day elaborated by skilful inventors, and perfected by experiment. The signals and tactics I was fortunate enough to get introduced myself, some ten years ago, when detailed as chief of that department. Some said, at the time, that I was riding my hobby too fast, but you know that in life, if a man ever does get a chance, he generally prefers his own old war horse to a new mount, and takes off the curb, if necessary, to keep ahead; and if Columbus had not set his egg on end some one else might have done it as easily, but perhaps after a long interval.

For this victory the Navy has, in the first place, to thank our people, then our Naval Academy, our Naval experimental battery and torpedo school, and last, but not least, our Naval Institute, which has been the means of collecting and encouraging the ideas of officers. This institution had a hard time in its youth, but it now stands amongst the first societies of technical learning in the world. I believe that you are still an honorary member; are you not?

For this victory, in return, our country has to thank our Navy, its officers and men. We have wiped out the old stain of Cadz, and our flag can now float in any part of the world the proudest of the proud, because it represents the first maritime and the first commercial nation of the globe, and we have earned a lasting peace by displaying our full preparation for war.

Excuse me, dear old fellow, if I seem to be carried away by our suc-

cess, but I am sure that you will overlook anything from an old friend after a return from a 35 minutes residence in the infernal regions.

Write soon and let me know how my farm is getting on. I hope to be home before the harvest is ripe and hang my laurels on my garden gate.

Yours sincerely,  
THOS. NOSAM.

R. SREGOR, ESQ.  
OAKLANDS.

LIEUT. RODGERS inquired whether the line of battle formation proposed by the gentleman was adapted to any number of vessels.

LIEUT. MASON replied that it was adapted to any number greater than three.

LIEUT. VERY requested the gentleman to explain what difference existed in the code of signals suggested, between the signals "South West" and "South by West."

LIEUT. MASON replied that there was no difference. He stated that he was not prepared to argue any question in relation to his suggested code of signals. He was satisfied that it was deficient in many respects. The idea, however, of using solid flags, barrels and cones in place of the flying flags he thought worthy of some consideration, and it was simply to illustrate the forms of these signals that the chart had been drawn. As to the other charts, he was ready to discuss any question that came under them.

COMMANDER FARQUHAR objected to the line of battle formation advocated, on the ground that two-thirds of the vessels of the fleet could not use their batteries on going into action, without firing into one another.

COMMANDER SAMPSON stated that, in his opinion, the same objections urged against the old line of battle, could be well taken in regard to the proposed one. A few ships would be compelled to do all the fighting. The proper formation, he believed to be the one in which all the ships could be brought into action at once. Under Lieut. Mason's plan only a few ships could act, unless the enemy was very accommodating, a very improbable thing. After exchanging broadsides, he said, everything depended on the courage and judgment of the commanding officer, consequently the most favorable circumstances should be taken advantage of in the outset.

LIEUT. MASON replied that he could not see how the enemy could

bring any more force to bear upon him than his front commanded. The object of his formation, he said, was to break the line of battle proposed by Commander Noell, or even to pass through it. Supposing, he said, the two lines of battle had passed through one another without breaking, under his system all that would be necessary would be for each individual ship to go about, and the same line of battle was presented to the enemy, while under Commander Noell's it would be necessary to re-form, or his fleet would be placed at a great disadvantage.

LIEUT. VERY stated that he granted that there was great strength in the line of battle proposed by the member; suppose however that his line should be broken, would he, or rather could he re-form? Under Commander Noell's system, his line being broken, the vessels then acted in detached groups.

LIEUT. MASON replied that he had provided for such an emergency. He had not abandoned entirely the system of detached groups. If possible he would re-form, if not the group system would be used. He thought, however, it would be a difficult thing to break his line, as after the two lines had become engaged he could bring a terrific concentrated fire to bear in almost every direction.

ADMIRAL RODGERS stated that while he did not agree with Lieut. Mason in a great many of his arguments, especially in regard to his line of battle, he deemed the paper a valuable one, and a great many ideas advanced in it worthy of consideration. He moved the thanks of the Institute be tendered to Lieut. Mason.



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June 16, 1876.

Chief Engineer CHAS. H. BAKER in the Chair.

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THE COMPARISON OF STEAMSHIPS.

BY PASSED ASSISTANT ENGINEER THOMAS W. RAE.

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The paper here submitted to the Institute is substantially the same as a lecture delivered, a fortnight since, to the present graduating class of Cadet Midshipmen. Its object was to prepare them to judge intelligently of questions that at times agitate the Service to its depths, and again become dormant. Friendly critics considered the method of discussion to possess a certain interest, and that its more general publication might prove useful. In deference to these opinions it is offered almost as it was first written—the only changes being some new instances adduced and an effort to deprive it in some measure of its didactic character.

A great many statements pass for truth in the world because people have not the facts and figures at hand to disprove them. One may be perfectly satisfied of the fallacy of an assertion, but to bring to his views another who may be indifferent or opposed, he must argue step by step from sure grounds. The object of this discourse is to supply you with points relative to a subject which you will hear much discussed in your future career, and upon which you may be called to give a decision. I refer to ships-of-war, and their motive power.

The constructive Bureaux of the Navy undergo periodical attacks, whose recurrence is as well established as that of the seasons; and

while they last one is apt to be overwhelmed with chagrin at learning how far inferior to the navies of the world his own is, unless he chance to be in possession of definite data with which to test the mortifying asseverations thrust upon him. These crusades are sometimes initiated by private builders of ships and engines anxious for Government contracts, and at others by people within the service for a variety of motives. Young officers are very prone to the affectation of decrying the *materiel* of their own navy and lauding that of others, without any very accurate knowledge of either. It is supposed to evince a mastery of naval science that is vouchsafed to few. An eminent officer of the navy whose discrimination and broad views have become a proverb in the Service, declares it to be a notable fact that while foreign officers hold up the best phase of performance of their ships in discussing them—ours as persistently exhibit the worst aspect of our own as the criterion. What may be the cause of this difference of mental habit it is hard to say, but the justice of the stricture will doubtless be recognized by many. In comparing the navy of one country with that of another, it is necessary to understand the requirements of both, and this aspect of the case is too often overlooked. To illustrate by an extreme case: a nation without a seaboard would stultify itself in possessing any ships at all, while on the other hand an insular power with limited territory and large population must have the best or—perish. The swarming inhabitants need colonies to give them room; as well as importation of food from less crowded lands, and the commerce thus engendered as well as national integrity can only be maintained by a powerful navy. The unvarnished fact is that to a country which can easily feed its inhabitants a navy is a luxury, its only function being to protect the trade that importation of luxuries develops; since the foreign commerce that a fruitful and not over populous land maintains, clearly cannot be one of necessity. When therefore it is regretted that we have no large cruising iron-clads as other maritime powers have, it must first be considered whether armored batteries for harbor defense do not serve our need better. It is far from the purpose of these remarks to argue that our foreign interests are unimportant, or even that our cruising navy is commensurate with them. They are employed only to illustrate that a suitable naval armament for one nation might be preposterous for another of equal wealth and commercial strength, and also to point out what prescribes it when viewed as a strictly politico-economic question. Comparisons between navies taken *en masse* are irrational. It is only permissible to consider

similar types of vessels in the different services and thus learn whether our own are better or worse.

The charges brought against the *materiel* of our Navy are numerous, the principal ones being as follows.

- I. Excessive cost.
- II. Expense of maintenance.
- III. Lack of durability.
- IV. Excessive bulk of Machinery.
- V. Deficient speed.

They pertain more particularly to the machinery, but are in part applicable to hulls. In every comparison there must be a standard, actual or hypothetical, and in discussing the foregoing indictments that most commonly employed in such cases will be designated. First comes the charge of excessive cost—this is preferred against navy-yard work as compared with that of private ship-yards and generally by interested parties. The accusation if true—which there is ample reason to doubt, where regard is had to the quality of the work—may be accounted for of late years, by the Government practice, of paying ten hours wages for eight hours work. While this custom exists, private yards will have a certain advantage, but whether they do actually profit by it or not, cannot be positively asserted without having at hand statistics and figures which it is nearly impossible to obtain. As a matter of opinion, I have no hesitation in stating that work similar, in thoroughness and nicety of finish, to that done in navy-yards cannot be turned out of private establishments at so little cost. It must not be forgotten that while the Government gives twenty-five per cent. higher wages, it is absolved from the necessity of paying ground rent, taxes on expensive plant, tools, and raw material for which civil builders are liable, and these items in gross probably amount to enough to offset the higher wages.

Next comes cost of maintenance, and, before discussing this point, it is necessary to define strictly the term. It includes the cost of producing a certain amount of mechanical work as well as the expenditure of keeping the apparatus in repair and must therefore be considered in detail. The practice is to estimate the cost of work done in pounds of coal per H. P. developed. The work done in this case is always that performed in the cylinders, as this eliminates the influence of better or worse lines in the hulls of competing ships.

If the cost of the H. P. is estimated in pounds of combustible instead of coal, it eliminates the influence of better or worse fuel. The

amount of combustible is the difference in weight of fuel put into the furnace and the dry cinder and ash withdrawn from it. I have laid stress on the point of the refuse being dry, as it is the custom of stokers to drench it with water as it comes from the furnace, to escape the discomfort of heat and dust; and the weight of water absorbed by it would seriously affect the calculation. Three to three and one-half lbs. per H. P. may be taken as the average performance of Navy vessels and better results are nowhere recorded. In the matter of repairs, men-of-war are contrasted with mail steamers and unfavorable inferences drawn in regard to the former. Here again a total lack of statistics baffles investigation, but much may be learned by a glance at the practice of both. Accidents to the engine proper are now a days of much more frequent occurrence in the mail service than with vessels of war—when no emergencies require excessive driving—and even during the war when the most unforeseen and exacting demands were made upon our machinery, the exhibit of casualties was no greater than in the mail service. With regard to the English Navy—the annual report of the Royal School of Naval Architecture, for 1871, reveals a status to which our Service affords no parallel.

After commenting upon a long list of cracked cylinders which includes those of the “Tenedos,” “Black Prince,” “Lord Clyde,” “Hercules” and others—it uses the following expressions. “No one will deny the need of further improvement—no one at any rate, acquainted with the lengthy catalogue of cylinders broken year by year in Her Majesty’s Navy—we cannot go on much longer without making some decided alteration in construction, for even cracking cylinders become monotonous after a time.” Boilers seem to fail with us sooner and oftener for the reason, that disuse is more destructive than use, even with the most stringent regard to preservation. Mail steamers renew boilers about once in three years. We retain them four or five times as long, eking out their existence by repairs more or less extensive. Immediate economy is attained in this manner; but whether enhanced possibility of failure in an emergency does not neutralize the advantage, is an open question.

The Naval drill at Key West in 1874, revealed prominently the danger of this practice. Nearly all the ships possessed boilers whose lease of life had been supplemented by every device that ingenuity could suggest; and the routine of a three years cruise, while as favorable to their preservation as possible, had not made (and rarely makes) such pressing demand as would reveal unsuspected debility. When the

emergency arose and the strain was applied, they failed as must always be the case in similar circumstances. Mail steamers are put in thorough repair every trip. No sooner are they alongside the dock, than they are boarded by gangs of mechanics, who labor night and day as long as anything remains to be done. Our vessels have been known to stay at sea from six to nine months, perpetually under steam, and effectually maintaining a close blockade. This illustration shows clearly how little similarity there is in the exigencies of a civil and military marine.

Much has been claimed in the way of economic maintenance for the compound engines introduced of late years into the merchant service, but the absence of reliable data, makes it impossible to say whether or not they have done better than the same class of machinery designed by the Bureau of Engineering. That this type possesses certain features favorable to economy is evident; it makes practicable a greater degree of expansion than the simple engine permits, and separates more thoroughly the boilers and condensers, greatly lessening the interaction of the fluids in each—with the difference of whose temperatures, efficiency varies: that is, the hotter the cylinder and the colder the condenser, the greater the work done between them. But granting all this, their applicability to vessels of war is not finally settled. The lessened facility of manipulation largely affects other merits. The foregoing gives opportunity for certain corollary observations which must not be omitted. They are concerning the weight which should be ascribed to economy of maintenance as a quality of marine machinery.

Without advancing any positive views on the point, a few facts are submitted to illustrate how entirely different are the considerations which rule in various cases. To a merchant steamer, which makes prescribed voyages whose duration hardly varies a day, from year's end to year's end, economy is of prime importance. Every cubic foot of room saved from the space allotted to fuel, may be filled with freight which pays its way over and over again, instead of material whose carriage is an expense, in all senses, to the ship. And yet in the face of this, it may occasionally pay better to carry fuel instead of cargo, as in the case of steamers plying between New York and Rio Janeiro, which take out coal for the round trip of two months. Brazil having no coal must import it, and the cost is such as to make it cheaper for steamers to transport fuel for the home trip all the way from the United States to Brazil, rather than occupy its room with paying

freight. In the blockade-running days of the war, it was estimated that three successful trips were all it was advisable a vessel should make for the greatest profit, and they were built and run with this principle in view. Anything like judicious use or conservative precaution in regard to them was unknown. Our torpedo-boats employ the most wasteful propeller known to the profession, but its wonderful effectiveness in manœuvring, which is the chief desideratum in the vessels with which it is used, overshadows many and grave defects. Enough has been said to make it clear that in each class of vessel, some one of a number of desirable qualities has the greater weight and that it is rarely the same in different classes: you do not look for speed in an iron-clad floating battery, whose function is little more than harbor defense, nor for impregnability and heavy guns in a dispatch-boat; yet the criticasters, who periodically dispose of our Navy in the daily press, would have it appear that one vessel may include all these features. It may be fairly questioned then, if economy is the great desideratum of a man-of-war. She need never be compelled to make long runs at full speed, but may be often called upon to develop her maximum power at short notice and a moment's tardiness in this, may lose the chance to strike a telling blow upon an enemy, or leave her helpless in his power.

Sails spare a man-of-war the necessity of using fuel for extended periods and even the exigencies of a state of war do not affect this to any degree, for every campaign—if such a term may be applied to maritime warfare—is fought out on a definite plan from fixed strategic points and it does not require extraordinary fore-handedness to have one's ships in the vicinity of these, ready to assume offensive operations. It will be small consolation at such a time to know that your machinery develops a H. P. for half a pound less coal than your adversary, if it do it so tardily that he has time to escape your attack, or you have not time to evade his. A ship may have shown unparalleled economy of maintenance for years, but if it cannot strike surely and heavily when the chance offers, or work out of danger with celerity when over-matched, it utterly fails of its purpose. There are times when a horse is literally worth a kingdom. Lack of durability is next charged, and at first glance not without cause. So much of this accusation as pertains to boilers, has been discussed under the previous heading, and the facts of the case elicited; let us now consider it with regard to hulls. During the war some two hundred and eight vessels were built by the Navy Department, of all possible classes—iron-clads for sea and inland

waters, general cruisers, light draught gunboats, "double-enders" for river use, etc., etc. Of these, about fifty remain in service to-day. This seems a small per centum, but, besides the casualties of war, which were large, it must be remembered that with the advent of peace the occupation for craft designed for inland waters ceased, and they were gotten rid of as quickly as possible. Storing *material* for such a contingency as a civil war would have seemed insanity twenty years ago, and the quantity of seasoned ship timber in the docks, when it burst upon the country, was not a moiety of what was needed to create a navy. It takes from two to eight years to properly season live oak, and as such delay was not to be thought of, constructors took what they could get. I quote from the Honorable Secretary's report for 1862, which describes the situation very graphically:

"The war found us literally destitute of material in our navy-yards, as well as with but few ships to sustain the national integrity. From mistaken economy, or from design, the government was, in its need, deficient in ships and destitute of material for their construction. No alternative was left, when resistance was made, but for the Department to build its vessels as speedily as possible and of such timber as could in the great haste and emergency be procured. As a consequence, vessels that should have lasted for years will soon perish, and must in the meantime involve heavy expense for necessary repairs in order to keep them afloat."

With the proper material no better hulls are built than our own; and the concluding words of the Honorable Secretary might have been adduced to explain the facts that gave rise to the charge against naval vessels of excessive cost of maintenance, discussed under the previous heading.

Excessive bulk of machinery is a favorite reproach, and contrasts are drawn between naval and merchant steamers, to the disadvantage of the former. You will hear it said in such comparisons, "Such an engine develops so many H. P. and occupies only so many feet of the length of the ship—in a Navy ship it would have taken half as many more." This sounds like a grave accusation until it is considered that, for safety from shot, naval machinery is kept entirely below the water line, while in merchant vessels there is no limit vertically to the room which the machinery may occupy. The real criterion is the cubic feet of space occupied per H. P. developed, and, measured in this manner, our vessels are second to none in economy of space. In ships of pre-

cisely similar lines the fraction of length devoted to machinery is a fair measure of comparison, when the necessary passages about the engines, the boilers and coal bunkers are considered; and this suggests a caution which must be heeded in applying this gauge. Let it be clearly understood what is comprised in the question. An example will illustrate the importance of this. Suppose you were comparing a certain machine, using anthracite, with another driven by bituminous coal. Both fuels weigh about alike, per unit of volume and their evaporative efficiencies are very nearly equal. It would then seem that they might be dismissed from the question. But bituminous burns about two and one half times as fast as anthracite coal, and the comparison hinges upon this fact. For example, a boiler burning bituminous coal can develop the same power in the same time as an anthracite burning boiler with a grate of two and one half times larger area, and consequently may reduce its boilers in the proportion of two to five as compared with the latter. This point would give the engine driven by bituminous coal vastly the advantage in economy of space if the investigation had stopped here, but it has to be pursued farther.

Although space occupied by machinery proper has been economized by the adoption of quick burning soft-coal, it is clear that the room saved must be devoted to the bunker, if the ship is to carry fuel for the same number of days' steaming; and the consideration of this point is next in order. Our vessels carry enough for full steaming from ten to fifteen days, and twelve may be assumed as the average. We have one class built solely for speed. I refer to that specified in the Navy Register as the "Connecticut class," which carries fuel for barely six days; but as this means a consumption of 135 tons per diem, and an average speed of 16.95 knots, the showing is by no means bad. If you apply the law of speeds varying as cubes of power developed—or, what is the same thing, coal burned—you will find that ships of this class carry fuel enough to drive them 5,000 miles at the rate of 11.25 knots, which will accomplish about every voyage possible on this planet. English vessels, and in fact all that employ bituminous coal, do not carry more than four days' fuel, and this must be remembered in contrasting them with ours.

It is then permissible only to compare engines with engines, and by this I mean apart from boilers and all appendages. If the contrast is to be carried further it must include boilers and bunkers carrying the same number of days' consumption of fuel. The space occupied by propeller shafting may be excluded in calculating room occupied by



engines, as various circumstances influence the proximity or remoteness of the engine, from the propeller, which do not result from the design of the machinery. Although definite data for this comparison are difficult, if not impossible to obtain, something may be arrived at by inspection of the drawings, published by Scott Russell, of the fastest specimens of English-built steamers, viz., the Dublin and Holyhead Mail Packets. These maintain 14.5 knots per hour, for four hours. The space occupied by machinery relatively to H. P. developed, shows clearly that our designers have nothing to learn from such models. Recurring to foregoing remarks on the importance of economy of maintenance in men-of-war, it will be seen that the use of a fuel which burns two and one half times as quickly as others, is a long stride

in the direction of obtaining ships which can develop their maximum power in the least time. The dense smoke of this fuel is, however, an objection to its use, as revealing a ship's position in blockade, and enhancing the obscurity involving an action at sea. The last, and a very serious charge against our Navy, is deficient speed. This has almost come to be accepted as a fact; but with what justice let us inquire. The fair way is to take our Navy list and contrast each class of ships in it with similar vessels in some other navy, and see how we bear the test. We will neglect auxiliary

TABLE I.

I.	II.	III.	IV.	V.	VI.
4430-3980	3250-2700	2400	2220-2100	1900-1550	900
S	S	S	S	S	S
Connecticut Florida Iowa Tennessee Antietam Delaware Nova York Pennsylvania Susquehanna	Lanester Brooklyn Pensacola Hartford Richmond Congress Severn Vorester Penton	Alaska Benicia Omaha Plymouth	Lackawanna Ticonderoga Cannondagha Monongahela Shenandoah	Junata Ossipee Quinnbaug Svartara Galena Vandalia Marion Proviouis Kearsarge Adams Enterprise Essex Alliance Alert Harpor Ranger Wachussets Mohican Tuscarora Wyoming	Kansas Nipic Saco Nyack Shawmut Yankee
16.95 16.95 12.75 11.00 11.00 11.00	9.50 9.19 10.00 9.50 9.50 13.00 13.00 13.00	12.00 12.00 12.00 12.00	12.00 12.00 12.00 12.00 12.00	11.00 11.04 11.00 11.00 11.00 12.00 11.70 11.70 11.70 11.06 10.06 11.30 11.30 11.30	10.00 12.00 12.00 12.00 12.00 9.75
Average speed 13.73 knots.	Average speed 10.81 knots.	Average speed 12 knots.	Average speed 12 knots.	Average speed 11.30 knots.	Average speed 11.15 knots.

steam-powered ships, such as the Colorado and class, and paddle-wheel steamers, like the Powhatan, because they are of an obsolete type.

Dispatch-boats and screw-tenders are also excluded, and although we have nine doubled-turretted iron-clads, of an average tonnage of 1,750 and fifteen single-turretted, with an average tonnage of 610, the speed of all of which ranges from 5 to 10 knots, we must ignore them, as there is nothing in other navies with which they may properly be compared. Inspection of the Register will then show that there remain six classes of ships, (*see Table I*), for which we may find counterparts in other navies—for example the English. They are as follows:

CLASS I.

CONNECTICUT AND CLASS.—Disp. 4,450—3,980 tons.

Speed 16.95—11 knots—av. 13.73.

CLASS II.

LANCASTER AND CLASS.—Disp. 3,250—2,700 tons.

Speed 13—9.19 knots—av. 10.84.

CLASS III.

ALASKA AND CLASS.—Disp. 2,400 tons.—Speed 12 knots.

CLASS IV.

LACKAWANNA AND CLASS.—Disp. 2,220—2,100 tons—Speed 12 knots.

CLASS V.

JUNIATA AND CLASS.—Disp. 1,900—1,550.

Speed 12—10 knots—av. 11.30.

CLASS VI.

KANSAS AND CLASS.—Disp. 900 tons.

Speed 12—9.75 knots—av. 11.15.

Taking from the Royal Navy list of 1876, groups of ships, (*see Table II*), of the same average displacement of each of our six classes, as enumerated in Table I, we have, to correspond with our first class, twelve ships whose average speed over the measured mile is 11.5 knots. To obtain a sufficient number for a just comparison, it was necessary to exceed the limits of displacement of our first class, viz. 4,450—3,980 tons, and the twelve examples quoted fall outside of them some two per cent. each way. For the second class, it was hardly possible to obtain a counterpart in the English Navy. Even by reducing the number to seven, the displacement ranged from ten per cent. below to two per cent. above our limits, viz. 3,250 tons—2,700 tons. The average

TABLE II.

I.	II.	III.	IV.	V.	VI.										
4150-3850	3250-2700	2100	2220-2700	1900-1750	900										
S	S	S	S	S	S										
Aboukir Arlaine Bristol Galathea Hindaya Liffey New Castle Nile Rohney St. George Topraz Undanted	9.57 13.06 10.34 11.79 12.02 12.16 13.28 8.30 11.47 10.93 11.12 12.02	Aurora Erythron Porte Nereissus Pembroke Simoom Urgent	10.30 11.27 11.48 10.33 7.60 11.38 12.71	Barrasa Jason Raccoon Redtsnake Wolverine Challenger	11.51 12.01 10.31 12.27 12.25 9.65	Janibus Cherybels Inno Pearl Sardille Seout Scylla	10.97 10.08 10.53 11.45 10.26 10.87 10.53	Bianche Dance Baphne Dido Druid Dryad Edipse Fox Nympho Spartan Vestal	10.66 .40 9.50	Average Knots.	12.47 .20 11.22	Average Knots.	12.47 .20 11.22	Average Knots.	12.47 .20 11.22
Average Knots	11.57 .90 510.3	Average Knots.	10.77 .40 9.70	Average Knots.	10.41	Average Knots.	10.66 .40 9.50	Average Knots.	10.66 .40 9.50	Average Knots.	12.47 .20 11.22	Average Knots.	12.47 .20 11.22	Average Knots.	12.47 .20 11.22

speed over the measured mile of this batch is 10.77 knots. The third class is somewhat nearer ours. It comprises six ships whose displacement exceeds our standard, 2,400 tons, some four per cent. each way. Its average speed over the measured mile, is 11.57 knots. The fourth class though numbering but seven ships, falls within our limits, viz. 2,220—2,100. The average speed of this group over the measured mile is 10.66 knots.

The fifth class numbers twelve and falls entirely within our limits, viz. 1,900—1,550 and the average speed, over its measured mile, is 12.47 knots. The sixth class also conforms to our standard, viz. 900 tons, and numbers eight. The average speed over the measured mile is 9.42 knots. Tabulating the foregoing compilations, the showing is as follows:

## OUR SHIPS.

13.73

1ST CLASS.

10.84

II<sup>D</sup> CLASS.

12.

III<sup>D</sup> CLASS.

12.

IV<sup>TH</sup> CLASS.

11.30

V<sup>TH</sup> CLASS.

11.15

VI<sup>TH</sup> CLASS.

## ENGLISH.

11.50

10.77

11.57

10.66

12.47

9.42

Our Ist class is notably ahead.

Our IId “ is about on a par.

Our IIId “ slightly better.

Our IVth “ decidedly superior.

Our Vth “ as much worse as the preceding class is better.

Our VIth “ markedly better.

In justice to our Vth class it must be said that it includes many yet untried ships, whose speed will no doubt considerably increase the average. Among these may be cited the “Quinnebaug,” “Galena” and others whose probable speed is twelve knots. It should be remarked, moreover, that the scanty record of our ships is not only due to the fact that many have not yet undergone trial—as in the Ist and Vth classes—but also to the practice of running upon half, or some fractional power, on ordinary occasions. To obtain the speed at sea, under full power, from log-books, can only be done by applying the law of speeds varying as cubes of powers, and is so tedious as to be practically impossible. The introduction of the English test over the measured mile would greatly facilitate comparisons of this nature. English ships of this class have engines of some fifty per cent. greater horse-power than ours.

This exhibit must again be modified for the following reasons. The speeds given are for a measured mile in the case of the English ships, and in ours for the average performance at sea, for periods of not less than twelve hours; and the two are vastly different. The former means the speed from five to seven minutes in smooth water, and without touching a fire, or feeding or blowing down the boilers. The conditions are the most favorable possible. Speed at sea means that, for hours and days in rough water, and with the firing and feeding and blowing down of boilers necessitated by the longer period of trial. A board, of which Rear-Admiral Goldsborough was President in 1868, thus mentions that of the “Wampanoag” in a report which, while condemning her for general cruising purposes, recognizes her complete fulfilment of the object for which she was designed.

“She, as her log shows, did go on an average, for 24 consecutive hours, 16.95 knots, her maximum speed during the period being 17 $\frac{3}{4}$  knots.” The wind was fair throughout, with a force from three to four. It could scarcely have been of any service upon the occasion and no canvas was used.

The log of the trial characterizes the sea as “rough,” and the wind “a strong breeze.”

Long and careful averaging of log-books has made it possible to deduce a ratio between performance over the measured mile and at sea, and the latter is variously given as eighty-five and ninety per cent. of the former, Captain Gore Jones, R. N., Naval Attaché of the British Legation at Washington, puts it at ninety per cent. and Mr. Reed, the late Chief Constructor of the Royal Navy publishes it at eighty-five per cent. Although the latter, has probably wider and better opportunities of judging, as it is to him that all returns and statistics of this nature naturally come, we will adopt the larger coefficient, and apply it to the comparison already made. It modifies it as follows.

OUR SHIPS.		ENGLISH.
13.73	I <sup>ST</sup> CLASS.	10.35
10.84	II <sup>D</sup> CLASS.	9.70
12.	III <sup>D</sup> CLASS.	10.41
12.	IV <sup>TH</sup> CLASS.	9.59
11.30	V <sup>TH</sup> CLASS.	11.22
11.15	VI <sup>TH</sup> CLASS.	8.47

In this exhibit we take the lead in all classes. Bear in mind that these results are averages, and that in every class there is little doubt but that the best English ship would badly beat our worst; but no sound logician argues generally from isolated cases, and the conclusion is unavoidable that our vessels are as fast as any built.

The object of this discourse has been to put you in possession of means wherewith to meet the attacks upon the *materiel* of our Navy, which are daily put forth, in and out of the Service, by loose-tongued and irresponsible people. All that is needed to discomfit such indiscreet folk are facts and figures. It is impossible to controvert an assertion advanced with an air of authority, unless one has at hand statistics, and because these are so difficult to obtain, the reckless statements made concerning our ships as compared with those of other nations, have so long passed unchallenged. If in addition to furnishing you with means of vindicating our naval architecture from the aspersions cast upon it by heedless detractors and calculating malcontents, I have made clearer to you the importance of never hazarding an opinion upon any subject from insufficient data, the imprudence and presumption of endorsing every cleverly expressed assertion, without holding it up in every possible light, and applying to it every available test, these words will not have missed their mark. There are

plenty of opinions current which are built on no better foundation than some epigrammatic phrase which one speaks "trippingly on the tongue,"—a mere argument to the ear, which nevertheless to inconsiderate minds has all the ring of true coin. There is as much worldly as spiritual wisdom in the injunction

"Prove all things."

COMMANDER FARQUHAR inquired how the maximum and minimum speeds, as set forth in the comparison, had been obtained.

P. ASSIST. ENGINEER RAE replied, that they had been obtained partly from personal observation, and partly from the statements of officers who had been either in command of or attached to the different vessels that had been spoken of.

LIEUT. R. P. RODGERS stated that in his opinion the lecturer had certainly over-estimated the speed of that class of vessels to which the "*Plymouth*" belongs. While he was attached to her the best she ever did, under the most favorable circumstances, was eleven knots.

LIEUT. MASON agreed with the gentlemen who had just spoken. He was attached for some time to the "*Omaha*." Her maximum speed was nine knots. He was on the "*Benicia*," on one occasion, when she made eleven knots, running from San Francisco to Mare Island, in California. The tide however was in her favor. He believed the speed of the above mentioned class of vessels to be rather below the presented estimate of Mr. Rae.

P. ASSIST. ENGINEER RAE replied, that not having the log-books of the different ships at hand, he of course could not substantiate and verify the given speeds of the different classes of ships. In some cases, where he was present himself, he could vouch for the accuracy of the figures; in a great many cases, however, he had simply derived his information from officers in command.

P. ASSIST. ENGINEER JONES stated that the "*Contocook*" of the ass under discussion, made on her trial trip, thirteen knots.

P. ASSIST. ENGINEER RAE remarked that he remembered that circumstance very well himself. The "*Alaska*" also developed a good speed.

COMMODORE PARKER inquired whether the speed thus obtained was taken for one, twelve or twenty hours.

P. ASSIST. ENGINEER RAE replied that it was taken for from six to twenty-four hours. The "*Lancaster*," he stated, had made twelve knots for hours without any difficulty.

LIEUT. SPERRY stated that although some of the vessels mentioned might have failed to come up to their standard on different occasions, others had gone beyond it. The "*Kearsarge*", he stated, made a run of five hundred and fifty miles in fifty hours, an average of ten and a half knots, with one of her fires banked. She could make more than ten knots without sail.

COMMODORE PARKER moved that the thanks of the Institute be tendered to P. ASSIST. ENGINEER RAE for his valuable and interesting paper.

CHIEF ENGINEER BAKER stated that before putting the motion, he had some brief remarks to make on the subject under discussion, and would claim the indulgence of the members for a few minutes. It should be borne in mind, that in making comparisons of speed between British and American men-of-war, the circumstances under which their trial trips take place ought certainly to be taken into consideration. On the one hand, a corps of thoroughly trained officers, especially employed for such purposes, is placed on board an English man-of-war on her trial trip. A full crew of firemen, coal heavers, &c., are furnished. The best of coal is picked out for the occasion. Even the wind, tide and condition of the water, are taken advantage of. On the other hand, in a great many cases, our vessels on their trial trips are short of officers, firemen, &c. The coal cannot be compared to that used by the English on such occasions. These facts, well known, and easy to be established, certainly should cover up any little discrepancies that may exist in favor of the English.

The thanks of the Institute were then tendered to P. ASSIST. ENGINEER RAE.

At the time of submitting the paper to the Institute, the speed of United States vessels of war, in Table I, had been compiled from personal observation and that of officers accessible to the writer—as transpired in the discussion which followed the reading. Since then the table has been reconstructed in accordance with official Logs in the Navy Department, and no speed entered that was not maintained, under steam alone, for at least twelve hours. This recourse has confirmed, to an unexpected degree, the position originally taken.





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U. S. NAVAL ACADEMY, ANNAPOLIS,  
OCTOBER 12, 1876.

Professor CHAS. E. MUNROE in the Chair.

The Secretary read the following paper :

HYGIENIC NOTES ON SHIPS' BILGES.

BY LIEUT. COM. CHARLES F. GOODRICH.

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I.

It is an unquestioned fact that, in the internal arrangements of our ships of war, naval constructors have been pre-eminently conservative.

Whatever of new and progressive they have given us has, as a rule, been devoted to the design and construction of the hull. In this respect, we must acknowledge their energy and clear-sightedness and their success beyond cavil. But while beyond reproach on the one hand, they have laid themselves open on the other to the charge of neglecting the internal for the external, and it is this charge which I purpose making definite, on one point at least, in a spirit of friendly criticism, to the end that they and we may both be benefitted.

It would seem as though the actual fighting qualities of the ship should alone be permitted to take precedence over that most essential requisite—a sound practical hygiene; and yet I fear this is often forgotten. To secure this requisite, there are needed a multitude of minor conditions and a few all-important ones. The latter will be largely fulfilled in a clean, dry, well-ventilated ship.

By a clean ship I mean something wider in its scope than spotless decks and ladders, fresh paint and glistening bright work. I pass these by as admirable desiderata which, however, scarcely touch the

objective—hygiene—and I ask, “Is the air pure? and are the bilges clean and dry from stem to stern?” How often the answer comes, “They are carefully cleaned every week *wherever they can be gotten at.*” That every inch of the bilge is not readily accessible is most certainly the fault of the constructor; and that fault is very grave.

To begin with, the fore peak, in even the smallest ships, should be high enough between the store-room deck and the keelson to permit a man to enter and to reach every part more or less freely. This, by the way, is a general rule applicable to all bilges.

Abaft this in our smaller sloops is the collision bulkhead. It should, like every water-tight bulkhead, be provided with bilge water gates worked from the berth deck.

Next, in the same class of ships, come the fore passage, with sail rooms and store rooms on either side, and the fore hold. In the former are stowed, under a flying deck, coils of spare rigging, cordage, et cetera, that rest on a dunnage floor; in the latter, the wet provisions, et cetera. I have always found this floor, in both hold and passage, of heavy plank, fitting tightly and *spiked down*. Possibly there may be one pair of scuttles in the whole length of the passage, and another pair in the hold. Ten chances to one, the space under the floor is too small to admit a man to scrape and whitewash. The consequence is, that the bilge is only cleaned in the immediate neighborhood of the scuttles, leaving the dirt elsewhere to undisturbed evolution of poisonous gases which superinduce ship fever and erysipelas and a low sanitary state of the ship's company; and which account but too well for the stubborn resistance to medical treatment and the long, tedious convalescence noticed on board certain of our men-of-war.

I say without qualification that this arrangement is dangerously wrong, and that we should not hesitate to rip up the planks that protect this vicious process, placing in their stead a series of scuttles fitting neatly enough to keep dirt from falling through, yet freely enough to lift up without trouble.

In the design of every ship this point should be carefully attended to, and the dunnage floor fitted with scuttles and raised high enough to admit a man for cleaning purposes. If this is not practicable, the only resource is to alternate scuttles and solid planks the whole length of the dunnage floor.

These scuttles and a high bilge become of the utmost importance in cleaning under water tanks, chain lockers and coal bunkers. A little forethought in building the ship will save much hard labor to those

destined afterwards to live in her, for water tanks are awkward things to move, and lifting one hundred and twenty or more fathoms of chain soon grows monotonous. Even in the chain lockers, with too low a bilge, provision is never made for getting underneath the floor.

In lockers and bunkers a simple scuttle would not answer, the weight above is too great. As a substitute, one plank might be laid in loosely, its ends resting upon the main and bilge keelsons. Should the working through of dirt or coal dust be apprehended, nail battens over the seams and butts. These can be taken off when desired and the plank raised without trouble.

I have often found a collection of pipes from the deck pumps and the boilers at the forward end of the fire-room which so blocked up the bilge that a man could not pass under a bunker forward, and even that crude method of cleaning the bilge—the use of a force pump—had to be abandoned. It is needless to state that a more open arrangement should be made.

To the fire-room, engine-room and shaft alley bilges, little objection on the score of design can be urged. I could suggest the insertion of dams with movable water gates into the bilges, both forward and abaft the engines, to prevent the oil dripping from the machinery from spreading into the forward bilges. The presence of oil in the bilges, is of course to be particularly avoided. These after bilges, as a rule, are so open and accessible, that their normal state should be that of purity—and a foul fire-room bilge a very rare exception.

To conclude these remarks upon the construction of bilges, I hold, first, that generally speaking, the bilges are not accessible when the ship goes into commission; secondly, that they should be accessible; thirdly, that the constructor is to blame for their not being accessible, and finally I cannot exempt this officer from a full share of responsibility for the fatal effects on board our ships of bilges not in their entire length scrupulously, absolutely clean.

## II.

It is but just to confess our own neglect as naval officers in the matter of keeping bilges in good order, for I am by no means sure that everything is done that can be done. In this, *thoroughness* should be regarded as an imperative duty, for carelessness will certainly defeat us.

Fonssagrives (I think) says that it is the water *inside* of a ship that kills sailors, *not* that *outside*. Accepting the dictum of this high authority I would suggest that, when it can be avoided, *washing out the*

*bilges*, be never resorted to. The dirt should be scraped up, any water found there wiped up carefully with swabs or oakum, and all the surfaces covered, not too thickly, with whitewash, sulphate of iron, or other disinfectant applied with a brush. After this, the scuttles should be kept open as long as possible, to permit the exit of foul air and the drying of the moisture.

The ship should be pumped out morning and evening, if the water in the well be above the "sucking" point—to keep the bilges as dry as practicable.

The water gates in the different bulkheads should be kept up, in port, and the fore peak open, so that a current of air, however feeble, may circulate through the bilge from forward aft. To some, this may appear a very slender reed, but until a much needed revolution in the ventilating of our ships takes place we must do this, the little in our power.

At sea these water gates should be closed. If open, the water tight bulkheads are rendered useless, and in the event of accident, the gates might be forgotten. A still more cogent reason is that through them the fine dirt and coal dust which unavoidably sifts into the bilge, from the fire-room, gradually work their way forward, acted upon by the water in the bilge set in motion by the pitching of the ship. By itself, this dirt would do little harm, but it takes with it oil and grease from the engine, absorbed into its pores, and these are fecund generators of noxious vapors. This is no fancy; I have known a steamer's forward bilges in a few months to accumulate stinking balls of mud, coal dust and grease, larger than a man's head, and every particle came through a small gate in a water-tight bulkhead.

Last, but not least, bilges should be cleaned frequently as well as thoroughly.

Accept the fact that the task is disagreeable and troublesome, but, notwithstanding, make every week, a vigorous attack on this hidden dirt—you will find your reward in unstained paintwork, a small sick list in all climates, and a robust crew.

LIEUT. J. F. MEIGS, U. S. N. I have made experiments in company with Dr. Howard Smith, U. S. N., and have found sufficient carbonic acid on the berth deck of the "OMAHA," to be exceedingly poisonous, especially in bad weather when the hatches are battened down; in which case I cannot see how the poisonous gas can escape. I found only eighty-nine cubic feet of air were allowed to each man.

Three thousand five hundred cubic feet are allowed in the Pennsylvania Hospital. I deem reform in ventilation advisable. I do not think that Lieut. Com. Goodrich quite goes to the root of the evil. I believe in forced ventilation. A long tube might be placed under the berth deck, with openings, through which air could be forced by an engine. I think the engine for this purpose could be run at a less expense than the galley stove. As an experiment I placed all the ingredients of bilge water in a bottle and after having kept it corked for some weeks could detect no unpleasant odor arising from it. I do not think that the trouble comes so much from the bilge water as from the confined air. I think that the automatic air pumps placed in some of our vessels are doing good, but there are not enough of them.

CHIEF ENGINEER BAKER. I think that Mr. Meigs is right. I believe that the employment of power alone can produce sufficient ventilation. I think, however, that the expense would be great, the object is well worth the expense however. Several years ago experiments were made to ventilate the Senate chamber. The amount of power necessary was estimated at from twenty-five to seven hundred and fifty H. P. The power necessary to force a column of air from the top being seven hundred and fifty H. P. In a ship where each person gets eighty-nine instead of three thousand cubic feet the process would be very heavy. I doubt whether ship ventilation will ever be successful until mechanical means are used. As to the expense, if a nation intends to have a navy it must pay for it. There is no use of having improved ships, guns and machinery if the men are not in good condition.

COMMANDER SAMPSON, U. S. N. I think that there is no doubt of the necessity of proper ventilation, especially when the men are below. I think that the carbonic acid gas comes from the combustion going on in the men's bodies. The carbonated hydrogen from the bilge also affects the air. I think that Lieut. Com. Goodrich is right to a certain extent, but good ventilation will never be obtained until mechanical means of ventilation are used.

REAR ADMIRAL C. R. P. RODGERS, U. S. N. I think that the paper deals with the neglect to make proper provision for cleanliness, which must greatly affect the ventilation, in a very thorough way. I think that the lecturer has gone very much to the inner matter. I think that the constructors are to blame for not making proper provisions to get at the bilges. Mechanics are careless and leave much dirt in the bilges. Cold chisels, clothes and all manner of things are found in the bilges.

These things become particularly obnoxious in the West Indies. In English ships the bilges are always as accessible as the cabin of the commanding officer. No man, who has been first lieutenant of a ship, will not say that it is almost impossible to get at the ship's bilges. I think that the paper is most excellent. When I was first lieutenant of the "*Wabash*," I had to crawl on my hands and knees, and even then could not reach many places which were indeed inaccessible and could never be cleaned. The old idea of letting in water to the bilges is bad on account of the foreign substances admitted with the water which combine or deposit. Care should be taken in using disinfectants which themselves often become obnoxious.

LIEUT. COMMANDER A. D. BROWN, U. S. N. In one ship to which I was attached we could not reach the bilges, beyond the engines and boilers. The flooring of the shaft-alley was spiked down. The floors of the shell rooms and store rooms came so close to the keelson, that I could hardly get my hand between them. We ran *hot* water from the donkey boiler into the bilges, and then pumped the ship out immediately, wiping up wherever it was possible, with good results.

PROF. MUNROE, U. S. N. I have listened to the paper with a great deal of interest. I am unacquainted with the subject except in a general sense. The sea water in contact with the wood generates hydrogen sulphides. I think that Mr. Meigs' experiment was unsuccessful because there was no air in contact with the water in the bottle. These gases are highly deleterious, having been known to produce instantaneous death. I think that it is highly important to have the bilges accessible, also to cover them with metallic paint, to prevent the water from coming in contact with the wood. The decomposition of oily, fatty matter is still more productive of evil.

REAR ADMIRAL RODGERS. We use in the Service several metallic disinfectants.

PROF. MUNROE. Those are not exactly what I referred to. When the water becomes acid in any way, they are again decomposed and the hydrogen sulphide is liberated in still larger quantities. If I understand Mr. Meigs correctly, he inferred that part of the carbonic acid gas came from the decomposition of the organic matter in the bilges. This is hardly possible, for, if carbonic acid is formed, then it would be consumed in decomposing the sulphates of the sea water. This has been proved experimentally by mixing soda water with sea water.

R. A. RODGERS. The system proposed by Lieut. Meigs and Chief Engineer Baker, is probably that now in use aboard the monitors. I

have no doubt but that at a very small expense, we might get a very good system. I think that it is surprising that men can exist in such foul air, as they do when a ship is battened down.

CHIEF ENGINEER BAKER. I think that the furnace fires help to carry off a good deal of the foul air.

LIEUT. MEIGS. The engine used to drive the fan at the Philadelphia Hospital, is only 6 H. P. and burns 1 ton of coal a week; supply 1,000,000 cubic feet per hour. This force would not be necessary in a ship.

R. A. RODGERS. I think that a very small engine would do. The later monitors are probably better ventilated than any other ships of war.

CHIEF ENGINEER BAKER (to Mr. Meigs). Does all the air which is supplied to the rooms in the Pennsylvania Hospital, come through this apparatus?

LIEUT. MEIGS. Most of it does.

P. ASST. ENGINEER CRAWFORD, U. S. N. The "*Nehant*" had two five H. P. blower engines which consumed 1000 lbs. of coal per day. The heat of the ship was not intense even when the hatches were closed. We never were troubled with bilge gases. In some of the ships they are covering the floors with cement.

At the conclusion of the discussion, a vote of thanks was tendered to Lieut. Commander Goodrich, for his very interesting paper.





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U. S. NAVAL ACADEMY, ANNAPOLIS,  
JANUARY 11, 1877.

Lieut. DUNCAN KENNEDY, U. S. N., in the Chair.

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THE 100 TON GUN.

BY LIEUT. THEO. B. M. MASON, U. S. N.

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The gun designed by Capt. Noble was built at the works of Sir William Armstrong, known as the Elswick Ordnance Works, Newcastle on Tyne, England.

The contract called for a gun to throw a 2000 lb. projectile, with a muzzle velocity of at least 1,350 ft. per second. The proof, before acceptance, was to be 50 rounds fired with service charges, 5 of these rounds to be with projectiles weighing 2,500 lbs. the others with the service projectile. This gun is intended to form one-eighth of the armament of the turreted ironclads *Duillio* and *Dandolo*, now in course of construction. It has been nicknamed the "King Gun," by the Italians. Over two years were required to put this gun in existence. When completed it was taken to Spezzia, in a vessel arranged for its accommodation. At Spezzia, it was mounted on its carriage which for the time being had been placed on a large pontoon specially constructed for the purpose. On the 20th of October, 1876, everything was prepared for the trial.

The gun is constructed on the well known Armstrong principle, with the exception of the substitution of coiled for forged iron in the inner breech coil or tube. Some of its dimensions are:

Total length,	32' 10".5
Length of bore,	30' 6"
"    " steel tube,	31' 3"
Greatest diameter,	6' 5"

Diameter at trunnion coil,	5' 5".5
"    " muzzle,	2' 5"
"    of bore at present,	17"
"    " chamber "	17"
Breech preponderance,	4 tons.
Rifling,	27 grooves.
Twist increasing from 1 turn in	150 calibres.
to                  1 " "	45 "

The A, or interior tube is of steel, made in two parts varying in thickness from the rear where it is 6" to the muzzle where it is 3".5. The thickness of the end is 9".

Over this A tube are ten coils of wrought iron bars, six of which refer to the breech and four to the muzzle.

For a distance of 13' from the rear end of the gun, the steel tube is enveloped by a breech coil 7" thick. This overlaps the rear of the A tube, and receives the cascabel piece, which is of forged iron, 1' 7".5 thick being held in place by a screw thread. Through the axis of this cascabel piece is the vent, and at the right side of it is the safety gas escape.

Over this first coil is a second one 9' 6" long and 8" thick. The trunnion coil is next with a thickness of 11" and a length of 2'.

Over the second or B coil is a third one 5' 6" in length, and 9" thick, forward of which and reaching to the trunnions is another 6".5 thick. From the trunnions to the muzzle are five coils tapering down to 2".5.

By this arrangement we have 30" around the powder chamber and seat of the projectile and 2' 4".5 to the rear of the charge. The coils are so arranged that they interlock and overlap each other slightly, at the junctions. Around the C coil and let into it are two strong wrought iron bands which connect the gun, by means of a key, to the sliding block of the elevating apparatus.

The carriage on which the gun is mounted, and which is constructed without any reference to being worked by hand, was designed by Mr. G. Rendel, the experienced engineer of the Elswick works. All motion is received, given and controlled by hydraulic power. It is at present placed, as heretofore stated, on a specially constructed pontoon. The idea of the pontoon is to put the gun afloat, and to give it the training facilities that it would have in its turret. The trunnions are mounted on heavy blocks of wood which slide on the carriage proper. To each trunnion is attached the piston of a strong hydraulic cylinder, which is secured at the rear of the carriage so as to be one on each

side of the breech. These two cylinders take up the horizontal component of the recoil, which, except at great elevations, is by far the greatest. They also serve to run the gun out. By means of valves attached to the cylinders the recoil pressure is regulated and the gun checked in running out. Under the breech and joined to it by the key, previously mentioned, is the sliding block of the elevating apparatus. This block slides on a lever plate, which is pivoted horizontally at the rear of the carriage. This pivot is so placed that the gun will come level at the end of the recoil. Under the lever plate, and attached to it by a horizontal pivot bolt, is the piston of another hydraulic cylinder, which serves to elevate or depress the gun, also to take up part of the vertical component of the recoil. At small elevations it is assisted by the trunnions, and at great ones by a rubber buffer which receives the end of the lever.

For sponging and loading, the gun is run in and depressed so that the muzzle points into an armored hood. The sponging is done by a telescopic handled sponge to which motion is given by hydraulic power; a spring valve in the side of the head of the sponge is pressed upon by the bottom of the bore, when it reaches that part, and a stream of water ejected which assists the sponging.\* The gun being sponged, the cartridge and projectile are brought on the lower deck, under the muzzle, on a truck; this truck is elevated to the muzzle on a hydraulic lift; the checking apparatus, which checks it when the cartridge is in a line with the bore, acts automatically. The sponge, now become a rammer, pushes the charge and projectile home together. The projectile is of the Palliser nature, similar to those used in the heavier English guns; the studs which strain the gun and weaken the projectile having been omitted and an expanding copper base ring substituted. This ring acts as a gas check and also communicates the rifled motion to the projectile. In order to insure perfect accuracy of fit and to render more easy the loading, the ring is scored to correspond with the lands. The ogival head is struck with a radius of  $1\frac{3}{4}$  diameters instead of  $1\frac{1}{2}$  as usual, making it a little more pointed. The service charge which is at present 341.6 lbs. of English mammoth powder  $1''\cdot5$  cubes, made at Waltham Abbey, or 400 lbs. of Fossano Progressive Powder.

The cartridge is pierced from the rear in the direction of its major axis, and connecting with the vent, by a light copper tube. This tube

\*This is an American invention first proposed by E. A. Stevens, Esq., of Hoboken, and designed by Alex. L. Holley, B. P. C. E.

extends to the middle of the mass, the idea being to insure that points being the first to be ignited. The exterior of the cartridge is banded to give it compactness.

The trials of the gun took place against five targets made to represent what might be the armor of the *Duillio* and *Dandolo*, the idea being not only to test the gun but also to determine the best style of armor to oppose it, and the best way to attach that armor to the ship's side. We will designate the targets by numbers.

**No. 1** was constructed of two plates one above the other, both of rolled iron and both 11' 6" long, 4' 7" deep and 22" thick, both bolted through and through. The backing consists of two thicknesses of timbers, the front ones laid horizontally, the rear ones vertically, together giving a thickness of 29". Behind the backing is the skin consisting of two  $\frac{3}{4}$  in. plates of wrought iron—the whole supported by irons representing the ribs of the ship, the deck beams being bent down to the ground and well strutted out. The upper plate was made by Cammel, the lower one by Marrel.

**No. 2** on the same frame as **No. 1**, consists of two soft steel plates made by Schneider at the Crenzot works in France. The upper one 11' 6" by 4' 7", the lower one 10' 9" by 4' 7", both 22" thick; backing, &c., same as **No. 1**. Bolts screwed into the rear of the plates and penetrating only part way.

**No. 3**, called sandwich, on account of its construction. Upper part 12" wrought iron plate by Marrel, 11' 6" by 4' 7", next horizontal wood backing, next 10" Marrel plate backed by vertical balks, skin, &c., same as **Nos. 1** and **2**.

Lower part, face plate 8" wrought iron backed by vertical timbers, next a Gregorian cast iron plate 14" thick, next vertical balks; skin, &c., same as others.

**No. 4** on the same frame as **No. 3**.

Upper part. 12" wrought iron plate by Cammel 11' 6" by 4' 7", next horizontal wood backing, next 10" Cammel plate, backing and same as upper part of **No. 3**.

Lower part. Face plate 8" wrought iron, immediately in rear 14" Gregorian cast iron plate, backing, &c., same as **No. 1**.

**No. 5**. Erected after the destruction of **Nos. 1** and **2**, consisted of two Brown 22" wrought iron plates of the same dimensions and with the same backing as **No. 1**.

The horizontal balks were further secured in all the targets by wrought iron L irons fastened to the vertical balks.

The sum of all the wood backing in each target was 29'.

The Gregorian cast iron mentioned is worthy of notice. It is made near Lake Como and is used, in the construction of ordnance, by the government at the Royal Arsenal in Turin. The guns, there manufactured, have always been noted for their excellence, far exceeding any other European cast iron ones, and nearly equalling our own hollow cast Dahlgrens. It has a tensile strength of from 16 to 17 tons per square inch and is very hard.

The targets were placed in front of a bluff, on the left of the harbor, which had been excavated and the sloped faced with fascines and gabions well shored up with heavy timbers.

The pontoon was anchored at 100 yds. from the targets so placed that the guns, by turning, could also be trained to seaward for long range firing. Screens for determining the velocity were erected on each of the ranges, one being also placed immediately behind the targets to ascertain remaining velocities after passing through.

A battery of two 10" and one 11" rifles was also erected on the shore. These three guns were tried against the different targets. It would be interesting to follow out the relative effects but our space will not permit us.

The gun was fired by electricity, first from a distance, but eventually from the deck of the pontoon close to the gun.

It is interesting to note in the different fires, the smallness of the pressures. These pressures are the *mean* not the *maximum* however. The great muzzle velocities, far in excess of what was contracted for, or what is needed to pierce any armor now in existence. The ease and smallness of the recoil, the smallness of the jar or concussion, (the oakum in the decks of the pontoon in front of the gun was not even started) all this seems to show that the gun has not been overworked, and that if the chamber were increased in diameter, much greater results might be obtained.\* Heavy guns seem to work easier afloat than they do ashore, due probably to the fact that the vessel acts as a secondary slide, taking up much of the recoil and cushioning on the water.

The carriage and other machinery gave the greatest satisfaction. As to the targets, they were destroyed in every instance. The Schneider steel in its destruction stopping the projectile however, and the Brown plates giving wonderful proof of endurance. One thing is worthy of note; that is that the steel that stopped the 100 tons projectile

\* This has just been tried with the 80 Ton gun.

was more deeply penetrated by the smaller gun's projectiles than the wrought iron plates which were thoroughly pierced by it. Cast iron even of the best quality seems to be utterly useless for armor purposes.

The pontoon was towed out and moored on the 20th of October, on which day the firing began and was continued with intermissions until Dec. 14th, when the 50th round was fired.

The accompanying table shows most of the items of interest developed by the different fires.

No. of Round.	Date 1876.	Charge weight and nature in lbs.	Projectile weight in lbs.	Velocity, feet per sec.	Mean pressure in bore.	Stored up work.	Recoil valves set to lbs.	Recoil in inches.	REMARKS.
1	Oct. 20	300 WA 1½ in.	2000	not obs'd	8.7	.....	1050	20	Taken to test carriage working.
2	" 21	300 "	2000	"	16.6	.....	33	36	Screens did not work, elev. 5°.
3	" 22	300 "	2000	1375	15.9	.....	1150	34	" " " " " " " "
4	" 23	300 "	2000	.....	.....	.....	.....	.....	" " " " " " " "
5	" 24	300 "	2000	.....	16.0	.....	.....	35.5	Chamber pressures very low, 5 tons
6	" 25	300 "	2000	1374	16.0	.....	.....	37.5	per sq. inch less than elev. 1° 48'.
7	" 26	330 "	2000	1456	20.8	29.400	.....	.....	[80 ton gun.] " 1°.
8	" 27	319 "	2000	1424	18.0	28.120	.....	42.5	" " " " " " " "
9	" 25	319 "	2000	.....	not obs'd	.....	.....	44.75	" " " " " " " "
10	" "	336.6 "	2000	.....	19.4	.....	.....	46.3	elev. 1°5.
11	" 21	319 "	2000	1437	.....	28.625	.....	42.6	At earth faced with gabions.
12	" 21	341 "	2000	1475	19.75	30.130	.....	47.1	At Cammel W. I. P. Upper No. 2.
13	" 27	341 "	2000	1478	19.75	30.300	.....	46.0	At Cammel W. I. P. Upper, No. 1, Rem. Veloc. 650 ft. = 5,500 T.
14	" "	341.6 "	2000	.....	.....	.....	.....	.....	Shot broke up in bore.
15	" "	341.6 "	2000	1500	20.6	31.200	.....	.....	At Marrels W. I. P. Lower No. 1.
16	" 28	341.6 "	2000	1498	20.1	30.920	.....	48.2	At Schneider Steel Plate Upper No. 2.
17	" "	341.6 "	2000	1492	19.2	30.880	.....	46.0	At Marrels Sandwich Upper No. 3.
18	Nov. 2	319 "	2000	.....	.....	.....	.....	.....	At Sand butt, Shot curved and came
19	" "	319 "	2000	1294	19.0	29.027	.....	44.75	[out at top well to the rear.
20	" "	319 "	2000	1293	19.0	29.000	.....	44.5	
21	" "	319 "	2000	1293	18.8	29.000	2000	44.25	
22	" "	319 "	2000	.....	.....	.....	.....	42.5	
23	" "	319 "	2000	.....	18.6	.....	.....	40.5	
24	" "	276 Fossano.	2000	1165	.....	.....	1850	23.5	Progressive Powder (experimental).
25	" "	300 "	2000	863	10	.....	.....	17.0	Powder could not have burned well.
26	" "	319 WA 1½ in.	2000	.....	.....	.....	.....	.....	
27	" "	4319 "	2000	.....	.....	.....	.....	36.0	
28	" "	319 "	2000	.....	.....	.....	.....	.....	
29	" "	319 "	2000	.....	.....	.....	.....	35.25	
30	" "	.....	2000	.....	.....	.....	.....	.....	
31	" "	.....	2000	.....	.....	.....	.....	.....	
32	" "	.....	2000	.....	.....	.....	.....	.....	
33	" 7	253 "	2000	1512	.....	31.700	.....	42.5	Charges increased by permission of
34	" "	364 "	2000	1514	19.8	31.750	.....	42.8	contractors, on condition that the in-
35	" "	375 "	2000	1542.8	21.4	33.000	.....	.....	crease should be gradual.
36	" "	8319 "	2000	1348	.....	25.200	.....	.....	
37	" "	341 Fossano.	2000	1415	.....	27.750	.....	.....	Progressive powder, Considering
38	" "	363 "	2000	1408	.....	27.500	.....	.....	smallness of pressures velocities are
39	" "	363 "	2000	1444	13	28.900	.....	.....	400 lbs. P. P. = 341 lbs. W. A. P. [good.
40	Dec. 13	.....	2000	.....	.....	.....	.....	.....	Fired to determine charge necessary to
41	" "	.....	2000	.....	.....	.....	.....	.....	give reduced velocities for plate tests.
42	" "	.....	2000	.....	.....	.....	.....	.....	The gun having been accepted.
43	" 1	240 Fossano.	2000	1050	.....	.....	.....	.....	At Cammel Sandwich Upper No. 4.
44	" "	240 "	2000	1050	.....	.....	.....	.....	At Brown's No. 22" W. I. P.
45	" "	400 "	2000	1491	.....	.....	.....	.....	At Lower Plate No. 3.
46	" "	400 "	2000	.....	.....	.....	.....	.....	Shell broke up in gun.
47	" "	400 "	2000	1502	.....	.....	.....	.....	At Lower Plate No. 4.
48	" "	240 "	2000	1062	.....	.....	.....	.....	At Brown's 22" W. I. P.
49	" "	400 "	2000	1199	.....	.....	.....	.....	" " " " " " " "
50	" "	264 "	2000	1299	.....	.....	.....	.....	" " " " " " " "

No. 1 was fired after some delay, owing to bad weather, and the cartridge, which was very small, not igniting properly. This was to test the recoil apparatus only.

Nos. 2 and 3 were fired with service charges, but no velocities were taken as the screens were out of order.

Nos. 4, 5, 6, 7, 8, 9 and 10 were fired with charges up to 341.6 lbs., and gave excellent velocities with very small corresponding chamber pressures; less in proportion than the Krupp or Woolwich systems.

No. 11 was fired into the embankment, which might be supposed to represent an earthwork 27' high, and 52' thick; the shot buried itself so deeply that it could not be dug out on the day of firing. No. 12 was fired against the lower plate of target **No. 2** (Schneider steel). The plate was broken into fragments and fell in a pile at the foot of the target, except some small pieces left attached to the bolts, and some which were projected through the air in all directions. The backing was not pierced but the framing was dangerously bulged and torn.

No. 13 was fired against the upper plate of **No. 1** (Cammel's wrought iron). It pierced from front to back, coming out at the rear with a remaining velocity of 650' per  $\equiv$  5,500 foot tons of energy. The plate was destroyed and the backing broken up into splinters. The hole made would have caused the sinking of the vessel almost immediately.

No. 14. Shot broke up in the bore from some unknown cause. A man was sent in, on a peculiarly arranged rest, but could find no evidences of injury to the tube.

No. 15 was fired against the lower plate of **No. 1** (Marrel's wrought iron), destroying the plate as in No. 13, which was to be expected, as this plate had already shown less resistance than Cammei's in the smaller gun trials.

No. 16 was fired against the upper plate of **No. 2** (Schneider steel). This plate had already been struck and cracked by the smaller guns. The result was the same as in No. 12, although the projectile had a greater velocity and the plate had been injured.

No. 17 was fired against the upper place of **No. 3** (Marrel's sandwich wrought iron), same results as Nos. 13 and 15.

No. 18 was fired against the earth butt. The projectile described a curve and came out at the top well to the rear.

Nos. 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31 and 33 were fired for general results.

No. 33. At this round the weight of the charge was increased by permission of the contractors, who had the fullest faith in their weapon. They stipulated, however, that the charges should be increased gradually. The charge was therefore 353 lbs. of W. A. powder.

Nos. 34 and 35 were fired for general results with increased charges. The air space was increased in 33 and 34 but remained constant in 35.

Up to this fire the gun had exceeded its stipulated capabilities by 33 per cent.

No. 36 was for general results.

No. 37 and 38 were experimental with charges of a new style of powder, denominated "progressive," previously used in 24 and 25. It is manufactured by the Italian government at Fossano, in the following manner. Mealed powder is pressed into cakes which have a density of 1.79. These cakes are then broken up into regular grains of from an eighth to a quarter of an inch in thickness. The grains are then mixed with a certain quantity of fine grain powder, and the whole mass is pressed into a cake which has a density of 1.776. This second cake is then broken up into tolerably regular pieces about  $2\frac{1}{2}$  square, by  $1\frac{1}{4}$  thick. These grains if they can be so called, are therefore composed of a number of small pieces with a higher density placed like raisins in a plum pudding, in a sort of conglomerate powder material of a lower density. The intention of the inventors of this powder, was to bring about a condition of affairs in which more gas would be produced in a given time, when the powder had been partly burned than at the beginning of the ignition. The pressures were found to be abnormally low, and the velocities may therefore be considered as most satisfactory.

Nos. 40, 41 and 42 were fired to determine the charge of powder requisite for giving the 2000 lb. projectile, the reduced velocity with which it was determined to commence the renewed experiments against the plates. It was well known now that all the targets would be penetrated with a great surplus of power, if the gun were fired with the charges previously used. It was therefore necessary to reduce the charge to such a point as would render it possible to compare the relative resistance of the targets. The government had determined to accept the gun.

No. 43 was fired against the upper plate of **No. 4** (Cammel's sandwich wrought iron). The projectile passed through the first plate and cracked it from top to bottom, passed through the wooden interior, and entered the second plate 6".8. The base of the shell broke up and the



remainder was starred. Judging from the past experiments with gun cotton shells the committee considered that had this shell been loaded, it would have blown off the front plate. The skin was cracked and the rib behind much bent. All this with an extremely small charge and a very low velocity.

The target previously referred to as **No. 5**, was now erected. The plates were rolled at the works of Sir John Brown & Co., in England.

**No. 44.** The sea being rough, the pontoon moved visibly after the gun was laid. The aim was at the lower part of **No. 5**. Owing to the motion, the projectile instead of striking the point aimed at, hit the plate on its lower edge, and broke into several pieces, which were deflected downward and made a hole in the ground about 8' deep, in a slanting direction, under the target. Though lost, for the immediate object of the experiment, this round was of great interest, for it showed that a shell striking the edge of a narrow belt of armor, which will soon be all that ships can afford to carry, will tear through the bottom of the vessel with force enough to pierce engine-room and boilers, and pass out at the other side.

**No. 45** was against the lower plate of **No. 3** (sandwich cast iron). This round had been looked forward to with great interest, as great things were expected from the chilled cast-iron plates, on account of the results already obtained with the smaller guns. The plate, however, was not able to withstand the shock. The projectile was broken into many pieces, which dashed through into what would have been the interior of the ship, carrying with them a great number of ragged fragments of broken plate, and causing such a hail of iron that nothing could have lived between decks. The sand bags behind were deeply pitted with many hundreds of pieces. The experiment proves that the old faults of cast metal still exist—namely, that when it breaks under the influence of a heavy blow it is crushed to pieces.

**No. 46.** Shell broke up in gun; no damage could be discovered.

**No. 47** was fired against lower plate of **No. 4** (combination cast and wrought iron). The target was completely penetrated and ruined, a large portion of the front plate being torn off at the same time. In these two remarkable rounds (45 and 47), not only were the fragments of the cast-iron plates driven forward, but also out of the sides of the targets.

After the failure to strike the right spot, recorded in **No. 44**, on account of the motion, the firing apparatus was transferred to the deck of the pontoon, from which spot in the succeeding fires the gun

was pointed and fired with remarkable accuracy; the projectile striking each time exactly on the spot previously marked on the target.

No. 48 was fired with a reduced charge of powder at **No. 5** (Brown's 22" plate). The shell broke up the front part, remaining in the hole, having penetrated 15".6. Comparing this with No. 43, at **No. 4**, we see that **No. 5** had much the best of it. The velocities were nearly the same. In 43 the projectile penetrated 31", of which 19" were through iron.

No. 49 was fired with 400 lbs. of "progressive powder," equal in effects to 341.6 lbs. W. A. powder. This is, for the present, the service charge. The aim was at the right of **No. 5**. A large portion of the plate was torn off. The target was completely penetrated, and the rear of it so ruined as to be incapable of repair. The hail of fragments was not so terrible as in the case of the target backed by cast iron.

No. 50 was fired with the small charge of 264 lbs. W. A. powder. The effect was as expected. Aimed at the centre of Brown's plate, the projectile just passed through, tearing off a large fragment and splitting it from top to bottom. The backing was not pierced. Brown's plates may be said to have come out **No. 1**, in the target class.

This terminates the series of tests. The weapon has proved that it can destroy any vessel now afloat. It can therefore be said that the gun is now ahead in the great contests of ordnance *vs.* armor. We now hear rumors of a 200-ton Woolwich gun; we know of a 124-ton Krupp gun being in course of construction; France and Russia are waiting to see this game of bluff well underway before they show their hands, and *we* cannot even put up an anty; perhaps, however, by not playing we may save money in the end and at the same time learn the game.

An English firm is ready to furnish 40' plates to any one who wants to buy them.

I have derived my facts from

The Engineer,  
 " Engineering,  
 " London Times,  
 " " Standard,  
 U. S. Army and Navy Journal,  
 Revue de l'Artillerie.

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U. S. NAVAL ACADEMY, ANNAPOLIS,

FEBRUARY 8, 1877.

THE VICE-PRESIDENT, MEDICAL-INSPECTOR GORGAS, U. S. N.,  
in the Chair.

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SANITARY COMMONPLACES APPLIED TO THE NAVY.

BY ALBERT L. GIBON, A. M., M. D., MEDICAL INSPECTOR U. S. N.

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*Mr. President and Gentlemen:*

The revolution effected in modern habits of life by the teachings of Sanitary Science has only recently been felt in the Navy. There, more than elsewhere, the resistance to change has been stoutly maintained, by the older men, because the dreary monotony of their occupation, and the habit of command, indispose them to look beyond the narrow domain in which they have lived and reigned, while, when those younger have ventured to suggest improvements, these have been sneeringly unheeded, and all discussion of existing evils sought to be smothered under the established "customs of the service," that unwritten law from which there is no appeal, and against which it is imputed heresy to protest. Medical officers, whose especial duty is to advise upon everything affecting the health of the navy, are not listened to, or their advice is disregarded, through a jealousy of their interference in any way in its discipline. They are reminded that they are only healers of the sick, despite their protest that sickness is the opprobrium of their profession, and that their higher function is to banish it from the earth. The sanitary improvements that have been effected in the naval economy, have come about almost imperceptibly. There has been no open recognition by the authorities of the

importance of Naval Hygiene; no sanitary code has ever been promulgated by the Department; no commanding officer embodies in the internal regulations, which he establishes at the outset of his cruise, a set of specific sanitary rules by which, only, the health of his crew, and its consequent efficiency, can be secured. Little by little, however, changes have taken place in the method of ship-life. One abomination after another has disappeared, and a general sum of good has been accomplished, which can only be appreciated by comparing the navy of to-day with that of fifty years ago. The old dirt-begrimed tar has vanished, bewailed only by the old sea-king who was his sovereign and his God. With him have also gone his old-time attendants, scurvy and ship fever. Disease still claims its victims, as shipwreck still sacrifices life and wealth, but as the laws of storms, unknown and unintelligible to the ancient mariner, are being, year by year, more clearly understood, and the ocean robbed of its prey, so light and air are flooding the pest holes, where the Benbows and Tom Fids of the past dragged out their wretched existence, and clearing away the filth, and vermin and disease, which, with ignorance, superstition and degradation, were their only companions.

A few years ago, I would have felt little encouragement in coming before an audience of naval officers to talk to them about Naval Hygiene. If I had not been sharply reminded of my impudence or imprudence by empty benches, I could, at most have counted upon the presence of a few stern faces, which, with puritan firmness, had determined to face the devil and to frown him down; but the knowledge that, only a short time since, a paper by a Lieutenant-Commander in the Navy, on the defective hygiene of ships' bilges, was read before this Institute, and that one of the most enthusiastic workers in the determination of the elements of the foul air of berth-decks is a Lieutenant, now one of our honored colleagues, and the assurances I received from several commanding officers, on the occasion of an address I had the honor to deliver in Boston, at the last annual meeting of the American Public Health Association, that they cordially endorsed all that I had said, have determined me to repeat here a few of the common-places, which there found such considerate auditors.

I shall not be discouraged if I do not gain a single convert. I have little hope of working such a change of heart or kindling such a repentant spirit as the successful evangelist, who scares men into believing that they are in peril from evil doing. "What is a man profited, if he shall gain the whole world and lose his own soul?" no one gainsays;

neither ought he this no less gospel truth. What is a man profited, in this life, if disease saps his strength, impairs his powers, dulls his senses, clouds his brain, or lays him in a coffin? yet many a widowed wife and many an orphaned child to-day weep sadly beside graves yet green, because the simple facts I have to tell you, were not listened to, or if listened to were not heeded.

It ought to be unnecessary to urge the importance of hygienic observances on board ship. It must be evident to every thinking man that the efficiency of a vessel will be directly proportionate to the available human force required to perform its evolutions, control its engines, and man its guns. Every sick man not only unduly encroaches upon the restricted space, but deranges the organization of the crew, and interferes with the regular exercises and routine of the vessel. His condition appeals to the humanity of his shipmates. To contribute to his comfort or necessities, they are incommoded, sometimes themselves become diseased, and the sick may even multiply until the whole machinery of the vessel may be arrested. No matter what the numerical strength of an army, if it be borne on hospital registers, marches can not be made, battles cannot be fought, skilfully planned campaigns cannot be executed. On shore, the despotic power of government, or the necessities of an overflowing population, may force new material into the gaps made by disease, and navies also have this resource in time of peace, in every port they visit, when they rid themselves of their invalids as they do of their spoiled provisions; but when the emergencies arise for which navies exist, then the men enfeebled by disease can neither be gotten rid of, nor can their places be supplied by others; and the ship is as effectually disabled as though by burst boilers, rotted rigging or inferior armament. Three years ago, there was to have been seen at Key West, a splendid frigate, perfect in all her appointments, only a few hours out of our most important dock-yard, swinging idly in quarantine, when she should have been ready at a moment to have avenged the national honor, and, on the very eve of hostilities, displaying instead of the guidon of battle, the yellow signal, which appealed to the pity and humanity of her foes. Neglected hygiene had already vanquished her, as it had almost disabled two of her consorts. Splendid armaments and accomplished officers could do nothing with hearts that were no longer stout and arms that were no longer strong. As one of the sanitary board, appointed on that occasion, I can bear testimony to the earnest attention given to every suggestion of the medical officers, to the courteous deference and

ready acquiescence in their every opinion, and to the cheerful alacrity with which every order and request were obeyed; but what if such earnest attention, such courteous deference, such ready acquiescence and such cheerful alacrity had been shown *before* instead of after?

It is the same with the men who live upon the sea, as with those who dwell on shore, and him who reigns in Tartarus, who when ill would even be a monk, but when well "the devil a monk was he." So the feeble imitators of his sins, when sick, swallow noxious drugs with avidity and are rather aggrieved at the implied neglect if these are not supplied fast and freely enough, whilst they resent the physician's counsel how to live that they may not get sick. The medical recruiting officer can poke and pommel and make the unlucky candidate, be he landsman or lieutenant, perform all sorts of gymnastic antics, that no unfortunate inheritor of his parents' vices, or no victim of his own imprudence slips into navy blue but, this done, he is stopped and no longer permitted to say, "You must do this, or you must not do it, if you would remain as healthful and as vigorous as you are to-day." The naval medical officer has no place in the dock-yard, no voice in the administrative councils of the Navy Department. The coarse pleasantry of the steerage, which sobriquets him "Pills," and asks, "What do you know about ship-building, or ship-keeping, or ship-cleaning?" is only translated into a politer euphemism, when he is styled the gifted healer of the sick, the beneficent friend of the blind and the lame and the halt, the ever welcome guest in the invalid's chamber, and in the same breath, asked "What have we who are well to do with you, or what have you to do with us?" If he insists upon a hearing, his statements are ridiculed as absurdities, or his facts flatly disputed, his prophecies of evil are scouted as phantoms, and his warnings, rung in never so many changes, laughed at as bugbears, whilst his advice is resented as an encroachment upon a domain too sacred for his tread.

Furthermore, though the physician on shore is never suspected of aspiring to other's dignity in the Navy, there is no doubt a dread, lest this Roderick Random may not some day, while old Trunnion sleeps, smuggle himself under his cocked-hat and steal his trident, a dread that has done more than anything else to retard the cause of sanitary reform on shipboard. Let us hope the day is not distant, when, with mutual confidence begot of mutual appreciation, we can all labor cheerfully in concert, for the greater good of that service to which we have all devoted our lives. Rest assured that no physician, who has

ever read beyond the opening chapter of that work, which is the study of a lifetime, can ever envy any other occupation under heaven, and that he, who has once realized the divine ennoblement of that science, which has the phenomena of existence for its principia, can look on any other as not its humble handmaid. If there be such, he is no master in his craft, and the profession he disgraces, instead of offering him the right hand of fellowship, points at him the finger of its scorn.

The first fundamental lesson in Naval Hygiene, as it is the A B C of Sanitary Science in general, is well expressed in the homely aphorism, "An ounce of prevention is worth a pound of cure." Worship in the temple of Hygeia rather than at the shrine of Therapeia. Pray that you may not be led into the temptations, which end in sickness, before you ask to be delivered from the bodily and mental evil that follows their indulgence. Dread doctors and doctors' stuff as you would disease and death, and welcome him who, while barring the door against the entrance of the one, opens the window to throw out the other.

I am sadly conscious that my words fall idly on most of you. Feeling well, you do not care to think that you may ever get sick. Every face around you reflects your own sense of well-being, and if you do confess an ailment, it is with that comfortable acquiescence that is so often experienced when well-fed parsons denounce themselves and all their hearers as vile sinners. You think you can afford to jeer at my scarecrows, and if I protest against any individual prominence as a sanitary teacher and point to the unbroken front of medical men, civil, military and naval, of every nationality, you intimate that it is professional clannishness, which prefers to sustain a brother in the cloth than to take sides against him. In these days of universal education, every one stoutly maintains his right to his opinion, as well in matters of medical fact, as in religious doctrine and political theory, and not unusually the most valiantly, when he has the slenderest foundation of information. Every mother of a family has her decided views of the fundamental methods of cure, and defends her pet pathy as stoutly as if she were not ignorant that there are such things as physiology, pathology and therapeutics. "I don't believe in malaria," said a worthy old commodore, who could not have told whether malaria was a solid, a liquid, or a gas. "You doctors are all wrong; you don't know as much about these matters as other people," condescendingly remarked another, who has not the reputation of being a bright light in his own vocation. It is this credulity of little knowledge, or of no

knowledge, that is at the bottom of most of the physical ills men suffer in this life. What grander study for any human being than the study of himself, yet how little does the mass of mankind know of itself, and how much it thinks it knows, especially each of his individual self! Who among you does not believe he is best cognizant of his own idiosyncrasies, and of the particular wants and necessities of his own constitution? From the moment the helpless tenant of the cradle can swallow, it is opposed in its natural instincts and made to swerve from its natural tendencies. It is denied its mother's milk on some old dame's dictum that it is too strong or too weak, and fed on ptisans and potions, against which it lustily rebels until it has to surrender from sheer exhaustion. It is narcotized into quiet and then jostled back into noisy life. As it grows older, its animal impulses to grovel with kindred beasts in the mother earth, under the vivifying sun of heaven, are restrained by prim, starched dresses and costly laces that must not be torn, while its appetite is whetted by the sight of food it is not permitted to eat, or only at times and in quantities fixed by some unwritten arbitrary standard, transmitted with the family bible and traditions of the family greatness. Finally success rewards the systematic efforts to dwarf the creature whose innate efforts and longings are toward improved development. Aided by inherited defects of organization (which it in turn transmits intensified), the perverted instincts are irrevocably fixed, and the maturing youth exhibits anomalies of taste and desire, which are rather proudly recognized as having characterized his maternal grandfather. One pale-faced girl resolutely abjures all fat as food, while another meagre damsel refuses to eat anything that has had life in it, meaning, however, only the slaughtered ox and murdered lamb. This youth can stomach only kiln-dried viands—that pretends that eggs and milk and bread and butter do not agree with him, while pies and fries do. A little later in life, the stomach, that organ of whose existence we should only know by negative, which should be the hidden fountain of joy and well-spring of pleasure, which was fit throne for the *archæus*, who thence governed the whole economy of man, has gained a pre-eminence, to which, perhaps, its long endurance of floods of abominations justly entitle it. Instead of the robust, hale and hearty man, self-opinioned obstinacy and self-sufficiency have evolved the *dyspeptic*, that huge gasteropod, which has scarcely anything human about it but its form.

The disbelief in the simple teachings of Sanitary Science, and the almost superstitious belief in the saving power of nostrums, are the



foundation upon which astute quacks build colossal fortunes—belief, which to-day gives you, and those wiser than you, faith in Brandreth's Pills and Jayne's Expectorant, such faith as even Peter, prince of saints, lacked in the word of the Master, but such as filled the noblest of England's aristocracy, who took up their beds and walked at the bidding of so undivine a master as Saint John Long—which opens your ears to homœopathic jargon about potencies and dilutions, and closes your eyes when Regina dal Cin mutters "*finito, finito*"—which causes you to play deliberate havoc with yourselves at the command of the charlatan, who fleeces you of a fee, while you deride the ignorance of the physician, who, though he may have made his profession the earnest study of his life, has the impolitic honesty to say "You want no medicine—go, mend your ways."

It would be only human retaliation for the physician to fold his hands and say, "Drive, if you will, without bit or bridle, and with broken traces, on the brink of the precipice—you may reach your goal, and if you fail you cannot say I was to blame." The practitioner on shore has some excuse for complacently watching his fellow mortals sow the seed from which he is to reap a golden harvest; but if he would, his naval confrère can offer no such plea for non-interference. He dares not be silent. The government has confided to him a sacred trust, which absorbs every individual consideration. Men and women on shore may do what damage to themselves they see fit, provided they do no damage to the communities of which they form a part, but in the Navy there is no such thing as individual license. Personal identity is wholly lost. You and I are only cogs, which help to constitute the machine, and we must fit one into the other, and run without jolt or jar, if it would do its work well. Each of us may be replaced by others and the integrity of the whole be unchanged. The public interest is always predominant, and hence, while the naval medical officer has no popular caprice to which to cater, no prejudices to conciliate, no influence to cultivate, he has a straightforward duty to perform, and if he fails fearlessly to perform it, he betrays his trust, disgraces his office, and, above all, dishonors his profession. His naval uniform absolves him from none of his professional obligations, but with his colleague on shore, his mission is, in the words of Maudsley, "to lessen the sum of human sorrow on earth," and to secure for his fellow mortals the enjoyment of that perfect health, without which there can be neither physical, intellectual, nor moral vigor, and upon which depend, more than upon anything else, perfect contentment and

unalloyed happiness. Holy as is his ministry as a healer, his is the still holier office to keep humanity on that upward approach toward complete development, which began myriads of ages ago, when energy first manifested itself as life in the primordial cell. Disease is the stigma of the physician, the evidence of failure, as the well-filled dispensary and glittering armamenta are the sad expedients of failure. He has best right to boast success who has most packages unbroken, most of his keen knives sheathed. The physician, says Stuart Mill, is the *φυσικος*, the naturalist, and until a comparatively late period physicians were the only naturalists, for though certain phases of this study have been assigned to a class designated in contradistinction by that ill-sounding word "physicist," he it is who is *doctus*, learned in those most mysterious of nature's processes, which distinguish the living from the dead; and though, on shore he is belittled, in the vulgar mind, by association with a herd of sectarian homœopaths, allopaths, antipaths, hydropaths, electropaths and kinesipaths, and the striped pole of the barber and bleeder regarded as the legitimate wand of the surgeon, who, with the eye-doctor, and the ear-doctor, the accoucheur, and the corn-doctor, is only a domestic servant of an upper class, in the service of his country, he is untrammelled by the necessities which oppress the practitioner who has to bid for bread with the masses in the race of life, and, he of all others, therefore, should appreciate the exalted dignity of his office, and the tremendous responsibility it imposes.

Setting aside the flimsy pretence, that if the advice of the medical officer is always sought and his every admonition heeded he will come to fancy that his *ipse dixit* has the force of a military command, a pretence unworthy a mediocre intelligence, there is among the really able men of the service a dread lest all this ado about food and clothing and air and water will tend to the degeneracy of the sailor. If this be so, Nature must have reversed her processes, and we must look to the past for the standard of nautical manliness and proficiency. Where shall we find this typical man of the sea? Was it when Drake and Van Tromp swept the ocean with brooms at their mastheads? Was it when Smollett and Marryatt lived the lives they have recorded—when press-gangs over-ran the streets, and hurried belated men and children from their doorsteps, like droves of captured cattle—when the cat scored bloody grooves in writhing human flesh, while the surgeon or his mate stood with finger on pulse, to gauge how long that flesh could endure, and how close to murder the torturers could

strike; or was it, in our own time, when men were taught obedience shut up in narrow "sweat-boxes," where physiological experiments of the human endurance of foul air, were performed not always short of asphyxia, and discipline was enforced by tricing up alike the indolent, the stupid, and the vicious, inside the rigging, with only their bare feet on the cutting ratlins to relieve their livid wrists and swollen ankles? Was it when semi-annual liberty was the rule, and men and boys, dazed by freedom, were given license for mad, licentious revel on shore, and when brought back with brains on fire were gagged into silence? Was he the model seaman, who hung suspended by his thumbs, his toes only touching the deck, and he the model apprentice, who ironed and bucked, was displayed on the quarter-deck until shame had died in him and vindictive hatred had been born? Was he the typical master of his craft, whose begrimed body was jocosely likened to the barnacle-covered hull, whose only language was blasphemy and obscenity, and whose only longings bestial; who had neither country, home nor kindred, and who hastened on shore after a three, four or five years' cruise, to be beguiled by harpies, who sent him back, after as many day, torn by their rapacious claws, to the officer, a professing Christian perhaps, who welcomed his pitiful coming with a joke and for the time spared him from punishment?

Will you lament as the lost master of a lost art, "honest Jack Ratlin," who could not read, or Tom Pipes, who could only speak a lingo scarcely understood to-day? You must also bewail Commodore Trunton and Lieutenant Hatchway, who joined in the chorus of his drinking song and lifted their cans, says their chronicler, with admirable uniformity "to drink all the while" and resumed with a twang equally expressive and harmonious. Sir Walter Scott says of these characters, every one of which belongs to the old English Navy, that "they preserve the memory of the school of Benbow and Boscawen, whose manners are now banished from the quarter-deck to the forecastle. The naval officers of the present day," he adds, "the splendor of whose actions has thrown into shadow the exploits of a thousand years, do not affect the manners of a foremastman and have shown how admirably well their duty can be discharged without any particular attachment to tobacco or flip or the decided preference of a check shirt over a linen one." It was a landman's natural inference that the quarter-deck had affected the manners of before the mast, when in fact the same atmosphere was breathed both forward and aft. "Damn your eyes"—"You lie you lubber"—"Damn your bones, you porpuss-faced

swab"—“You and your list be damned, I say I shall have no sick on this ship while I command her,” were random phrases of a dialect well understood by the poor brutes to whom they were addressed; and while Captain Oakum cursed and despotized, Doctor Mackshane played the abject sycophant to those above him and the merciless tyrant to all below.

The change which led Scott to remark that these manners were banished from the quarter-deck to the fore-castle, has been gradually going on ever since. Education and refinement have entered not by the hawse-holes but by the cabin windows, and as their light has grown brighter it has illumined the foul corners of the fore-castle, and the dirt and disease are vanishing with the darkness.

“The piece of old sail for a table-cloth—the pewter plates and spoons without handles and abridged in their lips—the salmagundy of beef fresh from the brine, mixed with an equal quantity of onions, seasoned with a moderate proportion of pepper and salt and brought into consistence with oil and vinegar;”—“the boiled peas on the wooden platter, enriched with a lump of salt butter scooped from an old gallipot and a handful of onions stewed with some pounded pepper,” are not now the garnishments of an officer’s mess; and midshipmen no longer use supple-jacks on men and boys already clotted with blood, nor are themselves delivered over to the master-at-arms to be clapped in the bilboes. But is this, too, a tale of rude forefathers, though forefathers only a century removed, “Here I saw about fifty miserable distempered wretches, suspended in rows, so huddled one upon another that not more than fourteen inches space was allotted for each, with his bed and bedding, and deprived of the light of day, as well as of fresh air, breathing nothing but a noisome atmosphere of the morbid steam from their own diseased bodies”?

It was but little more than twenty years ago, that I saw sixty miserable distempered wretches, suspended in rows not more than fourteen inches apart, breathing just such an atmosphere of morbid steam, and this—because hygiene was believed to be a land exotic, which could not flourish on board ship—because human bodies, which exhale every day half a gallon of fluid from skin and lungs alone, were doled out only a pint of water for cooking and drinking and another pint for ablution—because they had been fed with spoiled provisions, which in blind adherence to routine regulations to use the oldest stores first, required beef hard as mahogany, green pork, beans alive with weevils, worm-eaten bread, and mouldy rice to be served out before fresher

articles could be opened—because, with stolid blindness to cause and effect and stolid deafness to reason, the tanks had been filled with unwholesome water, rather than incur a trifling expense for filtering, though five times the sum had subsequently to be expended for costly drugs to neutralize, and not always successfully, the needless harm that had been done—because in the same spirit of misdirected economy which refused to employ native boatmen, the crew had been recklessly exposed at fatiguing work to an intense tropical summer heat—and because, in accordance with the false system of discipline of the time, they had been imprisoned eight months on board ship, and then hurried on shore for forty-eight hours to riot in debauchery, and return with brains crazed by rum and bodies inoculated with a poison, which was to ruin them and their children and their children's children.

It was but three years ago, that I saw as many more miserable distempered wretches, suspended in rows, only fourteen inches apart, breathing just such an atmosphere of morbid steam; and this—because hygiene never entered into the thoughts of the constructors, the engineers, the equipment officers, and the recruiting officers, who built and furnished this home for human beings and left no chamber in it where health could dwell—because, as it had been built it was peopled, and stalwart, intelligent defenders of the country, had been sought among the chance waifs of the street, and ragged starvelings and bezonian outcasts were sought to be converted into seamen and gunners—because a drove of inexperienced, incompetent and enfeebled landsmen (two hundred and forty-nine on board one ship had never been to sea before) had been herded like sheep on damp decks never dried, exposed to the inclemencies of winter weather insufficiently clad, many without bedding or sleeping billets, sea-sick, homesick and consequently ill-natured and physically unable to perform the arduous labors expected of them—and because medical examiners, whom neither age nor incapacity should excuse, had certified falsely to the physical fitness of recruits, who were condemned as invalids with long standing disabilities, the very day they were received, and sent back by the very transport which had brought them.

And, to-day, if you will stand over the fore or main hatch on board any vessel in the service, just before the close of a night watch, when all hands have been below, you will be sickened by a single whiff of just such a steaming, noisome, morbid atmosphere from men wedged in hanging rows only fourteen inches apart—well men, but well only until they chance to come within the orbit of some of those morbid

germs, which circle around the earth and which will find in them the soil they need to be ripened into epidemic malignancy.

A great change has really been accomplished in the conditions of life on board ship and especially during recent years. There are many officers in the navy who have never seen a cat nor a gag, and who read of the "sweat-box" and bucking stick, as they do of keel-hauling; but all has not yet been done that may. There is good water in plenty, but is it always bountifully issued, even in hot climates? Food is abundant, but are fresh potatoes, onions and succulent vegetables carried as sea-stores for the crew? The clothing-room is well stocked, but are the contents of the best quality that can be provided? The clothes-bag is portly enough at the end of the cruise, but how is it at the beginning? Men are advised to be cleanly in person and attire, but is this more than a formal requirement, and are bathing facilities accessible even to officers? Hammocks are scrubbed often enough, but do the mattresses and other bedding get even aired as often as the regulations require, and is not a cloudy day considered rather a joyful escape from a disagreeable necessity and a fortnight allowed to elapse before the routine brings another bedding-day with perhaps the same result? Better food, better water, better clothing, better treatment, has each accomplished its share of good—but the worst enemies of the sailor still remain to be subdued. I repeat here, as I have reiterated elsewhere, that foul air and the vapor of water, are the direst foes which menace the sea-farer. Leagued together they are greatly more to be feared by him than the atmosphere of the most sickly climate, or than the boundless waters which environ him; and the object I have had in coming before you to-night will be fully accomplished if I succeed in giving any of you an impression of the terrible power for evil of these allied princes of darkness. When scurvy and dysentery and ship-fever were accounted the plagues of the sea, these did the larger share of the deadly work, and since the ravages of those blatant destroyers have ceased, these are still silently but rapidly adding new names to the roll of the dead. There is now no "intolerable stench arising from the space as dark as a dungeon below the water-line, where provisions were being served out"; but "by the faint glimmering of a candle," one may still see a "man, with a pale, meagre countenance sitting behind a kind of desk, spectacles on nose, and pen in hand," the man who is being slowly poisoned by foul air. The decks are not slippery with filth, and the air alive with reeking horrors as in the fore-castle of the merchant ship to-day, that neglected

field of missionary labor, where brutal savages with Christian names, for whom the Deity is only the capping of an oath, are ignored, that greasy, well-fed negroes, rolling on "Afric's golden sands," may be clothed in unnecessary trousers. There are no blackened paint, no untidy bunks, no disordered kits. Everything is in beautiful array when the inspecting officer makes his morning rounds, or when expected visitors gaze with bewildered admiration at the well-scraped planks and well-scoured brasses. Over the starboard side of the quarter-deck, down the after ladder, along the port side of the gun-deck to the galley and back, and, should some one ask to go still lower, after a momentary delay and the sound of feet rushing up the fore hatch, the visitors are marched along the berth-deck, bright with lighted candles, into the sick-bay, also ablaze with candles—all "so nice," "so still," "so roomy," "so cool," "Is it possible so many men live here?" "Where can they all be?" This is the man-of-war as dames and damsels and learned land lubbers only know it. These never see the decks when they are ankle deep with water, and never crouch and crawl under the crowded hammocks to shoulder themselves through the rows of closely-packed humanity. Few officers, indeed, ever breathe this atmosphere but those of the medical corps and their subordinates; certainly never those who wear the mantle of authority and the ermine of judgment, and who are not, therefore, assailed by that rude appeal to the senses, which carries speedier conviction than figures the most exact and logic the most sound. If ships are overcrowded and badly ventilated, it is because they are believed not to be so. It is from ignorance, perhaps inexcusable, not from deliberate, unpardonable indifference to the result. Ships are not deluged with water to make them unhealthy, nor to spite doctors, nor to inconvenience or punish crews, but to make them clean, in compliance with a system which long custom has perpetuated and identified with the service, as it has the meaningless clatter of the tattoo, and the puerile piping of the side, which with the absurd parade of two, four, six or eight ungainly boys is the measure of approaching or departing naval dignity. As soon as a pendant is hoisted, as the symbol of a naval command, be it over never so small a tug-boat or surveying schooner, commences the servile imitation of the doings of the frigate, where spar-deck and gun-deck, berth-deck and orlop are inundated every day in the year, in all weather, at all seasons, and in all climates. The creak of the deck pump, the squeak of the squilgee, and the rumble of the holy-stone open the day, and after hours of hard labor, Jack sits down to a meagre breakfast

on soggy sodden planks, which have been cleaned of all but water, to breathe an air which all his cleaning has only loaded with uncleanness. Bits of yarn and spots of grease, though unsightly, are less dangerous to health than the gallons of water which fills the air as vapor, saturates the clothing, and permeates the very tissue of the wood of which the vessel is built. It is not the water without the vessel, but that within it, which imperils life. It is this invisible agency which gives potent virulence to the microscopic germs which are born and brooded in the stagnant corners of the holds and bilges and berth-deck, which is the fuel that kindles into destructive activity the morbid influences of over-crowding, which dissolves and, having dissolved, introduces into the body and blood those pestilential seeds of disease, which will there ripen and multiply, until they blight and wither and destroy. A very hasty reference to a few established physical facts may satisfy you that this is no romance.

You are all aware, as is every schoolboy, that we are surrounded by an invisible atmosphere, composed of oxygen and nitrogen gases in the proportion of one-fifth the former, to four-fifths the latter, a proportion which is uniformly maintained as well on the summit of the loftiest peak as at the bottom of the deepest abyss, as well on the surface of the earth a thousand miles from the sea-coast, as on the surface of the ocean as many miles distant from the shore. Of these oxygen is the great awakener of energy, the supporter of combustion, the sustainer of life. The human, with every other being in the flesh, must have oxygen to live, and in a proportion as invariable as the constitution of the air itself. Flint says of large bodies of men subjected to exposure or frequently called upon to perform great labor, that collectively they are like a powerful machine, in which a certain quantity of material must be furnished in order to produce (evolve) the required amount of force; but to make this material available, there must be oxygen supplied, as it must be supplied to the machine made by man's hand to burn its fuel and release its pent up force. The ruddy fires of the engine darken and its work slackens as the supply of oxygen is diminished and mechanical ingenuity is strained to feed it with too much rather than it should suffer any want. The ruddy blood of man, which awakens the brain from its death-like sleep, which warms the muscles into pliant vigor, which lifts the veil that screens the senses from the outside world, darkens, and all these processes, the sum of which we call life, are imperfectly performed, if the supply of oxygen is diminished; but what mechanical ingenuity is



strained that this, the very food of life, should be furnished in even bare sufficiency? Under ordinary circumstances, the function of respiration introduces into the lungs, where it comes in contact with the blood, about twenty times a minute, twenty cubic inches of air—a total of about fourteen cubic feet per hour, or from three hundred and fifty to four hundred cubic feet—that is from two thousand two hundred to two thousand five hundred gallons of air a day. About one-fiftieth of this totally disappears, the not quite five per centum of oxygen, which has been absorbed, having been replaced by something more than four per centum of carbon di-oxide. The skin also acts as a respiratory organ, performing two and a half per centum of the lung work, the cutaneous exhalation of carbonic acid being greater in a moist than in a dry atmosphere. This one human machine has, therefore, not only robbed the air of more than one hundred gallons of its vital constituent, but it has added to it nearly a hundred more of one of the subtlest, deadliest enemies to life that is known. So intolerant is the human system of this poison, that while four parts are normally present in ten thousand of air, the mere increase of two parts in ten thousand is immediately resented, and first inconvenience, then injury, and finally death are caused by it. This is not speculation. These are physical facts, arrived at by experiments upon living creatures, human and animal. One human being having consumed over one hundred gallons of oxygen, and having manufactured between ninety and one hundred gallons of carbonic acid gas, it is a very simple matter of calculation to show that to dilute this down to within the limit of what Parkes terms “permissible impurity,” will require a minimum hourly supply of nearly twelve hundred cubic feet of air, or about twenty cubic feet or one hundred and twenty-five gallons per minute. I repeat this is not a theoretical assumption. History has furnished its verification, one instance of which, however familiar to medical readers, may be new to some here.

“One hundred and forty-six prisoners were confined in a room eighteen feet square and about ten feet high, having an air space of twenty-two cubic feet per man, without estimating for the air excluded by their bodies. Two small windows opened into this room, and allowing that through these windows there was a supply of four feet of air per minute for each individual, (that is twenty-five gallons of fresh air per minute for each prisoner,) before five minutes after the door was shut, the hapless inmates began to re-inhale their own exhalations, and this process was repeated at each successive period

until death began to reduce their number. At the end of six hours, ninety-six had died—two hours later one hundred and twenty-three were dead—and of the twenty-three survivors several subsequently died of putrid fever.”

This great physiological experiment, which lives in the annals of history as the tragedy of the Black Hole of Calcutta, but which had a mortality of only four per centum greater than that of the prison in which two hundred and sixty out of three hundred Austrian prisoners were suffocated after the battle of Austerlitz, has been frequently repeated in a minor degree on board emigrant vessels and slave-ships. Carpenter narrates the following nautical instance of comparatively recent occurrence:

“On the night of the 1st of December, 1848, the deck passengers on board the Irish steamer “Londonderry,” were ordered below by the captain, on account of the stormy character of the weather; and although they were crowded into a cabin far too small for their accommodation, the hatches were closed down upon them. The consequence of this was, that out of one hundred and fifty individuals, no fewer than *seventy* were suffocated before morning.”

But carbon di-oxide is not the only impurity added to the air by the respiratory process. The expired breath is loaded with putrescible organic matter—it is saturated with the vapor of water—and raised to the temperature of 95° to 97° F., while cutaneous transpiration, as already stated, adds its quota of gaseous and organized waste, so that, though twenty cubic feet per minute of fresh air are required to dilute the carbonic acid gas alone, at least fifty cubic feet (over three hundred gallons) per minute, three thousand cubic feet per hour, are required to overcome the entire pollution of the atmosphere by a single individual. The loss of weight, by insensible perspiration from the surface of the skin and lungs, has been experimentally shown to amount to three avoirdupois pounds daily, and the offensive putrescent character of the effete organic matter thus added to the atmosphere is manifest to any non-professional observer, who has the courage to visit a crowded berth-deck, or simply hold his head over a fore or main hatch or opposite a berth-deck ventilator. There is a horrible mawkish something in the air, which something is what pathologists term the poison of *Ochlesis*,—the poison of over-crowding. It is the mother of that family of destroyers, ship fever, jail fever, typhus, which has made such sad havoc in the human race. How largely it accumulates was shown by Angus Smith, who found in the hills above

Manchester only one grain of organic matter in two hundred thousand cubic inches of air, while in the crowded courts of the town there was one grain in only eight thousand. How fatal to life are its effects upon the human system, Carpenter illustrates by the following example of the tendency of the respiration of an atmosphere charged with the emanations of the human body to favor the spread of zymotic diseases:

“The dwellings of the great bulk of the population of Iceland seem as if constructed for the express purpose of poisoning the air which they contain. They are small and low without any direct provision for ventilation, the door serving alike as window and chimney; the wall and roof let in the rain, which the floor, chiefly composed of hardened sheep-dung, sucks up: the same room generally serves for all the uses of the family. The people are noted for their extreme want of personal cleanliness, the same garments (chiefly of black flannel) being worn for months without even being taken off at night. Notwithstanding the number of births is fully equal to the usual average, the population is stationary, and in some parts is diminishing, the average mortality during the last twenty years, during the first twelve days of infantile life alone, being no less than sixty-four per centum or nearly two out of three.” “Now,” continues Carpenter, “it is a little remarkable that under conditions almost identically the same, the island of St. Kilda, one of the Western Hebrides, has a diminishing population, four out of every five dying during the eighth and twelfth days of their existence, the great if not the only cause of this mortality being the contamination of the atmosphere by the filth amidst which the people live.”

Visible, tangible filth is instinctively shunned by every human being, who has been raised above the level of brutish animality, but the invisible filth, which befouls the air in the crowded car, in the theatre, in the private chamber, and in the house of God, is breathed without loathing or aversion by the gentlest born and by the already frail in health. “The foulness of air due to the non-removal of the volatile refuse of the human body,” says Simon, the distinguished English Sanitarian, “is as strictly within the physiologist’s definition of filth, and as truly a nuisance within the scope of sanitary law, as any non-removal of solid or liquid refuse.”

About twenty years ago, the frightful sickness and mortality on board emigrant ships coming to the United States induced a Congressional inquiry by a select committee of the Senate of the United

States, of which the Hon. Hamilton Fish was chairman, and they, as non-medical laymen, reported unanimously, from the numerous examples before them, "that the atmosphere when charged with the effluvia caused by the exhalations of the human body, if inhaled into the lungs, will inevitably produce disease and death," and they found the natural remedies in less crowding and a bountiful supply of pure air.

The Calcutta experiment demonstrated that twenty-two cubic feet per man, each receiving four cubic feet of air per minute, were not enough to sustain life; and Dr. John H. Griscom of New York testified before this committee of the Senate that "a recent examination of the two steerages of one of the largest packets belonging to this port gave as a cubic space for each passenger, not deducting the room occupied by the necessary solid contents of the bodies of the passengers, for the upper apartments one hundred and three feet, and for the lower one hundred and twelve. This vessel lost on her homeward passage one hundred passengers at sea," and Dr. Griscom stated, and this committee of Congress indorsed his statement, that not less than two hundred and fifty or three hundred cubic feet of air should be given to each passenger.

The English Army Sanitary Commission's report, published in 1858, shows that the excessive mortality from consumption in particular regiments, was due to contracted quarters and insufficient ventilation. The air space in the barracks of the Foot Guards only amounted to 331 cubic feet for each soldier and the mortality from pulmonary phthisis alone was 13.8 per thousand. In those of the Horse Guards, on the other hand, with a space per man of 572 cubic feet, the mortality from phthisis did not exceed 7.3 per thousand. After the report was made, the number of cubic feet was increased and the ventilation improved, with a material diminution in the number of patients.\*

Now, very few of you are probably aware that the dimensions of the best wardroom staterooms in our Navy are less than the smallest of these numbers, and it must be borne in mind that even this space is encroached upon by a cumbrous bureau, by a bulky washstand, by a bunk which alone occupies one-fourth of the whole space, by clothing, by books, by purchases, and often by private stores, until the officer is really but little better off than the man before the mast, and how he is circumstanced may be judged by the official reports to the Navy Department for the years 1873 and 1874, which show that while on board

\* Donaldson American Public Health Association Report, vol. I, p. 102.

frigates of the Franklin and Wabash class, each man had from 125 to 175 cubic feet, the cubic air space for each individual on board the smaller vessels was only, on the Shenandoah 96, Monocacy 95.35, Saco 90, Omaha 89, Wyoming 89, Wachusett 88, Hartford 87, Kearsarge 81, Iroquois 80, and Kansas 60, the worst of all being the Juniata, which in 1874, gave only 55 cubic feet to each man with no less than *twenty-nine* of her crew reported as having "no sleeping-billets,"—yet this vessel was once a school-ship. Do not misunderstand me to imply that Sanitary Science is an alien only on shipboard. A formal medical report declares that a very large majority of the pupils in the Cincinnati public schools are to-day breathing an atmosphere containing more than one-tenth per centum of carbonic acid gas.

But carbonic acid gas and organic emanations are only two of the factors of this triune evil-doer: the third is water—water which constitutes so much of the earth's surface that were the land levelled, it would cover the whole globe in one continuous sheet a mile deep—water, which is by far the largest constituent of the human body itself—water, which exists with equal ease as solid, liquid or gas, but which is so delicately and accurately proportioned to the several wants of animated existence that the slightest irregularities in this distribution are productive of harm; and which better than any other natural agent typifies the creative Brahma, the preserving Vishnu, and the destroying Siva. Air is saturated at 52° F., by between one and two per centum of its volume of water in the state of gas, in weight about four and a half grains to the cubic foot. As the temperature rises it becomes able to retain a larger quantity in solution, being saturated at 77° by three per centum. The fluctuations which the rheumatic so sensitively appreciates sometimes correspond to a change in weight of less than a single grain, and it is within the experience of every one that simple changes in the temperature, as indicated by the thermometer, do not explain the varying shades of comfort or discomfort. The surface of the average adult human body represents a superficies of twenty-five hundred square inches perforated to the extent of several thousand openings to the square inch. Through these microscopic pores the gaseous and vaporous excreta of the body find exit. All human processes are essentially physical and governed by simple physical and chemical laws. The escape of water from the skin is by evaporation, and evaporation is rapid or slow according to the hygrometric condition of the atmosphere. The important function of calorification—so important that the intelligent physician to-day reads the issue of

life or death from the scale of his clinical thermometer—is largely influenced by the simple laws of evaporation, and in Carpenter's standard work on Physiology, it is stated, that "experiments made upon the living body show that the most important external factor in determining the amount of evaporation was the relative dryness or moisture of the air, next came the temperature, and then the ventilation or the amount of air blowing over the surface," and Lehman demonstrates that the cutaneous expiration of carbonic acid gas is also largely influenced by humidity of the atmosphere. Wagner states that warm and damp air most prevents the radiation of heat from the body through the skin and lungs, causes exhaustion of the muscular and nervous systems, restrains respiration, diminishes the appetite, impairs digestion, and increases perspiration. The report of the Irish Census Commissioners, quoted by Professor Donaldson, shows the mortality from consumption in the damp spring months for ten years to be twenty-two thousand more than at the dry season. "A dry atmosphere," says Hunt, "is a healthful atmosphere and opposed to the propagation of all zymotic diseases." "Humidity," declares Pringle, "is one of the most frequent causes of the derangement of health"; and Fonssagrives summarizes the experience of French naval medical officers in these terms, "Qui dit bâtiment très-humide, dit bâtiment malsain." "With naval medical men of all nations," authoritatively declares Surgeon-General Beale, "it has passed into an axiom that a dry ship is a healthy ship."\* Commander John McNeill Boyd of the Royal Navy, candidly admits that "the objections to wet decks are supported by the medical officers, with such a weight of evidence that they can not be gainsaid." Admiral Collingwood paid so much attention to the health of his men, "that in the latter years of his life, he had carried his system of arrangement and care to such a degree of perfection, that perhaps no society in the world of equal extent was so healthy as the crew of his flag-ship. She had usually eight hundred men; was on one occasion more than one year and a half without going into port, and during the whole of that time, never had more than six, and, generally, only four on her sick-list. This result was occasioned by his attention to dryness (for he *rarely permitted washing between decks*), to the frequent ventilation of the hammocks and clothes on the booms, to the creating as much circulation of air below as possible, to the diet and amusement of the men."†

\* Report of the Secretary of the Navy for the year 1876, p. 235.

† Life of Vice-Admiral Lord Collingwood, by G. L. N. Collingwood, London, 1837, Vol. II. p. 131.

Will you dispute in the face of all these authorities the assertion that the practice of daily wetting the decks, especially those on which men live and sleep is productive of harm? Is it a mere coincidence when a vessel on which the decks have been wetted once in every thirty hours, where the hygrometer shows an average saturation of over eighty per centum, requiring the fall of only a single degree to precipitate it in the form of a miniature rain, and this (I quote from the annual report of the Surgeon-General of the Navy) "notwithstanding steam was used for its drying properties on as well as below the berth-deck, some two hundred and three out of three hundred and eleven days,"—is it a mere coincidence when such a vessel, exhibits an excessive daily sick list and a constant shipment homeward of condemned invalids, captain, officers and men? Yet in the very teeth of experience, in spite of the advice of men competent and paid by the government to advise, the "Trenton," which presumably represents the acme of modern scientific naval construction, is provided with hawse-pipes leading direct to the berth-deck, conduits through which mud and water will necessarily pass. It was this and only this, which induced the removal of the sick-bay aft: but what a folly to pretend to care for the sick, when provision is made for creating sick by wholesale! Sick-bay bulkheads are not wanted when the whole berth-deck is apt to be a sick-bay. At any other cost than a wet berth-deck the removal of the sick-bay from its submarine abode in the obscure twilight and sluggish humid atmosphere of the extreme forward end of this deck would be some cause for gratulation. Here, for years, has been the prescribed home of the sick, the *hospital* proper, though not so designated, from conscious sense of inappropriateness in a place which is only a reservoir for the mephitic vapors which escape from the contiguous paint-room, oil-room, yeoman's store-room, and berth-deck, from leaking sewer-pipes led through it, and from the bilge-vents, which actually open into it. The intelligent landsman, on shore (and many besides physicians are sanitary experts), who foolishly fancies that the Surgeon-General of the Navy, the Chief of the Bureau of Medicine and Surgery of the Navy Department, has had everything to say about the proper location of a hospital for sick men, and who may even suppose that this high officer and his colleagues have been invariably consulted as to the means by which other men may be kept from getting sick, may well wonder at this site, which any graduate in medicine, with a diploma a day old, would never think of selecting. Experience has already indicated that the proper place for the sick is wherever they can

best be treated, and that is never in the sick-bay, where no one seriously ill ought ever to be confined, and where no case of minor degree can remain without risk of becoming worse. A large, well lighted dispensary should furnish proper facilities as a consulting, prescribing, and operating room; and besides this, canvas screens are enough to isolate the very sick, wherever the special circumstances of their cases or the public duties of the vessel require or permit them to be accommodated; while those unable to do duty from lesser ailments should have no loafing place below, but should be kept in view on deck, in the light and air, with some prominent mark upon their dress, as suggested to me by Lieutenant-Commander Brown (the Geneva Medical Cross upon the arm for example), to distinguish them from the rest of the crew and to indicate to the officers and others of the watch, those who are entitled to be excused from their customary work.

The same experience which has taught physiologists just how much food and how much oxygen are absolutely necessary to the body, has also taught them how much moisture in the air is healthful. Beyond this it is hurtful; cutaneous transpiration is checked and effete matters are retained, and as upon the activity of the removal of the waste of organic life depends the activity of vital phenomena, how quickly fatal this retention may be when complete, was strikingly illustrated by an instance, quoted from Laschkewitsch by Flint, of a child who died a few hours after having been covered with gold-leaf to represent an angel at the ceremonies attending the coronation of Pope Leo X.

The presence of an excess of water-vapor in a fetid atmosphere of elevated temperature increases its morbid power by presenting the noxious emanations in a soluble form. The rain, poured in through the crevices of the walls and roofs of the Iceland huts, was soaked up by the dried dung floors and then greedily absorbed by the warm foul air. The filthy decks of the pest-ridden ships are always damp, their air always moist. True ship-fever is no longer the scourge of the sea as of yore, since other improved sanitary conditions have moderated that intensity of crowd-poison, or mitigated its effects, which is necessary to develop fevers of this type into an epidemic outburst. But what means the long array of figures, in the medical return of the navy and merchant marine, of diseases of the respiratory apparatus? Is the seaman's vocation, particularly in the naval service, so arduous that the average duration of a sea-going mariner's life is now estimated to be only *twelve* years? Do we not, in the navy, by the most rigidly careful, preliminary physical examination, exclude not



only the feeble but those predisposed to disease, especially of the pulmonary organs? Yet are not ten, twenty, thirty a day no uncommon sick-lists for vessels with complements of only two or three hundred men? Is it not a fact that by the end of a three years' cruise, of the two hundred who had sailed from home, at least fifty per centum have disappeared—by discharge, by desertion, by invalidment—and have been replaced by recruits enlisted on the station? Why can I and others not much older look back and find ourselves the sole survivors of the messmates, who sat around the same table with us only twenty years ago? and why are so many of us to-day, the solitary representatives, upon the Navy Register, of classes who entered the service with medical certificates that they were not only free from disease but notably exempt from its inherited tendencies? Resignation has drawn some away to other fields of labor, but many of these had impaired health as their actual incentive. The common incidents and accidents, which assail life elsewhere, represent a still smaller percentage. Rum has slaughtered its hundreds, but can you say that the thirst for rum was not first developed by the sense of bodily and mental weakness induced by bad hygienic surroundings, which in a multitude of other though less conspicuous and demoralizing ways accomplish results equally pernicious to health?

It is no fanciful ideal, but a vivid reality, which may be seen on board almost every vessel in our Navy, of a once robust, healthy, intelligent and educated man, who must have fifty cubic feet of fresh air per minute, as he must have two and a half pounds of solid and three pints of liquid food per day to maintain his physical vigor and mental power and moral tone, sitting in a narrow stateroom, where furniture, bedding, clothes, books, purchases and human bodies leave space for scarcely one hundred and fifty cubic feet of air—a three minutes' normal supply—which can only be replenished (impervious bulk-heads shutting out every other inlet), through the doorways, oftenest shielded by thick worsted curtains, or through the little round air-port (or half an air port as in the Trenton) necessarily closed at sea and usually so in port to exclude "drafts" and "damp night air"; while it is being contaminated by the three pounds of effete matter which he and every one of his visitors daily add to it, by the four gallons of carbon di-oxide, which he and they and every one of his lighted candles pour into it, and by the emanations from his soiled linen, from his perishable stock of private stores, from the neighboring pantry and its odorous inmates, and from the foul bilges which discharge,

again, as in the Trenton, that newest of our men-of-war, beneath his bunk or directly into his lungs. I have seen this man, as you may all see him if you look with unclouded eyes, sitting night after night, reading, writing, studying; faithfully, earnestly, conscientiously striving to do his duty as an honorable officer and an upright man, but slowly, surely, inevitably ruining his health and shortening his life. Not more certainly does death come to the suicide, who closes his door to sleep beside a lighted charcoal brasier than it will to him. Sooner or later will be heard the cough, which he will attribute to wet feet, to exposure on deck, to drafts from windsails, to anything but foul air; ultimately, he will go home, invalided with pulmonary disease, who, a few years before, may have boasted his five inches of chest expansion, and who honestly and truthfully had certified that there was no hereditary taint or predisposition to disease in any of his blood. It was foul air—foul damp air, which has disabled and will kill him. What is true of the officer is equally true of his humble shipmate before the mast. Parkes declares that “statistical inquiries on mortality prove beyond a doubt, that of the causes of death, which usually are in action, impurity of the air is the most important,” and especially that the pulmonary consumption which has been almost epidemic on board some British men-of-war is due to faulty ventilation. I have myself no doubt that a large per centum of the invalids, who are now yearly discharged from our own service with “certificates of ordinary disability,” on account of pulmonary affections presumed to have been inherited, have actually been disabled only by the respiration of damp, foul air. Fortunately the daily labor in the open air somewhat counteracts the mischief wrought at night, but the effects of ochletic poisoning are cumulative and, sooner or later, destructive to health. There is no fact in etiology more firmly established than this—none which you will not, for all that, probably so readily discredit—you who on shore most dread and studiously shut out the night wind from the distant marsh, while you carelessly sleep in a ship’s bunk, directly over as foul a marsh as you can find anywhere on earth. The recognizable elements of malaria, any student of natural phenomena, whether you style him physician or physicist, will tell you, are decomposing vegetable matter, subjected to the simultaneous influence of air, moisture, and high temperature. The naval constructor supplies the first, when he builds the vessel, by planking up refuse chips where they can decay; heat and air are always present; while accidental leakage and deliberate deluging of the decks supply the only other lacking condition

for miasmatic life—excess of aqueous vapor. The fever ship is the fecund womb in which the deadly offspring of foul air and dampness are nurtured into being.

Naval Hygiene is not Naval Communism. It does not require captain and crew to cluster around the same messcloth. It does not seek to divide the ten thousand cubic feet of air space of the Admiral's quarters, nor the three or four thousand of the Commander's cabin, among the men who have only eighty or ninety. It recognizes the existence and the necessity of class distinctions. It would be no kindness to the wearer of blue flannel to submit him to the conventional restraints and formalities incumbent on the wearer of blue broadcloth. The food which the latter relishes would be as distasteful to the former as their respective avocations; but just as Christian law teaches that all men, coal-heaver and commodore, have equal hope of immortality, so sanitary law gives to every member of the brotherhood of humanity an equal claim to that light and air and water which are the common heritage of every human being, and makes it the duty of the community to see that they are supplied in abundance and purity. Especially is this the duty of the State toward those individuals who devote their lives to its service, as well in justice to them as with regard to its own economic interests. The British Board of Health has brought this startling fact to light, that the difference in the annual rates of mortality between the most healthy and the most unhealthy localities in England, amounting to no less than thirty-four in every thousand, is almost entirely due to zymotic diseases, which might be exterminated by well-devised sanitary regulations. What Carpenter terms "the *inevitable* mortality, arising from diseases which would not be directly affected by sanitary improvements, is a nearly constant quantity, namely, eleven per thousand. The average mortality of England, in ordinary years, is about twenty-two per thousand, or nearly double that to which it might be reduced, so that taking the population of England and Wales (as by the last census) at 20,000,000 the average annual mortality must be 440,000 of which 220,000 is inevitable and an equal amount *preventable*."

Dr. Simon, Chief Medical Officer of the Privy Council and Local Government Board of Great Britain, in his work on "Filth Diseases and their Prevention," just published, says: "That the deaths, which we in each year register in this country, (now about half a million) are fully 125,000 more numerous than they would be if existing knowledge of the chief causes of disease, as affecting masses of popu-

lation, were reasonably well applied throughout England, is, I believe, the common conviction of persons who have studied the subject."

Dr. Draper, Examiner of returns of Births, Deaths and Marriages in Massachusetts, reports in a letter dated September 25, 1875, to Dr. Henry Bowditch, Chairman of the State Board of Health, that "the total number of deaths in Massachusetts, during five years, from all causes, was 156,289. Of that number deaths from zymotic diseases comprised twenty-six per centum, those from acute pulmonary diseases seven per centum, and from phthisis seventeen per centum—so that if we include all these among the preventable diseases, the results from these causes represent one-half the actual mortality."

"From such imperfect statistics as have been gathered in this country," declares Mr. Bayles in the *International Review* for March, "it is safe to conclude that zymotic diseases cause, directly or indirectly, about one-half the deaths occurring in our great cities."

One-half of all the dead in the two most advanced of Christian nations sleep before their time! One-half the vital energy which is the motive power of modern progress needlessly wasted! Ordronaux has pointedly stigmatized preventable mortality as criminal mortality; and you and I are criminally responsible if we neglect to do with all our might that which may reduce this preventable mortality one solitary human life, just as criminal as though we should turn our back upon a would be suicide, or fail to snatch a helpless child from impending death.

I do not propose, this evening, to indicate what may be done in the way of sanitary reform in the Navy. I have only had time very cursorily to point out the most notable defects in our hygienic system, without suggesting in detail how they may be remedied. Fortunately there are no very difficult problems to be solved. The cubic air-space can not be augmented by enlarging the dimensions of our ships but by reducing the complements of their crews to their lowest limits. Labor-saving devices, as on board merchant ships, should supplant muscle wherever possible. The host of idle, unclean, dirt-producing landsmen and servants, now necessitated by the needless multiplicity of officers' messes, should be thinned out. The ship's cook should be dignified and as many testimonials of his competency exacted as are now required respecting the police ability of the master-at-arms. Improved methods of ventilation, such as that proposed by Passed Assistant Engineer Baird of the U. S. Navy, should pump out foul air and pump in fresh, and by keeping it in motion (pervious bulkheads

allowing it to course freely everywhere) prevent its accumulation in stagnant pools in obscure corners and culs-de-sac. The infamous system of discharging the emanations of the bilges through vents upon the berth-deck and into officers' staterooms, as is being done this very time on board the Trenton,\* should no longer be permitted to disgrace our naval construction. Above all, the air should be kept pure and dry; every deck below the water-line should be first painted, then coated with shellac, and, soiling being scrupulously prevented, cleaned only on proper days by mop and hot water, never deluged and then fruitlessly sought to be dried by mere steam heat, which only raises the point of saturation, since any old woman who hangs a wet shirt before a fire, knows that the water does not go out of the shirt into the fire but into the air. This is but an earnest of what ought to be done; but this little should be done at once.

Disproportionate as are our sick-lists to the normal accidents to health among adult men from whom all those liable to disease had been previously eliminated, they do not adequately represent the actual physical deterioration of the naval service. The grossly abused system of medical surveys is the covered drain out of which flows in a steady stream the wasted health and strength of the navy. I fear a whole hour might be profitably devoted to the discussion of the objectionable features of this one matter of medical surveys—too often the refuge of the malingeringer, who trades in idleness, and successfully crosses by this bridge between the rendezvous and naval hospital, and of the discontented officer, who does not scruple to avail himself of this questionable means to escape a distasteful ship, or station—too often the sham pretext for getting rid of incompetents, who should never have been enlisted—too often the pall hastily thrown over heedlessly squandered and fatally blighted health.

With good food and hearty appetites, pure air and ruddy faces, abundant water and clean skins rightly clad, there will be merry laughter and ready obedience, strong arms and self-enforced discipline; as without them, there will be prison-brigs never empty of sallow, surly, sullen faces, the unkempt, unclean doers of evil, and sick-bays overflowing with sick and malcontents—disobedience and disorganization before the mast; dissatisfaction and insubordination abaft. With no sick, no dead, no dying, the medical officer's occupation will be gone—gone, indeed, if you look upon him as standing, phial and catlin

\* Captain Davis had them closed on the representation of the medical officer, after the ship went into commission under his command.

in hand waiting for victims—not gone, but in the full tide of success, if you regard him as the pilot, who has safely steered your frail bark on its voyage over the stormy sea of life to the peaceful haven of a happy, healthy old age.

Cicero said it was the priest of health who of all men nearest approached the Divinity. Plato, in sketching the model Republic, recognizes the qualified physician as holding an important position among the officers of the government. Jackson, schooled on the battle-field, pointedly charged the sacrifice of life and money to the fact that “physicians did not have that place in the councils of military commanders that is due to science.” Guy has demonstrated that the effective force of the British Navy has been more than doubled—that one ship for every purpose of navigation and warfare is at least equal to two less than a century ago, in consequence of the meliorating influence of sanitary science. Hygiene is not the handmaid of the peaceful trader alone: it has as much to do with the triumphs of the warrior as sword and buckler. “The laws of health,” declares the Rev. Dr. Osgood, “marched with King William and his son, with Bismarck and Von Moltke to the Rhine, and diet and exercise, quite as much as the rifled cannon and the needle-gun, fought the battle of Sedan and changed the face of the world.”

I may claim almost to have outlived the time when personal considerations, which so acutely affect younger officers, can influence me; but before me sit many men, the issue of whose lives hangs on their acceptance as truth or disregard as fancy of what I have here said. Flatter not yourselves that your strong constitutions are a bulwark against disease. Believe me on the honor of man and officer and physician, that wet decks and foul air will shatter the broad chests and weaken the brawny arms you now boast, will make your wives widows and your children orphans, sooner than all the vicissitudes of climate you will ever experience on shore, all the tempests that will ever assail you at sea, or all the enemies you will ever encounter in battle.

## POSTSCRIPT.

The foregoing address will be found, as stated in the text, to be, to a certain extent, a repetition, in matters of fact, of a paper read before the American Public Health Association. It was prepared, in its present shape, at the instance of a number of officers of the Navy, who are deeply interested in the improvement of the service, that, what I am encouraged to hope may be its area of usefulness, may be more widely extended. I am particularly happy to have the opportunity of direct communication with all the officers of the naval service, to whom I take this occasion to appeal for information whether in refutation or confirmation of my statements.

I would not be understood to allege that every ship to-day presents all the anti-hygienic abominations to which I have alluded. On the contrary, individual instances, in recent years, stand out in bright relief, against the dismal background of the past. Thus it is with real pleasure I learn from Lieutenant Sperry that on board the Sacramento, Lieutenant-Commander Johnson not only had the men's mattress-covers regularly washed at frequent intervals, but had the mattresses repicked every quarter. The bedding is described to have been absolutely clean, and the cleanliness a matter of competition and pride among the crew. I have never witnessed such a procedure, in my own experience, which began more than twenty-two years ago, but I gladly learn and cheerfully record the fact, since what has been so successfully and satisfactorily done on board one ship, is itself the best argument that it should be done in all.

Again: Commander Howison informs me that on board the Pensacola, he not only substituted mess-lockers for mess-chests, but discarded mess-cloths for mess-tables and benches, and though a few barnacled salts at first demurred that they could no longer cluster on their haunches on deck and tear their food to pieces by claws and jack-knives, the force of example and the appreciation of comfort and decency ultimately asserted their influence until plates and cups and saucers came to be voluntarily substituted for the tins and the men went to their meals with hands washed and cuffs neatly rolled back. Nor was this only a temporary good which ceased with the individual who had inspired it. The seed which had been sown continued to bear fruit, and Lieutenant Mason and other officers assure me that the traditions of cleanliness, healthfulness and efficiency clung to this vessel and characterized her during her subsequent commissions.

Admiral C. R. P. Rodgers, as commander of the Franklin, showed that it was possible to provide a reading place with tables, books and papers, comfortable and well-lighted at night, where the man before the mast might and did read, write and study.

Captain Greer returns from his cruise on board the Lackawanna enthusiastic about his small sick-list, his contented and almost self-disciplined crew, and his own consequent relief from many of the worries and anxieties incident to command, and refers with pride to the Medical Officer's sanitary report which records the happy results of keeping decks dry and of exercising forethought in other matters affecting health.

I present this paper to my brother officers in the Navy, in the hope that others will enable me to fill pages instead of paragraphs with similar instances. I trust the number of those, who can bear personal testimony to the horrors of ship-life will become smaller every year. I hope to see more than one commanding officer point with pride to the Sanitary Report as fruit born of "his attention to the health of the crew"; more than one lieutenant, surgeon and engineer, with common interest and in friendly emulation, discuss the hygiene of the sea in its scientific as well as its disciplinary aspects. The American Public Health Association does not restrict its membership to medical men, but it seeks to enlist the coöperation of every intelligent member of the community: neither is Naval Hygiene a book of which only medical officers can interpret the language, but its simple doctrines should be familiar to every corps, and should be taught to the youths at the Naval Academy, as one of the most important applications of principles they have acquired in the study of Physics and Chemistry.

If every naval officer will but feel that he is a responsible member of a great national Board of Health and contribute his experience to a general fund, the sum of all the good things that have been done, here and there, will eventually become the basis of a practical sanitary code of broader scope and greater value than can be devised by any individual, and, while the resultant may not be a floating elysium, it can never be a "floating hell," for though there are discomforts and dangers inseparable from ship-life, there will be no longer any preventable nuisances, needless annoyances, or criminal negligences to disgrace the naval service.

U. S. Naval Academy,

Annapolis, Md.,

June 1st, 1877.



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#### ERRATA.

Page 21, †, for "Antigomus," read Antigonus.

Page 22, line 9, for "De Suffern," read De Suffren.

Page 54, line 5, "through the end tube" should read "through the casing and tube."

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U. S. NAVAL ACADEMY, ANNAPOLIS,

APRIL 20, 1876.

Commander N. H. FARQUHAR in the Chair.

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FLEETS OF THE WORLD.\*

By CAPTAIN S. B. LUCE, U. S. NAVY.

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It was a fine conception to draw up all the fleets of the world in one grand review for the inspection and criticism of the student and scholar ; and it is to be hoped that the author of "Fleets of the World" will be "encouraged," as he says in his preface, "to persevere in his undertaking," now so happily begun. As the history of fleets of war vessels, to which our author exclusively alludes, has much to say in regard to their military movements, we shall begin our examination of these works on the Socratic principle of first defining our terms. The word Tactics is derived from the Greek ΤΑΚΤΙΚΟΣ—*capable of arranging ; relating to drawing up ; as to arrange or draw up the line of battle.* Hence Tactics has been defined as the art of arranging troops, (or ships), for battle, or moving them while in the presence of the enemy. A simpler definition is that of Aeneas Tacticus who calls it "the science of Military Movements." The subject has generally been divided into two branches, grand tactics, or the tactics of battle ; and elementary tactics, or the tactics of instruction.

\* "Fleet Tactics under steam," by Foxhall A. Parker, Commodore U. S. Navy. D. Van Nostrand, Publisher. "Fleets of the World", by Commodore Foxhall A. Parker. D. Van Nostrand, 23 Murray St. New-York.

NOTE. This paper was read before the issuing of volume II., but was withheld for revision by the author.

The history of naval warfare, of which tactics forms so important a part, may be divided into the three grand periods of oars, sails, and steam.

**OAR PERIOD.** Beginning with the earliest authentic history we find that among the Greeks and Phœnicians the higher officers, and often the entire *personnel* of navies, fought on shore as well as at sea. It was natural, therefore, that the tactics of the land army, which was of an earlier growth, should be applied to the sea army as far as the nature of the two elements would admit. To understand, then, the character of the movements of a large fleet of galleys, numbering not infrequently two or three hundred, when preparing for, or actually engaged in, battle, it will be necessary to examine first the elementary formations of the army. In both the Athenian and Spartan armies the tactical unit was the *Enomotia* of 32 men, ranged in four files, eight deep. The phalanx, therefore, when in line, was eight deep. On a march, the column, the usual order in marching, would then be of "fours," or of "eights" according as it broke from either flank to the front, or was marched to the right or left. The line of battle was most commonly of the parallel order. This order naturally suggested itself even to the barbarians and was practised long after war came to be studied as a science. But in the battle of Mantinea, Epaminondas formed his line in the concave order, with the attacking wing strengthened by the double echelon, a combination considered as very powerful to this day. "Epaminondas," says Xenophon, "formed of his cavalry a strong wedge-like body." (Hellenics Bk. VII. 5.24.) In another place he compares the formation to the beak of a galley. "Epaminondas led his army like a ship of war with its beak directed against the enemy." To resist the attack of a superior force, the Greeks, copying from the Egyptians, were accustomed to form in a circle, and, placing their shields together, make a strong rampart difficult to penetrate. In the *Cyropædia* we are told by Xenophon that "the Egyptians formed a circle, so that their arms faced the enemy, and sat down under the shelter of their shields." Against this rampart Cyrus repeatedly hurled his cavalry in vain. In the *Retreat of the Ten Thousand*, "Xenophon and his party, being much harassed, marched in a circle, so as to hold their shields together as a defence against the missiles; and so with great difficulty crossed the river Caicus." In the *Commentaries of Hirtius* (African war ch. xv.) it is stated that "the legions being surrounded by the enemy's cavalry were obliged to form themselves in a circle, and fight as if enclosed with barriers."

The same formation was known to medieval times, being mentioned

in the account of a battle fought between the English under the Saxon king Harold and the Northmen under Tostig, A. D. 1066. It is not a little singular, if the digression be permitted, that the circular formation of the ancient Egyptians should have been recently revived in the U. S. Army (see School of Battalion, ¶ 535 Upton's Infantry Tactics.) "On the order: *Rally by Divisions*, the companies close in quick time towards the centre of division, and form a circle to the rear of the line, &c., &c."

The hollow square also was known to the ancients, being particularly mentioned in the account of the disastrous retreat of the Greeks under the unhappy Nicias, after their terrible series of reverses at Syracuse.

From the fact of the shield being carried on the left arm, the right remained uncovered, hence the right was considered the point of danger and consequently the post of honor. This idea prevailed both in the army and in the fleet, the command of the right wing in line being regarded as the highest distinction. Now it will be found that these several tactical formations of the army—the line for the order of battle, the column for facility of movement, the echelon or wedge shape for strength, the circle for defence—constituted in the main the several orders of naval tactics also.

The earliest authentic record of fleet evolutions is given by the "Father of History" himself. About twenty years before the battle of Salamis, or 500 B. C., Dionysius the Phocæan took command of a fleet belonging to the Ionian Greeks. Whereupon "he proceeded every day to make the ships *move in column* and the rowers to ply their oars and *exercise themselves in breaking the line*" (Herodotus Bk. VI. 12.) While this is the earliest example furnished by history of the practice of a regular system of tactical movements by a fleet, it fortunately presents at the same time the clearest indications of what those movements were. The passage is valuable also as showing that thus early the breaking of the enemy's line was a cardinal point in the system of naval warfare.

A few cases selected at random from various authors will illustrate the principal fleet formations of the ancients. On the invasion of Greece by Xerxes, the Persian admiral brought his fleet down the coast of Magnesia in "Column of Eights", the Greek phalanx in Column.\*

\* To avoid encumbering the text, the more striking points of similarity between the ancient and the modern systems of naval tactics will be indicated by foot notes: thus, the "Column of Eights" of the Persian fleet could be formed by signal No. 133 of the U. S. naval signal book, which is based on Fleet Tactics under Steam, by Commodore Parker.

In one of the battles off Artemisium, where the Confederate Greek fleet covered the right flank of Leonidas at Thermopylæ, the Persian line-of-battle was in the form of a crescent—the concave order of the army. The Greeks, greatly inferior in numbers, at a signal, brought the sterns of their ships together, turning their prows on every side towards the barbarians so as to form a circle—the circular formation of the army—“after which, at a second signal,\* though closely pressed they darted out and fell bravely to work.” (Herodotus). On the fall of Thermopylæ, Artemisium ceasing to be a strategic point, the Greek fleet passed down the straits of Eubia in column, in inverse order, the left wing leading.

But it is not till we reach the Peloponnesian war that we read of those tactical evolutions which, for rapidity, and precision of execution, command our admiration to this day.

The triremes were the line-of-battle ships of the period. As they were all homogeneous, that is all built on the same lines and propelled by the same means, their arcs of evolution were equal; hence were practicable, with a numerous fleet, movements which, these elements wanting, could only result in endless confusion.

Moreover, the endurance of the rowers and the high rate of speed at which they could propel the light triremes, rendered a certain celerity of movement possible which at this day is difficult to realize †. When to this it is added that the exercising of the fleet was incessant, it may readily be understood how a master mind, no uncommon thing in that age of high intellectual development, could manœuver a vast fleet as though it were a perfectly adjusted machine.

In a battle off Naupactus (the modern Lepanto), in the third year of the Peloponnesian war, we find the Lacedæmonian fleet passing up the straits in “*Column of fours*,” ‡ and, at a signal, suddenly swinging into line of battle by “*Fours left wheel*,” §.

\* How these signals, so frequently alluded to by Herodotus and Thucydides, and evidently so efficacious for the manœuvering of a large fleet were made, is fully explained in Potter’s American Monthly, April, 1877. Article, Signals and Signalling.

† “La grande vitesse que l’on pût obtenir de ces navires, (trirèmes) vietesse qui, d’après quelques circonstances bien connues, pouvait atteindre deux lieues marine à l’heure.” (Onze kilometres—equal to 6.8 statute miles.)

Essai sur les navires a rans de rames des Anciens. Par P. Glotin Ex. Lient. de Vaisseau. Paris; Arthur Bertrand, 1862.

‡ Signal No. 111. § Signal No 409.



In the battle off Cynossema in the Hellespont, the tactical skill of Thrasybulus, commanding the Athenian fleet, and that of Mindarus, commanding the Peloponnesians, are finely displayed. The Athenians leaving Elæus, near the mouth of the straits, pulled up the European shore, in seventy-six vessels, towards Sestos (to the northward and eastward,) in "column of vessels,"\* the left wing leading.

Thrasybulus, a distinguished Athenian, commanded the right wing, now the rear.

The Peloponnesians on their part had eighty-six vessels. The right was held by the Syracusans, esteemed at that time the best fighters; wing, the left, which was also the van, and contained the fastest ships, being under the command of Mindarus himself. The Peloponnesians, putting out from Abydos, on the Asiatic shore, extended their line, also in "Column of vessels," towards Dardanus, or to southward and westward, their object being to envelope the Athenian right, to prevent his escaping to the open sea, and to drive his centre on the shore. The Athenians, observing this, reversed the right wing, † and pulled to the southward and westward, to avoid being out-flanked. The left wing however, continuing on towards Sestos, had now passed Cape Cynossema, shutting out the other wing, and leaving the centre a weak line of scattered ships. The Peloponnesians, fell upon the centre, drove the ships aground, and landed to follow up the advantage. This partial success of the Peloponnesians, by carrying them too far, threw their line into confusion. Thrasybulus then ceasing to extend his wing, brought his vessels into line by "Wing by the left flank," ‡ fell upon the enemy, and, having put them to flight, attacked the victorious but disordered centre, and threw it into a panic.

The Syracusans had by this time given way to Thrasybulus and his left wing, and now took to flight on seeing the rest routed. (Thucydides, Book VIII, 101—107.) The moral and strategic results of this victory were very important to the Athenians. Depressed by the terrible reverses at Syracuse only two years before, the present success raised their spirits; while a Peloponnesian squadron guarding the coasts of Eubœa, which had revolted from Athens, had now to be called to the Hellespont, to strengthen the shattered forces of Mindarus.

This battle is the last recorded by Thucydides. As an admiral of the Athenian navy his descriptions of sea-fights are particularly valuable.

\* Signal 54. † Signal No. 436. ‡ Signal No. 298.

At the battle of Arginusæ, the Athenian fleet was drawn up in three grand divisions. The right wing was composed of sixty ships divided into four squadrons of fifteen each, two squadrons in the front line and two in the rear line as supports.\*

The centre was in a single line, but one of the isles of Arginusæ (in its immediate rear) gave it great strength; the left wing was similar in its disposition to the right.† The object of this particular formation was to prevent the enemy from practising those manœuvres known as the *Diekplous* and *Periplous*, and causing injuries which the trireme was well calculated to inflict but not to receive. *Diekplous*, from *diakplō*, to break through, meant to break through the enemy's line for the purpose of turning and ramming these ships in the flank or rear, or raking his oars from abaft. *Periplous*, from *periplō* meant the sailing round the enemy's fleet, to reach his rear by a flank movement, for the same purpose of ramming in the more vulnerable parts, or of cutting away his oars.

The proximity of the land ensured the centre against the *diekplous*, while the rear line on the wings, like a second line of infantry, supported the advance. The Peloponnesian fleet bore down to the attack in a single line. The battle was obstinately contested, but the Athenians, owing to their strong position, gained a complete victory.‡ The trireme, having its bow specially designed for ramming, was, in the hands of a bold and vigorous crew and managed by skillful officers, the real

\* Sig., No. 310.

† Since writing the above we have read with much pleasure the lecture on "Ancient Naval Tactics" by the Rev. Ed. Warre, M. A., before the Royal United Service Institute, London, Journal of the R. N. S. I. No. 88. The Reverend lecturer forms the wings of the Athenian fleet in columns of divisions. If his interpretation of Xenophon be correct, the Athenians were guilty of a great tactical blunder, which even their success does not excuse. The probability is that each wing was formed in a double line, with thirty galleys in the front, and thirty in the rear, as stated in the text.

‡ There was an unfortunate sequel to this great victory. Six of the Athenian Captains were, on their return, brought to trial for not rescuing the unfortunates left clinging to the wrecks, a gale coming on at the time. They were found guilty and condemned to drink hemlock. Like poor Byng of later times they were the victims of party politics!

weapon of attack, a condition which rendered it necessary that, when in an attitude for battle, the weapon should be pointed towards the enemy; and on this theory their system of tactics was based.

The battle once joined, it was by extraordinary strength and precision of rowing, by rapid and sudden turns, by feints, and skillful handling generally, that the Athenian trierarch, or captain, sought to drive the sharp beak of his vessel, against his enemy's side, or stern, or to cut away his oars. Nor was its facility for stern-board the least noticeable feature of the trireme. In a fight off Corcyra (Corfu), Nikostratus, commanding a squadron of but twelve Athenian triremes, did not hesitate to engage a force of thirty three Peloponnesians, although the latter had a division of twenty more near at hand.

The Athenian, having plenty of sea room for manœuvring, disregarded the numerical superiority of his adversary, more particularly as two of his twelve triremes were the picked vessels of the Athenian navy—the *Salaminia* and the *Paralus*. Nikostratus, avoiding entanglement with their centre, hung on their flank, and as he presently managed to ram and sink one of their vessels the Peloponnesians formed in circle and stood on the defensive.

The Athenians rowed round and round this circle trying to cause confusion by feigned attacks, and they might have succeeded, if the remaining twenty Peloponnesians, seeing the proceeding, had not hastened to join their comrades. The entire fleet of fifty-three triremes now assumed the offensive, and advanced to attack Nikostratus, who retired before them by *backing astern* and *keeping his ships heading towards the enemy*. In this manner he succeeded in drawing them away from the harbor so as to enable most of the allies, the Coreyreans, to get safely into port.

In the military schools of Greece the instruction was not confined to the elementary branches of the art of war. Those who would excel in the art were obliged not only to be tacticians but to understand the greater and more remote objects of tactical movements, of a battle, a campaign, or of a war. The general of an army was therefore called *Strategos*, whence our word *strategist*; while the commander-in-chief of a fleet was termed *Nauarchos Strategos*, naval strategist. Indeed there is abundant evidence to show that the Greek nauarchos, or admiral, was very far from being ignorant of those principles on which the science of war depends. From the battle of Lâdé to that of Salamis during the miserable Egyptian campaign, from the fatal disasters of Syracuse to the final catastrophe at Ægos Potamos, it will be found

that most of the movements belonging to the grand tactics of the present day were not unknown to the Greeks.

Severing an enemy from his base of operations, cutting off his supplies, breaking and doubling on his line, diversions, flank attacks, turning the flank, throwing a heavy force on a single point and thus beating him in detail, all seem to have been well understood; while boarding, the use of boarding bridges, ramming, crippling by various methods to prevent escape, grappling, surprises, feints, fire-ships (as at Syracuse), nearly all the expedients, in short, known to naval battles of modern times, save such only as depend on explosives for their action, were practised at one time or another by the Greeks. They may well be termed our masters in the art of war.

The Romans took their system of naval tactics from the Greeks. In their first essay in sea fighting, however, being totally inexperienced in the management of fleets, they attempted no manœuvring; but, closing at once with the enemy, they reduced the issue of the battle to a hand-to-hand conflict, in which Roman valor was sure to prevail over the less hardy Carthaginian. Their earliest effort, on opening the first Punic war, was not encouraging; but Duilius soon after gained off Myle, one of those great victories which serve to mark an era.

It was here that the *Corvus*, or boarding bridge, "invented by some one in the fleet,"—Polybius says,—but used by the Spartan Leotychides, at Mycale, some 200 years before, mainly contributed to the splendid success. (260 B. C).

The Phœnicians were, by far, the better seamen; but, besides their greater energy and intellectual superiority, the Romans brought their thorough knowledge of, and wide experience in military affairs to bear upon their naval enterprises. Four years after the above, we find the Romans to have greatly improved in their tactics. At the battle of Ecnomus the Roman fleet, having on board the choice of Roman troops, was separated into four grand divisions, each bearing a double name. The first division was called the *first legion* and first squadron, the second and third were similarly named; while the fourth was styled the *triarii*, the name given to the last division of the army. The first and second squadrons, composed of men-of-war alone, formed the right and left wings of the line of battle. The two admirals were in the centre of the line; the one, Marcus Atilius Regulus, (of unhappy memory), Roman consul and admiral, being on the left of the right wing; the other, Lucius Manlius Volso, on the right extremity of the left wing. In anticipation of an engagement, the two admirals drew

ahead, the ships of their respective wings following in succession, in close order, bringing the two wings into the double echelon formation, with the two admirals at the apex.\* The third squadron, in line, and having the transports in tow, formed the base of, and completed the triangle.

The triarii, also in line, and so extended as to cover both flanks of the advance, followed as a reserve. The Roman fleet numbered 330 line-of-battle ships—mostly quinquiremes (such had been the advance in Naval architecture) and carried about 140,000 men.

The Carthaginian fleet, consisting of 350 ships and about 150,000 men, had three squadrons in line, their right extending well out to sea with the view of enveloping the Roman left. The fourth division on the left of the line, was well in with the coast of Sicily, and formed in column of ships, concaved from the shore;\* its design being to pull up along the coast, and fall upon the right flank of the Romans. The object of the wedge form of the Roman advance was to pierce and break the enemy's centre; but the skillful and wily Carthaginians retreated, in conformity to previous orders; drawing on the 1st and 2d legions and separating them from the line of transports and the triarii. When the separation was deemed sufficient, the Carthaginians, upon a signal from Amilcar, suddenly assumed the aggressive, and fell upon their pursuers with the utmost fury. Hanno, in command of the right, now bore down on the left flank of the triarii, while the inshore division, moving by the oblique into line,\* fell upon the Roman third legion and transports. Thus three separate and distinct battles were raging at the same time. The fight was obstinate, and the issue for some time doubtful. The Carthaginians were far superior in the lightness of their vessels, and in their skill and rapidity of advancing and retreating, and attacking on every side; while the Romans relied for success on their steadfast courage and on their *corvi*. The latter prevailed; and having gained the victory and refitted, Regulus steered for Africa, the objective point of the Roman army.

In the history of the Alexandrian war we have an account of an en-

\* Signal No. 240, or perhaps from Regulus No. 229, and from Manlius Volso, No. 228.

† In Mr. Hampton's translation of Polybius (London 1773) this squadron is said to be formed in the shape of a *forceps*. It is hardly necessary to explain that no such order existed. It was the concave line pulling by the right flank, thus forming a concave column.

‡ Signal No. 304.

gement in which Cæsar himself commanded the fleet; but as the plan of the battle seems so similar to that of the Athenians at Arginusæ, further description is unnecessary. In the history of the Great Civil War there is much to interest the naval student, but little insight into the prevailing system of tactics is given beyond the examples already cited. It is much to be regretted that none of the writers of antiquity thought it worth while to transmit to posterity a dissertation on naval warfare; but it was doubtless considered that a treatise on the art of war embraced both the land and the sea forces.

The battle of Actium scarcely comes within the range of critical notice. Anthony, indeed, so disposed his fleet as to extort the commendation of his great rival; while the genius of Marcus Agrippa, who handled the Roman fleet, was never more conspicuous,\* yet the battle was thrown away. While victory still wavered in the balance Cleopatra sailed away and was speedily followed by "the noble ruin of her magic, Antony." Perhaps the only useful tactical lesson taught by this battle is in the advantage gained by the use of the light and swift *liburnæ*, adopted by the Romans from the Liburnians, over the heavy and unwieldy galleys of Anthony's fleet.

We have seen in the great "three-decker" and in the huge five masted iron-clads of our own days the same tendency to over-growth in ships of war, that existed among the ancients.

The foregoing examples have been selected from the history of naval battles covering a period of nearly five hundred years, without regard to order or political importance, and with the sole view of arriving at some conclusion in regard to the system of naval tactics which prevailed with the ancients; or, more particularly, with the Greeks and Ro-

\* Plutarch has assigned to Augustus the command of the Roman fleet. He did so command theoretically, by virtue of his position; but he had no capacity for naval affairs. Agrippa on the contrary was one of the most renowned and successful naval leaders of his age. Virgil, who wrote the *Æneid* to please and do honor to Augustus, says, or sings, in allusion to the battle:

"With favoring gods and winds to speed,  
Agrippa forms the line:  
The golden beaks, war's proudest mead,  
High on his forehead shine."

The latter is an allusion to the *corona navalis* bestowed for a great victory over the fleet of Sextus Pompey. For the victory of Actium, he received the *vexillum cæruleum*, or sea-green flag.

mans. The reader, we think, will have already anticipated us in the deduction that their elementary tactics comprehended the three simple orders of *line*, *column* and *echelon*, with the circular formation (equivalent to the hollow square) for resisting the attacks of a superior force; and that their line of battle was, what has been familiarly known in modern tactics under sail, as the *line abreast*, every ship heading for the enemy, or in the direction of the attack. There were, also, flank, oblique and perpendicular movements. The Greeks seem to have separated their fleets into the three divisions of van, centre and rear, when in column; and right and left wings and centre, when in line.

The Romans had four divisions. The line, with both flanks thrown forward, so as to form the concave order or crescent shaped line, was often made use of, as it enabled the admiral, in the centre, to see both wings, and facilitated the transmission of signals.

One of the most graphic descriptions of an ancient Sea-fight is given by Polybius in his account of a battle between the fleets of Philip of Macedon and Attalus king of Pergamus. "Both fleets, he says, "turned their prows the one against the other and, amidst the sound of trumpets and the noise of animating cries, engaged in set battle." The crushing in of the sides of great quinquiremes, and octoremes, the clashing of huge oars as they intermingled in the fray, the shouts of the soldiers and the cries of despair as the shattered wrecks subside beneath the wave—all the din and confusion of a great battle in which the loss to Philip alone was nine thousand men, are plainly discernible in the picture he has so vividly drawn. Add to this the bursting of monster shells, the explosion of torpedoes and the roar of escaping steam, and one may gain some faint idea of what a modern fleet fight would be. In an account by the same author of the bold operations and final capture of a Rhodian blockade runner, one might almost fancy the scene taken from the history of the blockade during the late civil war.

With the breaking up of the Roman Empire and the disappearance of the ancient civilization, naval tactics with many other arts was buried amid the crumbling ruin. What those arts must have been we may judge from the universal concurrence, of modern writers in comparing productions of modern art with the master-pieces of antiquity as the highest standard of excellence. A modern historian, describing the battle of Sluys, exhausts his praises when, in commenting on the skillful combinations that distinguished the movements of the English fleet, he compares it to "some master-piece of the Athenians." He could have paid no higher compliment to the tactical skill of the English king.

There seems to be but little doubt that the medieval navies revived the naval tactics of the ancients. Outside of the Mediterranean the Norsemen were the great sea fighters, but the only approach to any regular system was in their custom of lashing their vessels together in line to prevent the attack from breaking through.

The old chroniclers give us some interesting details in regard to the fleet of Richard I, during his voyage to the Holy Land. On leaving Messina the fleet was formed in the order of convoy. In the van were three large ships laden with stores, on board one of which was the fair Berengaria of Navarre, the betrothed of Richard, and placed under the immediate care of his sister Joan, queen of Sicily. The second line consisted of 13 ships; the third of 14; the fourth of 20; the fifth of 30; the sixth of 40; the seventh of 60; and in the eighth line Richard himself brought up the rear in his galleys. In this irregularly shaped wedge they proceeded to the eastward under sail. In the description of a battle which took place a short time before this (1190) we are told that the Saracens "brought out their galleys (from Acre) two by two (column of twos)\* and preserving a seemly array in their advance rowed out to the open sea to fight; our fleet (the Christians) making an oblique circuit to the left † removed to a distance so that the enemy should not be denied free egress. "Our ships were disposed in a curve, (the old concave order,) so that if the enemy attempted to break through they might be enclosed and defeated." "In the upper tiers the shields, interlaced, were placed circularly." So had the ancients done; and so early were the attempts to provide ships with armor to resist missiles!

In 1571 was fought the celebrated battle of Lepanto, which closes the old period in the Mediterranean. It had long since closed in the Atlantic. The scholarly and fervid pens of Prescott and of Motley, and the critical analysis by the author of "Fleets of the World" have rendered this battle familiar to the generality of readers. With all the splendor with which the opposing fleets were arrayed, the immediate results of the battle were, in a tactical point of view, "as barren," says Motley, "as the waves upon which it had been won." "It is an error to speak of the victory as barren" says Prescott, in quite a different sense, and referring to its remoter consequences, "for its *moral* effect was greatly adverse to the Turks, and from it dates the decline of the Ottoman Empire." (Motley's Dutch Republic. Prescott's Philip II.) Both were

\* Signal No. 74. † Signal Left oblique.



right. The remarkable feature of the battle was in its being among the very first of sea fights where heavy ordnance was employed.

Both fleets, we are told, were formed in the concave order, such as we have seen in the fleet of the Persian Megabates off Artemisium. As the line of battle of that day required every ship to be heading towards the point of attack, the guns, to be effective, had to be placed so as to fire in the same direction ; but, as vessels were still liable to be rammed, guns had to be placed in the sides and sterns also, to bear upon an enemy, making an attack from astern or abeam. Thus they had at this early day a practically full circle of fire. In this fight too, was clearly demonstrated the great advantage of a few guns of heavy calibre, over a larger number of lighter weight.

Although sails had been used, and several battles fought under sail, before this time, yet counting from Lade to Lepanto, we may consider the oar period to cover a space of a little over two thousand years. From the study of the operations of the Navies of antiquity, the student should pass to the histories of the Italian Navies. The protracted Naval wars between the sister republics of Venice and Genoa, are replete with lessons in tactics and strategy.

**SAIL PERIOD.** It must not be supposed that the oar period terminated abruptly, nor that that of sails sprang suddenly into existence.\* On the contrary two hundred and thirty years before Lepanto, Edward III, had carried his fleet in under sail, and had fought and won the great battle of Sluys, already referred to. At the battle of Damme, the first great fleet fight between the English and French, the English had "sailed in" over a hundred years previously (1213). In both of these battles it must be observed that the attack was made on ships at anchor. The first regular sea fight under sail in English history occurred off the North Foreland, ( Aug. 1217 ), between an English squadron commanded by Hubert de Burgh, and a French force commanded by the famous Eustace the Monk. With a fresh southerly wind the French were "going large" and steering around the North Foreland ; the English kept their luff as if bound for Calais, and having gained the wind of the French squadron, they bore down on them, threw their grapnels on board and fastened the vessels together. After fighting for some time the English boarded, and, cutting away the rigging and halliards, with axes, "the sails fell over the French." After this the enemy made but

\* The change from the one period to the other was so gradual that the tactics under oars was for a time applied to fleets under sail. Sixteen years after the battle of Lepanto the great Spanish Armada sailed up the English channel in the ancient crescent shaped, or concave order.

little resistance, were defeated with immense slaughter, and many of the vessels were sunk by being rammed with the iron prows of the galleys. It will be seen by this that from the very first the English sought to obtain the weather gauge; and, further, that the cutting away of the halliards was but a repetition of the stratagem made use of by the Romans under Cæsar, who, in the great sea fight with the Veneti, cut away their halliards with *falces*, and by thus letting down their sails prevented their escape.\* But with the introduction of ordnance, the gradual increase in the number of sails and masts, including the bowsprit, and the greater size of the war vessels, a radical change necessarily took place in naval tactics. Ramming under sail, was not practicable; nor was it desirable to run along-side and grapple. Instead of the simple and precise tactics of the ancients, whereby the change from one order to another could be performed with almost mathematical exactness, the inconstant wind now became the prime element on which the speed and direction of the fleet were mainly to depend. The interim between ancient and modern tactics lasted, reckoning from Lepanto to the battle off the Texel, 94 years.

In sailing vessels the offensive weapons being placed on the side of the ship, and the ship being under better control when by the wind, it was natural that when two or more vessels were operating together they should form for battle in a *close hauled line ahead*. Sailing in line ahead, six points (in actual practice seven points) from the wind, became, therefore, the technical *order of battle*. It is obvious from this that two fleets engaging on the same tack would find themselves on parallel lines and at right angles to the direction of attack. It was not however until 1665 that this order of battle, and the various orders which grew out of it, were regularly systematized. "This order of battle," says Paul Hoste, "was exactly observed for the first time in the battle off the Texel, where the Duke of York defeated the Dutch on the 3rd June, 1665, and it is to him that we are indebted for it in all its perfection." We have the testimony of James II himself on this point.

"On the 15th of March, 1665, the Duke of York went to Gunfleet, the general rendezvous of the fleet, and hastened their equipment. He ordered all the flag officers on board with him every morning to agree on the order of battle and rank. In former battles no order was kept,

\* This practice was continued by the French of modern times, who always fired high to cut away the enemy's spars and rigging.

and this, under the Duke of York, was the first in which fighting in a line and regular form of battle was observed." (Autobiography of James II). Such was the origin of the famous "Fighting and Sailing Instructions" so often quoted. It does not seem that they were ever given to the public, though they continued to be the rule and guide for British admirals for many generations.\*

Thirty-one years after the instructions were issued, or in 1696, Father Paul l' Hoste wrote his modest preface in Toulon. "The Marechal de Tourville has communicated his ideas to me," he says, "and ordered me to compose a treatise on a subject which, I think, has not yet been treated of." This treatise, giving "clear, simple and practical rules for naval evolutions, drawn from mathematical principles," is admitted by English writers to be "the root from which all other works on naval tactics have grown." Notwithstanding the confessed merits of Paul Hoste's work it was considerably over a century before a respectable translation of it appeared in England!

In 1762 was published Lieutenant Christopher O'Bryen's English translation of the 1st and 5th parts of Paul Hoste's work; and in 1790 Mr. John Clerk's Essay on Naval Tactics appeared.

The discussion which Lord Rodney's manœuvre of cutting through the French line in 1782 gave rise to, on the question of originality, shows how little attention had been given to the study of the art of war in the English navy at that day. Clerk's essay served its purpose, however, in calling attention to the subject of a manœuvre which had long been practised by most of the great naval captains; and he is deserving of credit for first enunciating the principle in an abstract form. In 1834 an English translation of Paul l' Hoste by Captain J. D. Boswell, R. N. was published; a work which at once took its place as a standard text book on Naval Evolutions under sail.

The introduction of steam as a motor power terminated the sail period which had lasted, reckoning from the battle of Lepanto, to the battle of Lissa, the first important sea-fight under steam, 295 years.

**STEAM PERIOD.** In naming Ladé, Lepanto and Lissa, it is to be understood, that they are arbitrarily assumed merely for the purpose of marking the great tactical eras. Considering the duration of the preceding periods, the changes of late years have been rapid and important.

\* They were printed for private circulation. One copy may still be seen in the library of the Royal United Service Institute, London.

Following the introduction of steam came increased power of ordnance; defensive armor; the addition of the spur, the *rostrum* of the ancients, and the consequent disappearance of the bowsprit. In the *Monitor* system these advantages culminated, with the addition of well protected-motor and steering power, a practically full circle of fire, and the exposing of the least possible surface to hostile shot. The *Monitor* was the crystallization of forty centuries of thought on attack and defense and exhibited, in a singular manner, the old Norse element of the American Navy: Ericsson (Swedish, *son of Eric*) built her; Dahlgren (Swedish, *branch of a Valley*,) armed her; and Worden (Swedish *Wordig, Worthy*) fought her. How the ancient Skalds would have struck their wild harps in weaving such names in heroic verse! How they would have written them in "immortal runes!"

The successful encounter of the *Monitor* with the *Merrimac* effected a sudden and complete change in naval warfare, and gave an impetus to the construction of defensive armor and the manufacture of heavy ordnance entirely without parallel in the history of the world. But as the monitors were designed for coast and harbor defense and not for navigating the open sea, they cannot be classed, in a tactical point of view, as vessels that can take their places in the line of battle on the broad ocean.

It is to Lissa, therefore, fought on the 20th July, 1866, between two squadrons of sea-going iron clads, in which the spur was effectively used, that we must look for marking the new era.

Among those who undertook, in the earlier days of steam navigation, to devise a system of tactics suited to the change in the mode of propulsion, Sir Howard Douglass seems to have been one of the few who approached the subject in the true spirit. Educated as a soldier and with a strong proclivity for naval affairs, he was peculiarly well qualified for the task. He followed instinctively the very course into which the ancients had been led by force of circumstances; and applied the rules of the military art to the military movements of a fleet. Though written in the early days of the Steam period, "Naval Warfare with Steam" has lost none of its value as a text book. But it deals chiefly with the tactics of battles, leaving the work, as a whole, incomplete. What was wanting in the work of Sir Howard Douglass, however, has been supplied by Commodore Parker, who has deduced a system of elementary fleet tactics under steam, which, while it fulfills all the novel conditions imposed by recent changes, is yet so perfectly adapted to the end in view that it is difficult to see how it could be altered to advan-

tage. Now, Commodore Parker attained his results just as Sir Howard Douglass had done, and in a manner analogous to that of the Greeks of twenty three centuries before, by applying in this case, the elementary movements of field artillery to the movements of a flotilla. That the system of naval tactics of the oar and the steam period should be similar will strike no one as extraordinary who for a moment reflects that as the two methods of attack require the same technical order of battle, the systems growing out of that order must, in their most perfect form, be the same. The numerous foot notes given in the description of the ancient tactics have already defined the present system. The new line of battle is given on page 10, fig. 1. "Fleet Tactics under steam", where the several vessels are supposed to be heading in the direction of the attack.\*

Having established his line of battle, the author of the work referred to judiciously ignores the nomenclature of the late system of sail tactics, substituting therefor the terms used for similar formations in the army. The old "line abreast" gives place to the "line;" the "line ahead" to "column," and "line of bearing" or "bow and quarter line," to "echelon" (single and double.) Those three formations, then, and the movements necessary to pass from one to another constitute, in the main, the elementary tactics designed by that officer and adopted by his government.

Commodore Parker makes some valuable suggestions in regard to the Commanders-in-chief, whose *rôle*, he justly observes, (page 219) approximates to that of the General. "He should take post, whence, without being an active participant in it, he may overlook the battle" and direct his forces.

It was the indiscreet valor of the Spartan Callicratidas and a false idea of his duty as Commander-in-chief, that cost him his life, and contributed largely to the loss of his fleet at Arginusæ. For his conduct on this occasion, and his answer to the advice not to attack the Athenians, that "he could not fly without shame," he was severely criticized by both Cicero and Plutarch (although the latter extols him as of all Greeks the most worthy of admiration); for he sacrificed his fleet and the interests of his country to his own reputation for personal courage.†

\* It is very evident from this order of battle that the modern ship of the line must have a full circle of fire, as at Lepanto. That every vessel of war is now fitted for ramming is assumed as a matter of course.

† Plutarch in his life of Pelopidas makes some very just observations on this subject. Contrast the reply given above with that of "Old Antigonus"—: The latter has the true Nelsonian ring.

Philip, (son of Demetrius,) during the great sea-fight with Attalus, already referred to, withdrew in a small vessel from the heat of battle, and took his station whence he could survey the entire scene of conflict. This enabled him to profit by the mistake of Attalus, and to capture the galley of that Prince. After the Comte de Grasse was made prisoner in his flag-ship, the *Ville de Paris*, in 1782, the French Government issued orders to the effect that Commanders of squadrons should do precisely what Commodore Parker here recommends. It was in consequence of this order that De Suffern, some months later, shifted his flag to the small frigate *Cleopatre* in one of the battles with Sir Ed. Hughes. Admiral Porter always preferred, during battle, to be on board a small and fast steamer. This enabled him to view his entire line and place himself wherever his presence might be needed. At the bombardment of Fort Fisher he carried his flag on board the *Malvern*, a small side-wheel steamer of 600 tons, that had been captured in running the blockade, and purchased for the navy.

In establishing the fact of a similarity between two tactical systems widely separated by time—more interesting to the speculative mind, perhaps, than valuable to the student, there is no intention of holding up the tactics of the ancients as worthy of imitation. Though we acknowledge the Greeks to be our masters in the art of war, yet tactics change with the change of weapons; what may have been admirable in their day might prove, therefore, utterly impracticable now. With strategy it is not so. The capture of Sphacteria (Navarino) by the Athenian fleet was a fine exhibition of strategy. As a diversion it was completely successful, bringing the Spartan Campaign in Attica to an abrupt termination. It has justly been regarded as one of the most brilliant *coups* of the Peloponnesian war. When Regulus defeated the Carthaginian fleet he might have continued on, to assist in the investment of Lilybæum; but he chose rather to cross over to Africa, making a great strategic move, and one which, under an abler general, would have resulted in the speedy reduction of Carthage. When Alexander the Great crossed into Asia, had the advice of Memnon the Rhodian been followed, and the Phœnician fleet sent to the coast of Greece as a diversion, the most splendid campaign in all history might possibly have been spoiled. Any of these movements would be judged skillful to-day.

The consummate strategy of Themistocles and Alcibiades are even now commended. The principles of strategy are immutable. Agatho-

cles, king of Syracuse, William the Conqueror, and Cortez, each in his own time, landed on an enemy's shore and burned his ships behind him. And so, to-day, any great leader, having the same motive, would resort to an equally desperate measure.

In regard to the tactics of battles it is not intended to speak further than to observe that there are certain general rules here too which are unchangeable.

The parallel, the most ancient order of battle, for example, has been condemned by military writers as the weakest of all. The parallel order reënforced at one point, is, however, based on sound principles.

The oblique order, is the most approved. It gives many chances for success, and provides, as far as possible, against mishaps, says Dufour. "L'ordre oblique est l'ordre de bataille le plus usite, le plus savant, et le plus susceptible de combinaisons." (Guibert, quoted by Sir Howard Douglass). With the advanced wing reënforced it is particularly strong, and in strict accordance with that principle so much dwelt upon, that an overwhelming force should be thrown on one decisive point of the enemy so as to crush that, and beat him in detail.

The double echelon is also a very strong formation, and its application to a fleet is sanctioned by the enlightened judgment of Sir Howard Douglass. Again, very great stress is laid by military writers on the necessity, in every case, for a reserve to reënforce a weak point, or aid in crushing the decisive point. These orders of battle are all applicable to a fleet; while celerity of movement, the advantages of assuming the offensive, great range and accuracy of fire, an unobstructed circle of fire, and the presenting of the smallest target for the enemy's missiles, all apply with equal force to naval operations as well as to those on shore. Now all these points were clearly recognized by the ancients.

It would be folly, even were it practicable, to attempt to form the new line of battle either with vessels that could not ram, or that carried their guns in broad-side only. It would be equally unwise to attempt to oppose short range guns to long; or low to high speed. And, finally, we are forced to the conclusion that the true way to study naval tactics is to do so in connection with the study of Military and Naval history and of the science of war as taught at the best military schools.

In the ardor of pursuing the theme we have been led somewhat beyond the range of the volumes under consideration, and must come to an abrupt conclusion. Full of historical research as these works undoubtedly are, the author himself teaches us, perhaps unwittingly, the best and most practical lesson, in affording by his own scholarship a

brilliant illustration of the change from the "rough and tough old Commodore" to the higher culture of the modern school.

Falconer, the Sailor-poet thought that going to sea made one stupid: that at sea the intellect was "blasted in the barren shade."

"Sad Ocean's genius in untimely hour  
Withers the bloom of every springing flower:  
Here fancy droops, while sullen clouds and storm  
The generous climate of the soul deform."

However it may have been in his day of long passages under sail, it certainly is not so in the steam period when more time is afforded for study and reflection. We commend the careful perusal of "Fleets of the World" to our young officers who are, in time, to mould *our* fleet and shape its destinies, in the hope that, at least so far as the economy and efficiency of the Navy are concerned, we may look confidently to the fulfillment of the celebrated prophecy that,

"The young America will soar to be what Athens was."



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Commander N. H. FARQUHAR in the Chair.

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THE DEVELOPMENT OF RIFLED ORDNANCE.

BY LIEUTENANT EDWARD W. VERY.

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GENTLEMEN:—With the introduction of the 8 inch converted rifle, the United States Navy has taken its first decided step in the practical development of a system of rifled ordnance; and it becomes a matter not only of interest but of the greatest importance to all naval officers, that they should be able to form a rational opinion of the value and probable results of this first experiment. We are all aware that in the composition of this ship's battery there is but little that is original with Americans; and in considering its details, those who have but lightly followed up the progress of rifle development in Europe find themselves lost in a maze of inquiries. Why, for example, is the Palliser mode of conversion taken instead of the Parsons? Why do we insert a tube into a gun of a large calibre instead of rifling and hooping an 8 inch smooth-bore on the old French plan? Why do we convert guns at all? If we build them, should they be of steel like the German, steel and wrought iron like the English, steel and cast iron like the French, or cast and wrought iron like our own Parrott guns? Should we have breech or muzzle loaders; mechanical fitting, expanding or compressing projectiles; regular or increasing twist, square headed or pointed solid shot &c.?

I wish that it were in my power to satisfactorily answer all or even a great part of the perfectly rational questions that might be asked on

the subject of the proper system of ordnance to be adopted; but as ordnance stands to-day, apparently so nearly perfect and yet developed in different countries in systems almost directly opposed to each other in details, no one can do more than carefully review the courses pursued by different nations; become acquainted with the difficulties that have been encountered and with the changes that have been introduced to surmount them, and then, by comparing the systems, choose such parts as seem most to embody correct principles, and combine them into an economical and trustworthy system. This is the course which I shall attempt to follow in my lecture. To enter fully into a discussion of the development of the different systems would carry me far beyond the limits of an evening discourse; I shall therefore restrict myself to the *history* of rifled artillery, dating from the commencement of the Crimean war. I shall take the systems as adopted in France, England, Germany, Russia, Austria, Italy, and Spain, confining myself as much as possible to naval artillery, and follow each system up from the time of its inception until the present; and although I may contribute no new ideas, I trust that such as I do express, will be detailed connectedly and in such a manner as not to prove a trial to your patience.

In this historical record I give to France the place of honor, as I believe that to Colonel Treuille de Beaulieu of the French Artillery belongs the merit of having proposed the first successful system of rifling for heavy artillery, about 1842. No opportunity or rather necessity for the development of his ideas occurred until the breaking out of the Crimean war when several experimental guns were put in the field and embarked on the French cruisers. The first of these guns sent to sea were of a calibre of 16 c. m., or, about  $6\frac{1}{2}$  inches. Although of the 16 c. m. calibre, these guns were cast to the dimensions of the service 22 c. m. smooth-bore; that is, they were not unlike the old 68 pounders, with 32 pounder bores. The twist of the rifling was from right to left, the reason for this arrangement being that the naval firing-ground at Gavre was on a beach with the water on the right, so that had the twist been to the right, projectiles would have drifted into the water and their records would thus have been imperfect. It would be well to remember this point, as at the present time the French navy rifle is the only one in the world aside from a few unimportant Italian field-pieces, having the twist from right to left. Their own army guns are all rifled in the opposite direction. They had two grooves of a regular twist, the origin being at the front end of the chamber, and at the extremi-

ties of the horizontal diameter. The reason of this arrangement was that spherical as well as rifled projectiles might be used in the gun without destroying the grooves ; since, as you know, the scoring caused by the balloting of round shot in a bore is always at its bottom and top.

The grooves were of a curved shape, the bottom being of a long radius and connected to the bore by sharper arcs, the loading and driving sides being similar. The studs on the projectiles were two in number, opposite the centre of gravity and cast in one with the shot, being finished to a size and shape such as would enable them to move easily in the grooves without jamming. This then was their first gun, and in this shape the experimental one first tested at Gavre stood one thousand rounds without bursting, while there was no noticeable deterioration of the grooves until after the six hundredth. In the course of experiments however, it was found that there was a great liability of the gun to burst without warning and after only a few rounds, and in 1858 we find several changes introduced ; and here it is interesting to note the attempts to cure the gun of bursting. It was noticed that fractures were determined in the grooves and near the seat of the shot ; so first we see the ingenious application of the increasing twist, commencing at nothing, so as to allow the shot to get started, and gradually increasing to the full twist at the muzzle. Then, since the planes of weakness caused by the grooves were opposite each other, we find another change, to three equidistant grooves, the grooves being made shallower. At first the origin of one of the grooves was at the top of the bore, so as to allow spherical shot to be fired. But here was a new difficulty. The vent opened into this groove, and the blast escaping through it rapidly destroyed its edges ; so the position was reversed and the groove commenced at the bottom of the bore. Again, it had been noticed that owing to the loose fit of the shot it wobbled or was irregular in its flight. Here was introduced a decidedly novel improvement. The stud on the shot was decreased in size and on its driving side a zinc attachment was dovetailed. The object of this is plain. Zinc being very soft, when the shot started the edge of the groove sheared it so that before going far it became wedged firmly by the overriding of the stud. In order to make this shearing process certain, the driving side of the groove was cut square, the sharp edge being beveled off slightly to assist the overriding. When this had been done a new trouble showed itself. It was found that the sharp corner at the bottom of the driving side made the gun liable to crack there, so we find them compromis-

ing a little and making a curve at this angle. About this time the army discovered the idea of centering shots on the simple principle of the resolution of forces, and bear in mind the distinction between their idea and that of Commander Scott which will be detailed farther on. In the army, the driving side of the groove was made in an inclined plane perpendicular to the resultant of the forces acting on the stud, so that the shot instead of depending on the shearing of the stud for firmness, turned into a section of a smaller diameter. The navy people saw a flaw in this idea in the great increase of strain on the walls of the gun caused by the wedge-like action of the shot, so, as I said before, they seem to have compromised by a curve on the driving side of a less radius than that on the loading, thus making the bursting strain less directly radial in its action. This groove, the idea of Naval officers, was what is known as the "anse de pannier" or basket handle, and is the one which under a modified form was adopted as the English Woolwich groove. It was never changed in the French navy and is the groove now used with their mechanical fitting projectiles.

While these experiments had been carried on, it had been found that the zinc part of the stud did not need the iron reinforcement, so it was abandoned; the shot were cast plain and the zinc stud was afterwards swedged into a countersunk hole. Ever since the commencement of the experiments, great trouble had been experienced with the breaking up of shot in the bore, and for a long time the trouble could not be accounted for, as the shot were made of the best material; but finally it was found to be owing to the thumping of the shot in the bore. Remember that there was but one row of studs on the shot so that the ends were free to wobble, and by bumping along the bore the base was cracked, and of course the shot broke up.

The first suggestion would naturally be, apply another row of studs; but this was impossible with the increasing twist, as both sets would not of course take the driving edge. To remedy this a smaller row of studs or *buttons* was put on the rear of the shot in such a manner, that when it was first entered into the bore the main studs and these "plaques isolantes" or steadying buttons both rode in freely, but when the shot was home, the stud being properly in its seat, the button bore hard on the driving side. Being much thinner it sheared very easily and so allowed the main stud to get a bearing and the shot came out straight. This was an effectual remedy for the breaking of shot. We have now brought the experiments down to 1859 at which time the 17 c. m. gun was introduced; this and higher calibers being given five grooves. At

this time the idea of hooping guns was borrowed from England. This was accomplished by turning down the reinforce of the gun until it was cylindrical and then shrinking on hoops of soft puddled steel, the hooped part at first only coming as far forward as the trunnions, but, as charges and length of projectiles increased, the guns were cast without trunnions, and these were made up with one of the hoops. Great advantages were found from hooping. The gun was found to be greatly strengthened without the addition of much weight, the pieces did not fly about much when the gun burst and it was found that the gun would give a warning before bursting by a separation of the hoops. In 1860, immediately after the adoption of hoops, experiments were made in breech-loading and a system was adopted.

The gun being bored completely through was hooped, the last hoop being much heavier than the others and made with greater care. The breech mechanism was of the type known as the slotted screw. That is, a male screw-thread being cut on the breech-plug and a female one in its seat, three sectors of  $60^\circ$  each were cut out so that the plug could be pushed in and locked by one sixth of a turn. Through the axis of the plug ran an arm having at its outer end a handle, which served to push in or pull out the plug. On its inner end was a piece called the gas-check carrier. This was of steel and all except the front portion was of the diameter of the plug seat. Three scores were cut in the circumference of this carrier corresponding to the screw sectors, which kept the carrier from turning when the plug was in place. This was necessary in order not to disturb the gas-check when it had been carefully jammed into place. The gas-check was made of a single piece of sheet-steel, hot pressed into shape. It was circular with a turned up and bearded edge. A circular piece was cut from the centre and the check was held in place by a broad-headed screw which made a tight joint. The breech-block was hollowed out in order to make it as light as possible without weakening it, but even this was not found sufficient to allow the block to be handled easily. In order to overcome this difficulty a heavy piece of bronze was bolted to the right and below the rear of the bore. This piece of bronze had a groove, in which travelled a saddle so shaped as to receive and hold the breech-block when withdrawn; by pulling to the right the block and saddle were slid aside and the bore was unmasked. A small iron plate shaped to the bottom of the bore was then pushed in until it took against the seat of the gas-check, so that its upper surface was flush with the bottom of the bore and carried a prolongation of the lower groove which served to guide the projectile to its seat in

loading. There was danger, in loading, of pushing the projectile in too far, and to remedy this a short section of the lower groove was cut back making a little seat. On the projectile and alongside the "plaque isolante" a smaller button was dovetailed which brought up in this seat when the shot was home and was completely sheared off when it started out. In 1866 the sliding saddle was changed to the hinged one similar in its mode of working to that of our breech-loading three inch rifle. Since with breech loaders it became necessary to use great care against premature discharge and firing with the plug only partially locked, an arrangement was made which on locking caught and held the opening lever. Near this was an arrangement through which the primer lanyard rove and was firmly held until the locking lever released it. In addition, a small iron plate covered the vent until the breech was locked. All these attachments worked automatically by being touched by the locking lever when firmly in place.

At this time a slight change was made in the studs and grooves, the former, for the heavier patterns, were made of brass instead of zinc, and were a neat fit in the grooves when home. The grooves were made decreasing in depth from the seat of the shot to the muzzle so that the studs were pinched slightly. About this time, 1865, breech-loaders were definitely adopted as the service navy gun, and the calibres were increased up to 27 c. m. or  $10\frac{1}{2}$  inches. In 1865, Mr. Parsons, an Englishman, submitted a plan to the French government for strengthening guns by inserting a steel tube from the rear. A gun strengthened on this plan was tested at Gavre and showed a remarkable endurance. The French seeing at once a great advantage in this idea adopted it and worked it up. There was another point over which the French had studied for a long time. It was well known that the violent rush of gas through a windage ring causes quick deterioration of the bore. Many plans had been suggested for overcoming this difficulty and the first results from experiment appeared in 1871 when a new system was adopted full fledged. The calibres established for this system were 32, 27, 24, 19 and 14 c. m., or  $12\frac{1}{2}$ ,  $10\frac{1}{2}$ , 9 4-10, 7 4-10, and  $5\frac{1}{2}$ , inches. These guns like those already described were of cast iron and hooped, and in addition were tubed on the Parsons plan, the tube being of Bessemer steel tempered in oil. The length of the tube corresponded to the length of the hooped section and it was secured in place by screw-threads worked on the rear end. They were breech-loaders as already described. The great change however was in the substitution of the compressing for the mechanical fitting projectiles. The number of grooves corresponded

to the number of centimeters of calibre, or, when this was an uneven number, to the number plus one. I have called these *grooves*, although properly speaking they were ribs, this name for the projections being certainly more definite than the literal translation of the French term, "rayures saillantes," or projecting grooves. These ribs were equally spaced with square edges, the rib and bore being connected by an arc of small radius. The twist was increasing. The projectile was furnished with two belts, the forward one being of the diameter across the ribs and simply serving to hold the nose of the projectile in place, the rear one was of the diameter of the bore, the ribs cutting into it and giving the twist to the shot. These belts were made of brass and dovetailed into the shot. This, then, is the gun as fully developed up to the present time. It will be noticed that throughout the course of this development, the French held fast to a cast-iron body for the gun. They had two good reasons for it. First, there were no manufacturers in France who could produce steel of a proper quality in the required large masses and it would have been to the last degree impolitic to trust to foreign manufacturers. Again, throughout the whole course they, seemed to have an eye to the conversion of all their great stock of heavy smooth bores, which in a measure accounts for the careful nursing of the cast-iron. Here is a point that may well be soberly considered by those officers who sneer at the idea of doctoring up smooth bores. If such you meet, you may well cite to them the example of France, who is to-day contending for supremacy in ordnance power making new guns of cast-iron and still using effectively her old converted ones. I will here mention that the cast-iron system is not the final one of the French. Steel is their metal and they are now slowly introducing steel heavy guns, built I believe on the Vavasseur plan of hooping. This change cannot be called completed yet, however, as the steel is not considered fully enough worked up for the heavy calibres. Another point of interest is the tenacity with which they clung to the mechanical fitting projectile, doctoring studs and grooves and working against great odds until the minds of experimenters were fairly forced out of the rut they had been traveling in, when at once comes the radical change to the compression system. To sum up the French development then, that of the gun may be divided into five periods: 1st. that of the old smooth bore converted into a rifle by cutting two grooves in the bore, then the application of hoops to the outside, then the change from muzzle to breech loaders, then the introduction of the steel tube and finally the change now in progress, to an all steel gun.

With the rifling; we have first the regular and then the increasing twist. With the grooves; first the similar sided curve and two grooves, then the bluff fronted followed by the anse de panier groove, the change to three and afterward to five grooves, and finally the multigroove system for the compressing projectile. With the studs; first cast iron in one with the body, then zinc reinforced by cast iron, then zinc alone, then the plaque isolante, then the button for breech-loading, then the brass snug fitting stud, and finally the belt.

I will now consider the English development. Before entering on this part of the lecture I wish to emphasize the point, that in France, while following the same system in the main, the army and the navy worked independently of each other, each one building its own guns. In England matters are managed differently. The navy at first had nothing to do with the guns. They were designed, manufactured and even put aboard ships by the army. Finally, after Commander Scott and a few other naval officers had patiently labored until the war office was obliged to take some notice of them, the navy was allowed to suggest what it thought proper for its armament; but beyond that it has not been allowed to go; as witness a request of the admiralty to the war office for a gun that shall pierce twenty inches of iron at one thousand yards. Their request was acceded to, and the army are now making the final experiments with the navy eighty-one ton gun. I sincerely hope that American naval officers may always be given credit for being able to do their own work, and I might add that I hope that they will see to it that the credit is not misplaced.

We cannot with the English rifle as with the French, enter at once into the discussion of naval guns. Whether rifles were used aboard ship during the Crimean war or not I am unable to state but I think not; the first bona fide English rifle, however, used in service was the Lancaster gun, so named from the system of rifling proposed by the inventor Mr. Lancaster. The first of these guns tried at Shoeburyness was an eight inch cast-iron gun strengthened at the chase and muzzle with wrought iron hoops, the bore being oval in section. It stood the test quite well and a number of eight inch and sixty-eight pounders were immediately rifled *but not strengthened* and sent to the front. It had been found that cast-iron projectiles would invariably break up in the bore as there was no twist in their shape to correspond to that of the bore nor could there be since it was an increasing twist. Wrought-iron projectiles were, therefore, supplied. This type of gun almost completely failed, as the gun invariably broke up at the forward part of



the chase. They were used, however, and quite effectively after the chase had been blown away as howitzers in the parallels before Sebastopol. Mr. Lancaster afterward changed the twist of his rifling to a regular one and altered the shape of the projectile, but his system was never able to contend with the others presented. About the time of the introduction of the Lancaster gun Mr. Armstrong presented his system of breech-loaders. These guns were found good in every respect as field pieces and were formally adopted into service in 1858, Mr. Armstrong being shortly afterward knighted and appointed Superintendent of the Royal Gun factories. In order to follow up the development more clearly I will consider the changes in the different portions of the gun separately, commencing with the development of the groove. As before stated Lancaster's groove or rather oval bore with an increasing twist proved a failure, and the next in order is Armstrong's style of multigroove for compressing projectile. As submitted in his early patterns, this groove was saw-toothed in shape, the driving side being radial to the centre of the bore and the loading side curved off. The number of grooves varied with the caliber of the gun from thirty-six to seventy-six and had a regular twist. This system of grooves for the Armstrong breech loader has never been changed. In 1863 an Ordnance Special Committee was appointed to decide upon the respective merits of the Armstrong and Whitworth systems. In this contest three styles of grooves were presented. Whitworth's was hexagonal, a form with which you are no doubt all acquainted since it is one of the distinct features of his gun, differing from that of any other gun in the world. Armstrong's grooves were, the one just described, and the shunt groove for muzzle-loaders; an ingenious arrangement for centering shots. This groove was a double one, the driving half being shallower than the loading, gradually growing into the latter towards the seat of the projectile. The projectile being inserted into the muzzle with the studs in the loading side went home quite easily, being shunted off to the driving side by a slight cant of the loading side at the bottom of the bore. As in coming out it constantly met the driving side it gradually rose up into the shallower part where it was firmly pinched and centered. The result of the contest was in favor of the Armstrong systems, that is the breech-loader with the multigroove and regular twist, with lead coated projectiles for the light guns and the muzzle-loader with shunt grooves, regular twist and soft metal studs for the heavier. Both of these patterns were introduced at once into the navy. The shunt groove was found objectionable in the following points.

It was complex, requiring great care in cutting. The projectile met with a sudden increase of resistance which endangered the life of the gun at its weakest part, near the muzzle, and the studs tended to override the grooves thus making the accuracy uncertain. As at this time the government had decided to adopt muzzle loaders for the heavy calibres, it became necessary amongst other things to find a suitable groove. Guns rifled on different principles were submitted to a competitive test. The most prominent of these systems were the Lancaster, Whitworth, Armstrong, Scott, Britten and French anse de panier. I will here remark that of the ten or a dozen systems submitted but one was due to the genius of a British officer, that of Commander Scott of the Royal navy. His groove came very near winning in the contest and met with unqualified praise. It was a centering groove, constructed on scientific principles and certainly accomplished all that was demanded of it. The system submitted by Britten was suspiciously like our own Parrott rifling, being equally spaced rectangular rifling intended for a projectile with an expanding base-ring. It was condemned on account of the liability of the base-ring to fly to pieces. The contest resulted in favor of the Scott and French systems, Whitworth's being inseparable from his gun. Of the two successful grooves a compromise seems to have been made resulting in the Woolwich groove, which differs but slightly from the French navy groove. This is the groove as it stands to-day for all muzzle-loaders in the English service save the old Armstrong shunt guns which are still in use although none are manufactured. With regard to the pitch of the rifling, Armstrong had always used a regular twist but when the French groove was adopted the increasing twist seems to have been taken with it. Later, however, a return was made to the regular twist for all guns below a calibre of seven inches, above that the twist is increasing in order to distribute the strain better along the bore. I will now turn for a moment to the projectile. The segment shell, familiar to you all, was of Armstrong's invention and intended simply to present solidity enough for impact with breaking up power enough to serve also as shrapnel. The outer coating of lead of this projectile was about 1-10 of an inch in thickness, into which the grooves or fine teeth of the rifling cut. This shell was only used with the breech-loader. For the shunt groove a double row of gun-metal studs was used. Studs are of course necessary with the Woolwich groove and since the twist is increasing for the heavier calibres, the rear studs served simply as bearings for the rear of the projectile, while the front studs gave the spin to the shot. For a long time great

trouble was experienced with the action of the projectile. No doubt all of you have often read the discussions on the wobbling of the shot, and the battering of the bottom of the bore. Steel tubes were found to crack and become used up much faster than their strength seemed to warrant, and for a long time the excuse of poor steel was made; but evidently this excuse would not answer, for two reasons. First they used the best steel in the world and then the tubes always split in the same place. The true reason was this. Owing to the increasing twist, the rows of studs had to be quite close to each other to prevent the rear ones from overriding the loading side of the groove, so that the projectile was almost hung by its middle. It will be remembered that the French found difficulty with their single row of studs, in the shot breaking up through wobbling and they prevented it by adopting the "plaque isolante." Just why the English did not do the same thing long ago, I do not know, unless it was through obstinacy of the artillery officers who would not give up their plea of weak steel. However, they were all the time seeking a remedy not for the steel, but for the projectile and finally found it in adopting what they call a copper gas check, that is, a copper disc is bolted to the base of the projectile, which, if the projectile tends to thump, acts as a soft fender while being expanded by the explosion it stops up the windage ring and steadies the base of the projectile. This is the condition of the projectile at present, and if my opinion can be considered worth anything I should say that at least with the calibers below twelve inches it would be better to drop their mechanical fit projectiles and adopt the expanding base-ring on our system, instead of making a compromise between the two. If their copper gas-check can give the spin to their projectiles, and it certainly ought to if properly applied, the studs are useless. In 1867, Major Palliser introduced the chilled headed projectile which only differs from others in having the head chilled in a cast iron mould thus making it very hard. This is the present style of armor punching shot. I will now go back to the development of the gun. I mentioned that after the failure of the Lancaster gun, the Armstrong pattern was adopted. This gun was made up of a steel tube strengthened by wrought-iron coils. The merit of strengthening guns by hooping, in England, belongs to Captain Blakely, from whom I think that there is little doubt that Armstrong took his first ideas. They had a long controversy over the matter which was never definitely settled. There is this much, however, in favor of Armstrong, that his hoops were the first coiled ones introduced in England, and I think that the idea

of coiled hoops instead of welded ones is his. His breech-closing apparatus consisted of a steel block which was dropped into a vertical hole through the gun in the plane of the bottom of the chamber, and was pressed against the bottom of the bore by a hollow tube working in a screw-thread in the direction of the axis of the bore; the screw was set up by a crank on its end, the crank being very heavy and working freely through a small arc so that the joint could be tightened or loosened by the shock of driving the crank around. This gun has remained almost unchanged ever since as a light piece for broadside and boat service. The navy found a great deal of fault with it at first and to satisfy this branch of the service, a mechanism of slightly different character was introduced known as the wedge gun. This was found to be worse than the other, however, and has gone out of service. In 1863, an Ordnance Select Committee was appointed to decide upon the merits of different systems of guns, projectiles &c., and in this contest Armstrong won. Many will doubtless remember the bitter newspaper war that was waged from '63 to '70, on account of the decisions of this committee. Whitworth has always found many supporters, not only in England but all over the world, until last year when his twelve inch steel gun tested in France completely failed in endurance. In 1865, the English government decided to adopt muzzle loading for all heavy calibers, while for the lighter ones the Armstrong breech-loader was retained. The Armstrong method of construction was also definitively adopted. This was essentially the steel tube with wrought-iron coils, the number and size of coils increasing with the caliber. The breech-piece was forged in one, altering the direction of the grain of the iron in order to give greater longitudinal strength. The coils butted against each other and the layers covered joints. In 1867, Mr. Frazer modified the construction by doing away with the forged breech-piece and substituting a few large coils for the many small ones. Shortly afterwards Mr. Anderson farther improved the system by hooking the coils and since then the system has remained unchanged. In 1863, Major Palliser presented his plan for converting smooth bores, by means of inserting a reinforced coiled wrought iron tube from the muzzle, and securing it in place by a muzzle-ring. The plan was found to be excellent in every particular and was at once adopted. All the old guns, amounting I believe to about twelve hundred, 8 and 6 inch, that have been converted and sent into service, are rifled on this plan; with the Woolwich groove of course. This then constitutes the main part of the history of the development of rifled Ordnance in England. Un-

like that of France we see that the original ideas are almost entirely those of civilians, and they have been numberless. While the French carefully worked out a system having an eye always to the strictest economy, the English at once plunged into a series of costly experiments. Puzzled and distracted by the many and radically different systems, it was with difficulty that she chose from the many a single system, and although she finally succeeded, it has been at great cost and has involved her artillery in a complexity of calibers and designs puzzling even to the English. To name them all would be almost useless and I confine myself to the different calibers of Naval Artillery, omitting the patterns. The Armstrong breech-loaders are the 6, 12, 20, 40 and 64 pounders, and the 7 inch or 110 pounders. The muzzle loaders are the 7 pounder bronze and steel, 9, 40 and 64 pounder Woolwich and the 64 pounder shunt guns, the 7, 8, 9, 10, 11 and 12 inch Woolwich guns, to which will soon be added the 16 inch making in all 19 patterns, not counting sub-divisions, as against the 6 or 8 in the French service.

The next country to be considered is Germany and you may thank Herr Krupp and German economy that I cannot find systems and changes enough to try your patience to a great extent. Prussia, like all other European countries, has carried on unimportant experiments in rifling bronze and cast iron guns for the past forty or fifty years, but I cannot find that anything worthy of mention was developed before 1859 or '60 when Krupp presented patterns of muzzle and breech loaders. The muzzle-loaders were at first cast-iron reinforced by steel and afterwards steel guns, but I will omit descriptions of these as they were soon dropped for breech loaders. Since that time this firm seems to have enjoyed the monopoly of developing rifled ordnance in Germany under the superintendence of government. The firm claims a secret method of preparing their steel, but of late years the outside world has inclined to the opinion that the only secret about the metal is that the firm are very careful, and strictly honest in their contracts. The first style of breech-loading gun, presented by Krupp, as far as I have been able to judge, was what might be called the infant from which the present model has grown. The breech of the gun had a transverse slot in it, square in front and hexagonal at the back. Into this slot a wedge fitted, having pivoted at its large end a lever for loosening it after the discharge. The wedge was lightened as much as possible and to save the trouble of withdrawing it completely, a hole of the size of the bore was cut out of the part of the small end that was masked by the wall

of the gun when it was pushed home. I cannot warrant this description as being accurate, although it is taken from what purports to be Krupp's English patent. I am inclined to doubt its accuracy for the reason that I think there must have been some kind of a lock on the lever to hold the wedge in place during the discharge. I think also that there must have been a small chain or stop attached to the wedge to limit the withdrawal, so that the gunners could not accidentally pull the wedge all the way out and let it drop on the ground. The next pattern or possibly, it may be the first in point of time, was on the principle of Wahrendorff's mechanism, and here I will state that the Swedish Baron Wahrendorff is the real father of the present Krupp system, he having first shown the world the method of giving twist to a rifled shot by means of the lead coat and compressing system, besides the fact that his gun was similar in principle to the one about to be described. This system, known in Prussia as the Piston closure, was made secure by a keyed nut. The gun was bored completely through and a smaller transverse hole was bored at right-angles to the bottom of the bore. The breech-plug consisted of a heavy, short shaft with a disc on the end not unlike a piston and rod. The disc being pushed in from the rear formed the bottom of the bore when home. After it was in place it was keyed by a heavy cylindrical bar fitting through the transverse hole in the gun and a corresponding hole in the piston-rod. A sort of door hinged across the face of the breech and when closed the end of the piston-rod projected through it. On this end a screw thread was cut and a sort of nut with a conveniently sized handle when screwed against this door set all the parts tight against the big transverse key. A chain attached to the key prevented it from being drawn back any farther than was necessary to release the piston. This system seems clumsy at first, but its manipulation was easy. Suppose for example that the gun had just been fired. A half turn back of the nut loosened the key which was pulled back the length of the chain; then by pulling straight back, the piston was withdrawn until the head struck the door which opened, swung the block aside and unmasked the bore. This system bears date 1861. The next improvement was what is known as the Kreiner system. In this a rectangular hole was cut through the gun transversely at the bottom of the bore. In this hole fitted two wedges having their inclined faces towards each other. Now it will be easily seen that by pushing the wedges in contrary directions the thickness of the two was increased or diminished. A short round arm projected from one wedge having

a screw-thread cut on it, on which worked a nut which rested against the side of the gun. By turning this nut the wedge of course was moved. The other wedge was held fast by a collar which clasped the screw-shaft. The larger wedge was hollowed out on the masked part so as to admit of putting the load through it without pulling the wedges all the way out. This system was adopted in 1864 and is still, I believe, in vogue for light pieces; but when the heavy calibers were built, the well-known cylindro-prismatic or Krupp wedge was introduced. This was a single wedge, square in front and rounded at the back. The rear section of the slot was inclined at a slight angle to correspond with the slanting face of the wedge. On the back and at one end was the locking arrangement which was nothing more than a screw-shaft provided with half threads which travelled in female threads in the gun wall. These served both to lock and to set up or loosen the wedge. In the heavier calibers where the wedge is too heavy to be manipulated by hand there is another screw-shaft with a full thread working in the same manner in female threads and thus serving to traverse the block in or out. This is the Krupp gun of to-day. In the development of this idea we see, like the French, a system first carefully studied and adopted and then worked up. Unlike the French though, it commenced with an entirely new gun and while the French took cast-iron because they could not make the steel, and the English chose steel and wrought-iron probably more on account of Armstrong's powerful influence and reputation than anything else, the Germans went at once to work with the best and costliest material: they have brought forth an excellent system and apparently with less hindrance and false experiments than other nations, but precisely what and how many mistakes they have made it is probable no one will ever find out.

Next in the order of naval importance comes Russia. At the time of this rifle fever throughout Europe which may fairly be said to have infected the whole continent in 1860, Russia was in a similar position to the United States to-day. She had neither the work-shops nor experience necessary to turn out a good and original system. But she was not behind-hand in the race, and after a short examination of the different growing systems she adopted the French; probably on account of its simplicity and economy and its adaptation to smooth bores. By 1864 she had converted a great many of her smooth bores. Then came a short season of muzzle loaders and shunt rifling which had as it were come into fashion all over Europe, and she came near adopting the Armstrong

system throughout; but after the German war of 1867 she became enamored of the Krupp system and definitively adopted it. For some time she was totally dependent upon Krupp's factory, but with admirable energy she turned her whole attention to steel manufacture and in 1871 she could show a breech loader made of steel, claimed to be better than Krupp's. As far as experiment has been able to test it, it has shown itself at least equal to it. For light guns the breech-block is adopted from the Swiss system, which is almost identical with the Krupp, except that the block is rectangular instead of cylindro-prismatic. For heavier calibers the Kreiner system is used, differing from German guns in having the locking screw between the wedges so as to work both instead of but one, a simple and important improvement. For her heaviest calibers the Krupp system is used, differing slightly in a few minor details. For the comfort of Americans who so long clung to the idea that the smashing effect of huge spherical projectiles was superior to the penetrating effect of rifled ones, I will remark, that as late as 1871 I believe, the heaviest of Russia's iron clads the "Czar Peter the Great" was intended to carry a battery of twenty inch Rodman guns which with the fifteen inch had been definitively adopted into the Russian service.

Austria is the next country. In 1861, this country started out on independent experiments with gun cotton, and for a time bid fair to introduce a system of Artillery radically different from any other; but owing to frequent accidents with the gun-cotton, the idea was abandoned in 1869. She then found herself behindhand in the race and looked about for some system to borrow. Her smooth bores were, I believe, converted on the French plan while her navy was supplied with Armstrong rifles. These form her naval battery now, the majority of the guns being muzzle-loading shunt rifles. For light guns she adopted Krupp's Kreiner system, but owing to its cost and the dependent position it placed her in with regard to Prussia, she experimented with guns of her own, and by 1874, General Uchatius had perfected his improvement in bronze, and light batteries of steel bronze were introduced. The metal is ordinary bronze, cast in a sort of semi chill mould under pressure, the ingots after boring being put in a state of tension by driving mandrils through the bore. It seems that this metal cannot be applied to heavy calibers on account of the great cost of the large masses, and it will probably not find its way into the navy in calibers heavier than three inches.

We can hardly say that there was such a country as modern Italy



previous to 1861. Her artillery at the time of the consolidation of the kingdom was in a very mixed state and even now it is not reduced to proper shape. In her navy, however, Armstrong guns are found almost exclusively, the majority being muzzle-loading shunt guns except the very heavy ones which carry the Woolwich grooves. This country cannot however be passed by without giving honorable mention to Colonel Cavalli of the Sardinian service, who in 1846 presented a reliable breech-loader which until the rifle fever broke out found great favor throughout Europe. It was a cast-iron gun with two grooves on Colonel de Beaulieu's plan. The breech-closing arrangement was a simple wedge, sliding transversely into place, but having no lock to hold it. It was always displaced by the discharge but never to a great extent. The bore of the gun extended all the way through, and in case the wedge stuck fast it was loosened by prying with a hand spike inserted from the rear and fitting in a notch in the back of the wedge. There was a handle on each end, one of them being formed in a loop so as to allow the load to be passed through it.

Spain has no artillery of her own. Her smooth-bores were converted on the French plan with steel hoops, and in her Navy the Armstrong is the principal gun, although many Whitworth and Blakely rifles are found. In making up her battery she did not appear to follow any system exclusively but purchased as she needed from England. I believe that she has no Krupp guns.

Her army however has made many good improvements in minor points and they have facilities for building heavy guns. It is cheaper however, to go into foreign markets.

I have thus reviewed the Artillery of the chief nations of Europe, and find that there are three main systems. The French breech-loader, the English muzzle-loader, and the German breech-loader. All others are offshoots from these, and the question that we have to settle is, can we invent a better one of our own, or shall we adopt one of these. Now let us see in what direction our prejudices lie. The Parrott gun has been our only one, if we throw out the few rifled cast-iron guns which were only used on a small scale during the war. This Parrott system did us good service during our war but the unfortunate explosions at Fort Fisher may be said to have killed it, the more so as every one knows that it was only accepted provisionally, until we could get a better one. I think that if the question of efficacy was put to vote here now amongst you, the verdict would be an unsparing condemnation of a system based on the Parrott gun. I propose the English system;

and am I not right in the assertion that most here would shake their heads at it? Have we not read the alarming tales of England's cemetery of suicides? Do we not see almost daily complaints of the great extravagance, the perversity of the English "artillery ring," the faulty studs, and the thousand and one other lame points heralded forth by English journals? And then are we not prone to say that her principle is wrong; that it is no use putting this stretchy wrought-iron around steel. No, you say we should not take England's pattern as long as even she is dissatisfied with it. And what do you say to French? Well we don't hear much about French guns, and then they use cast iron, and haven't all the books for the past fifteen years been condemning cast-iron for rifles? Then again don't we know that France is going to use steel, as soon as she can make it of the proper quality? No, that won't do. Well, how will Krupp's gun do. Now there is something like a gun. Steel is the best metal of all, that we know. Then Germany certainly ought to know what is best, for has she not frightened half the world with her military perfection? Have not Russia, Austria, Turkey, Egypt, Japan, Chili, Peru, and a dozen other nations gone to her market for rifles? Does not Krupp boast that England dare not bring on her system for a competitive trial, and have we not ourselves seen that beautiful 35 c. m. gun, shining like a new dollar, with a breech-mechanism that works to perfection? That is the gun for us—if we only could build it. But we can't make the steel. What *shall* we do, for of all the systems that is the only one absolutely without a flaw. I think that I make no false hypothesis in stating that these are the opinions of the majority. But let us go slowly for a moment and consider. Now you all are absolutely certain that cast-iron is not fit for a rifle; that goes without saying. Well! At this moment, in Italy, a gun of ninety tons weight, intended to throw a projectile weighing seventeen hundred and sixty lbs, with a charge of three hundred and thirty lbs, is being built and it is to be made of cast-iron; not tubed, but hooped over the seat of the charge. Russia, to-day is building a sixty-four ton gun with a cast-iron body. France has already her thirty-five ton breech-loading cast-iron guns. Would it not be well to hold back our judgments a little? Hasty people are the ones who have said that cast-iron is too weak, and while they have been making an uproar, the students have tamed the powder until the metal will hold it. So much for the boasted superiority of steel. And if our cast-iron is strong enough, and it should be, for no country can show better, we can throw Germany and England out at once.

Do we want breech or muzzle loaders? This is a question that has not been fully solved, but I think that we might go the way of the world. This ninety ton gun that I spoke of is a breech-loader. The Russian sixty-four ton gun ditto. The French thirty-five ton guns the same, and now, in muzzle-loading England, Armstrong presents his twelve inch breech-loader. If then the navies of the world want breech-loaders, so do we. In the same way and for the same reason let our breech-loaders be on the French plan. All the heavy before-mentioned guns are, and when the world agrees we had best follow. But you ask, why don't we make breech-loaders of the eleven inch guns. It may be accounted for I suppose by quoting the French saw "*Le jeu ne vaut pas la chandelle.*" Those who are in favor of putting breech mechanism in the eight inch rifle, must not grumble at the three inch. You ask then, why make breech-loaders of the one hundred pounder Parrotts? Go back to Fort Fisher and you will see. The weak part is cut out and the gun strengthened and in making a breech-loader of it we can see just how to make one that will be effectual, on a larger scale. These eighty pounders, which I fear some are inclined to sneer at before looking at, are experimental guns. We are trying an experiment that we know will not spoil the gun and which may better it. In fact, gentlemen, I think that I can state with certainty that we are not engaged in foolishness in these few weak first steps. Remember, you who would criticise, that criticism of ordnance is at present delicate business for the best informed. We have converted eleven inch smooth-bores into rifles on the Palliser system because after a test of more than ten years it has proved to be as safe and efficient as the best, and absolutely the cheapest method. We have made them into eight inch instead of nine inch because the difference in power between the two calibers is not sufficient to counterbalance the increase in cost of ammunition and the increased difficulty of handling the greater weight. But with that weight of metal as it stands, eight inches is better than nine. We have mounted those guns on hydraulic-recoil geared carriages just to see for ourselves how to make such carriages for heavy calibers. And now it remains to watch carefully for the result. Failure there cannot be, imperfect success there no doubt will be, and when that imperfection has been cured we shall be ready to take another step but not before. Another word and I will finish. I think that the majority of those who only read of the progress of ordnance from time to time are prejudiced in favor of the Krupp system. There is something sublimely indefinite about it; and just for that reason I advise you all to study it closely. You know the minutest details of every English failure.

French mistakes leak out, but if we go by what we casually see there is no such thing as a faulty Krupp gun. The truth is this; Krupp could originally throw a greater strain on his steel gun than other nations could on theirs and so when the battle began, the marvellous velocities and calibres of Krupp took the world by storm; but other nations while holding to their systems, worked up their powder until they also could get the high velocities, and now we see Krupp using steel where cast-iron will do as well. I do not condemn this system in the least, but I only wish to show to those who may be such firm believers in German Artillery that while it may be the strongest in the world, that very strength may be a weakness in that it increases the cost without giving a proportional benefit. To those who favor England I suggest a careful consideration of the immense difficulties that we must encounter in order to take such a system. We have no Government shops in which such guns can be built. No private firm would undertake the construction with such slight guarantees as we could offer. Above all, skillful as our mechanics are, they cannot at once enter into the construction of such refined ordnance, and neither time nor expense can be spared for instruction. Journalists have no doubt greatly magnified the faults of the system but still the facts alone are sufficient to make us hesitate about such a serious matter as the adoption of a system. To those who favor the French system I offer the warning, that the life of a French gun is short. Although it may be fully proved that cast-iron can serve the purpose, it still is not safe with such powder as we have or as others have. To hoop and tube a large gun requires experience and money, and we have neither. Finally with regard to trusting to our own inventive genius; we must beware of England. We cannot encumber ourselves with false experiments and a multiplicity of calibers. There may be a man in the interior of Kentucky who never saw a ship, that might design a craft superior to anything afloat, but still you wouldn't go to a great expense to test his model, because you know that he has no experience to guide him. Just so with ordnance. Because a man can handle a shot gun, it is no reason that he can design a twelve inch rifle. In fact, rather the contrary, he is more liable to be guided by crotchets. Let us then make haste slowly with our judgment, and not jump at conclusions. There is no use in getting frightened because we haven't our thirty-five ton rifles. Why, if we had, we havn't any ships to carry them to sea; and take my word for it, when we have the vessels to carry the guns, the latter will be forthcoming; good reliable weapons with which we need not be afraid to back up

our assertions. Just now all we have to do is to calmly and diligently study, and when the time comes, and Congress turns to us for help and gives us money to work with, let us be ready to jump to the front and work quickly and intelligently.



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Commander EDWARD TERRY in the Chair.

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THE CONVERTED EIGHT INCH M. L. RIFLE.

BY LIEUTENANT DUNCAN KENNEDY, U. S. N.

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The new eight inch converted muzzle-loading rifle is made on what is known as the "Pallisser System"; that is converting a smooth bore into a rifle by inserting a wrought iron tube at the muzzle.

In this paper I propose giving a brief description of how this change is made.

The original eleven inch S. B. is placed in a lathe and bored out to a diameter of 13."5 from the muzzle to the bottom of the chamber a distance of 131."2; the corners at the bottom being rounded off with a radius of 1."7. The bore is very accurately gauged along its entire length and a plan made by which to turn down the outside of the tube. A course rounded screw thread is cut in the muzzle of the casing for a distance of 3."75 for the muzzle ring; and a further distance of ".5 without any thread, to insure the ring holding the tube close home. There is a small hole or gas escape ".2 in diameter, through the base of the breech from the right side of the cascable to the middle of the bottom of the bore, which is in connection with radial grooves cut on the bottom of the cup and tube, one of which joins the end of the spiral gas escape cut around the reduced portion of the A tube. The old vent is closed with a wrought iron screw plug, and the lock lugs on both sides removed, as it is intended to fire the gun with friction pri-

mers. A hole 1.75 diameter is bored in the chase at about 17" from the right rimbase for a screw steadying plug. As it was found that the gun when converted had a muzzle preponderance, the original cast iron trunnions were turned down eccentrically and a composition eccentric collar put on, the collar being secured to the trunnion by a screw key; the whole shifting the centre of support 1.75 further from the breech and giving the finished gun a preponderance of plus three hundred pounds at the base ring. The finished gun weighs seventeen thousand, three hundred and thirty pounds. The lining of the gun may be properly divided into three parts viz. A tube, B tube, and cup at the bottom of the bore.

The iron of which the tubes are made is obtained from the Ulster Iron Works at Saugerties N. Y., and is made from the best pig iron selected from magnetic and hematite ores taken from the mines of New Jersey and Lake Champlain. The pig iron is puddled for the purpose of purifying it from carbon, sulphur, silicon &c., four different kinds of iron being mixed in the furnace. When the mass is sufficiently purified and becomes pasty, it is separated into balls and passed under a steam trip-hammer, where the slag is removed and the ball formed into a bloom. The bloom is about 18" long, 4" or 5" square and weighs about one hundred pounds. This operation is very carefully watched, and balls showing any inherent weakness or want of proper puddling are rejected.

The blooms are then re-heated, rolled into slabs, cut into short pieces, piled, raised to a white or welding heat and again rolled into slabs. This process is repeated three times, great care being taken each time to maintain the fibre of the iron always in the same direction. The last pile from which the bar is finally rolled is composed of seventeen slabs, 51" long, 7" wide, the top and bottom slabs each  $\frac{3}{4}$ " thick and the intermediate ones  $\frac{1}{2}$ " thick, making a pile 51" x 10" x 7". This pile is placed in an anthracite furnace, raised to a welding heat (3000° F.) and passed through a succession of rollers of gradually diminishing dimensions until it is finally rolled into the bar required for making the tube. The cross section of the finished bar is nearly, but not perfectly, trapezoidal, the sides bulging out slightly. By making the bar simply trapezoidal in cross section, it was found that, in coiling, the sides became concave, thereby forming a pocket, which in the subsequent coil welding served as a receptacle for cinder and prevented a perfect weld. In order to avoid this the shoulders were added whence a supply of metal could be drawn to fill up the concavity of the sides.



The bars are 18' long, 4" outside, 3 $\frac{1}{4}$ " inside, 3 $\frac{3}{4}$ " across the shoulder and 3 $\frac{1}{2}$ " deep. When the bar is subsequently wound around the shaft, narrow side inwards, the inside expands, the outside contracts making the bar 3 $\frac{1}{2}$ " square. The slabs in the bar stand vertical in the direction of their length and in the coil welding which takes place on the side of the bar and against the flat of the slabs, they are driven more solidly together. The iron of the bars breaks at a tensile strain of fifty thousand pounds per square inch, and presents when fractured a bright fibrous appearance indicating great tenacity.

#### COILING.

The bar to be formed into a coil is about 34' long, being made up of two of the original bars welded together with a tongue weld. This tongue weld, or V scarf as it is sometimes called, by affording a firm grasp to the ends and by exposing a large surface for welding is thought to insure a strong joint; yet so great is the strain thrown on the bar in the operation of coiling, that separation does sometimes take place at this point. The weld is made in three heats. In the first, one end of the bar abuts against a heavy timber, and the other end is struck several blows with a sledge hammer to close and upset the joint. It is then twice heated and welded under a steam hammer, the hammering being on the sides. At the last heat the trapezoidal shape of the bar is restored by wedges between the bar and the hammer. At the same time the ends of the bar are tapered, and the end that is secured to the shaft in coiling is hammered into a knob and a hole punched in the end to hook a chain to, by which it is drawn from the furnace.

The furnace in which the bars are heated is 60' or 70' long, about 3' wide and 4' high, with seven fires on one side and the chimney at the end farthest from the coiling shaft. The bars being heated to a good red heat and drawn out and wound round a shaft 6 $\frac{1}{2}$ " diameter at the larger end and slightly tapered to facilitate the removal of the coil. The shaft is placed directly in front of the furnace, and has geared to it a feed screw carrying a block with a square hole cut in the top through which the bar passes. On the larger end of the shaft is a small ring or plate, in the side of which is a square bolt. The bar, when withdrawn from the furnace, is passed through the square hole in the block, under the shaft, and driven with a hammer between the square bolt and the shaft, close against the plate. The knob prevents the bar from drawing out. The shaft and feeding screw are revolved by a small engine, and the bar passing through the hole in the block,

which is moved by the screw, is fed along the shaft. The coils are all left handed. When the whole bar has been coiled the shaft is lifted from its bearings by a crane and the coil slipped off the smaller end, and landed on end on an iron plate, in order that it may cool without bulging or warping. The coil in this condition is about 50" or 60" long and loses about .2 of its length in the subsequent welding and turning, the finished coils averaging about 36" in length. After coiling, the cross section of the bar is slightly concave on the exterior and convex on the interior of the coil, while the distances between the folds are less on the interior than on the exterior. When removed from the shaft the folds are very open, and the ends of the bar project out from the coil. The ends are heated and hammered down to conform to the shape of the coil.

#### COIL WELDING.

The coil to be welded is placed on the end of a long porter bar, having a movable balance weight at the other end, and laid horizontally in a reverberatory furnace so that the flame may entirely surround it, and, as nearly as possible, heat all parts alike. When the coil arrives at a red heat it is taken out of the furnace on the porter bar, and shoved into an iron pipe which is canted on one side to receive it. This pipe is made of cast iron 4" thick, 4' long, and 14" interior diameter. The pipe with the coil inside is then placed directly under an eight ton steam hammer, and given a few light blows to force the coil firmly together along the surface of the bore. It is then removed from the pipe, replaced in the furnace and when raised to a welding heat again put in the pipe, a die placed on top and set under the steam hammer, when it receives seven or eight heavy welding blows. The coil is then returned to the furnace and the same process gone through with a second time, after which it is allowed to cool. This coil welding is considered the most important part of the whole conversion, as any impurities lodging between the folds of the coil before they are closed, or too great a loss of welding heat between the furnace and the hammer will prevent a perfect welding of the iron. In order to avoid weak or imperfect welding of the folds, it is desirable that the process should commence at the interior surface of the coil and progress gradually outwards, thus leaving to the last an open joint on the exterior for the escape of cinder squeezed out during the operation. This end it is thought is secured by the particular form of cross section given to the bar, and by the precaution taken of first closing the folds of the coil

along the interior surface. The use of the pipe for coil welding, by means of which the coil is prevented from bulging to any great extent or losing much heat, is different from the method pursued in England and thought to be superior to it.

### TUBE WELDING.

The welded coils when cool are bored out sufficiently to detect any flaws, and their ends faced and reciprocally recessed for uniting. The projection or shoulder is slightly longer than the depth of the recess, so that when the coils are pressed together in the furnace the first welding will take place in the interior. The recess is also slightly smaller than the shoulder, and is expanded and shrunk over it, thus holding the two coils together while being placed in the furnace. The furnace for welding the coils is 5' long by 18" wide, and in the centre of each side is a door through which the coil is introduced, and out of which the ends project. The fire is underneath and the flame made to entirely encircle the joint before passing up the stack, so as to heat all parts as equally as possible. On each side of this furnace is a cross head; one being fitted with a broad bearing plate for one end of one coil, and the other with a large screw for the opposite end of the other coil. This screw is turned by means of a long spoked wheel capable of exerting a pressure of one hundred tons. By means of keys, and slots in the rods connecting the cross heads, the latter can be secured at any required distance so as to accommodate any length of coil. As the joint arrives at a welding heat the press is screwed up, and the coils driven into each other. The two coils thus united form a section, and two sections similarly united form a tube. When judged to be perfectly welded, the section is withdrawn from the furnace, and the bulging straightened under the hammer. After the two sections have been united and straightened, the tube is bored out to within 1-10 of its final diameter (to 7."2) and a cut taken off the outside. It is then carefully inspected and subjected to a water pressure of one hundred and forty pounds to the square inch. After inspection the tube is put in the turning lathe and turned down at the breech end for a distance of 32" to an exterior diameter of 10" and the end of the cut rounded up to the outside of the tube. Around this reduced portion a spiral groove or gas escape is cut 0."05 deep and 0."1 wide with a pitch of 8," thus making four complete turns round the end of the A tube.

## B TUBE.

The B tube, which is shrunk on the reduced portion of the A tube, is 32."75 long, 1."75 thick, and the inner edge of its front end rounded to fit the A tube. It is made in one coil in the manner already described, wound in the same direction, and shrunk on with a shrinkage of 0."003 in the diameter. The B tube besides strengthening the system is a safeguard against the bursting of the gun. If the A tube is ruptured, the gas issuing from the gas escape gives timely warning of the damage done before the B tube and the cast-iron casing give way. The B tube in order to be shrunk on, has to be bored to that degree of smoothness which is necessary for close contact, and is gauged to 0."001 every few inches of its length; to these measurements the shrinkage is added and a plan made out by which to turn down the exterior of the A tube in order that it may exceed in diameter the inside of the B tube by the amount of shrinkage desired.

When it is necessary to make one tube fit over another, the inside of the exterior tube is always turned first to as near the required dimensions as possible, and the exterior of the other tube turned to fit it, for the reason that more accurate turning can be done on an exterior than on an interior surface.

The operation of shrinking on the B tube is comparatively easy and the heat required not very great. Wrought iron, on being heated from 62° F to 212° F (or through 150° F), expands linearly about  $\frac{1}{1000}$  of its length; therefore to obtain sufficient expansion to allow the B tube to pass over the A tube it is not necessary to heat the iron to more than 500° F or to a point where it has not lost its blackish hue and attained the red, which it does at 575° F. This leaves a wide margin for error as no harm is done by over-heating provided the temperature does not rise to the point where scale forms. In order that the shrinking may not be retarded by the expansion of the inner tube, it is kept cool by a stream of water on the inside. After the B tube is shrunk in place the breech end of the tube is closed with a forged wrought iron screw cup, which forms the bottom of the bore. This cup is 5."5 long, 8" in diameter across the threads and recessed on the front face to a depth of 2."5. The thread in the end of the A tube is raised above the surface of the powder chamber so that there may be no weakening by cutting away the metal unnecessarily. After the cup is screwed into place the tube is again subjected to a water pressure of one hundred and forty pounds to the square inch.

The tube is next placed in the rifling machine and rifled to the following dimensions:

Twist uniform, one turn in 40 feet (60 calibers).

15 lands and grooves, each 0." 83776 wide.

Grooves 0." 075 deep.

The rifling commences at 10", from the bottom of the bore.

After rifling, the tube is fine turned to fit the casing. The dimensions of the finished tube are as follows:

Length 131."2.

Thickness 2."75.

Length of bore 128." 2 (16 calibers).

Diameter of bore across lands 8."

External diameter 13."5.

The outside corner at the breech end is rounded with a radius of 1"75. This is a longer radius than that of the corresponding curve in the cast iron (1."7), in order that there may be no wedging action and a tendency to split open the casing when the tube is set out by repeated firing. The exterior of the muzzle end is reduced to 2" in thickness for a distance of 3".75 to admit the muzzle ring.

In point of fact the tube is a very little less in exterior diameter than given above, a play of not more than 0."007 at the breech end to about half way to the muzzle, and not more than 0."015 from there to the end being allowed. All this play is taken up in firing, and after that the tube calls directly upon the walls of the gun for support. The bore of the cast iron casing is measured with the star gauge at certain points and the outside of the tube with accurately prepared horseshoe gauges.

The next operation is the placing of the tube in the gun. On account of the play allowed the tube slides in quite easily, a small three-fold purchase being used to force it home. As perfect contact at the bottom of the bore is essential, the end of the tube is smeared with red lead, and then shoved home. On withdrawing it the prominent points are shown by the absence of the red lead and are filed down. This is repeated several times till the equal distribution of the lead on the end of the tube shows that it bears evenly against the cast iron. To prevent any working forward of the tube owing to the compression of the metal during repeated firing, it is confined by the muzzle-ring. This ring is made of composition, 3".75 wide, 12" interior diameter, 1." thick, with a rounded thread on its exterior to correspond with the thread already mentioned as cut in the cast iron. To prevent the tube from

turning in the casing, a steel steadying plug 1."5 diameter is screwed through the cast iron and 0."75 into the tube at about 17" in front of the right rimbase.

The gun is next vented. A vertical hole 1." in diameter is bored through the end tube, 2."5 to the right of the axis of the bore and 3."5 from the bottom of the bore. In this hole is screwed the copper bouching, which ends in a hexagonal nut or shoulder on the outside of the gun. Properly speaking the gun has no chamber, the unrifled portion having the same diameter as across the lands.

### PROOF FIRING.

The guns when finished, are subjected to a proof of ten rounds; five rounds with twenty pounds of hexagonal powder, and five with thirty five pounds: the shot in each case weighing one hundred and eighty pounds. The average enlargement of the tube at a point 118" from the muzzle or about the centre of the cartridge is 0."02, the play being deducted. The enlargement in the powder chamber gradually diminishes towards the muzzle and at a distance of 68" from it, no appreciable expansion can be found. Where the expanding ring on the shot takes the grooves the enlargement suddenly increases for two or three inches and then as suddenly decreases; this occurs at 28." from the bottom of the bore. As the thirty-five pound cartridge occupies but 24" from the bottom, and as the shot when home is placed close against it, the shot has evidently a forward motion of 4" before the ring fully takes the grooves. When the charge is ignited a comparatively small pressure is required to start the projectile from its seat, while a much greater pressure is required to expand the ring. When this expansion occurs, the windage being suddenly reduced and the shot in a slight degree retarded by the friction of the ring, an opportunity is given for the formation of a much larger amount of gas, which delivers a blow on the tube and shot. The latter being forced forward by this blow more rapidly than before, relieves the strain on the tube almost as suddenly as it was formed, but at the same time it leaves the tube slightly enlarged at this point.

The velocities obtained during proof, with Benton's Thread Velocimeter, were as follows; viz.

Charge of powder,	Number of Fires,	Average Initial Velocity.
20 lbs.,	16	1200.0 ft.
35 lbs.,	23	1466.7 ft.

The velocities were taken at a distance of 175' from the muzzle of the gun and with 1° depression.

The following is the average internal pressure, viz.

Charge of Powder,	Number of Fires,	Average Internal Pressure.
20 lbs.	13	20746 lbs. per sq. in.
25 lbs.	14	30080 " "

No flaws or imperfections of any kind were developed during proof.

Before deciding on the present method of conversion, an Army Ordnance board carried out a series of experiments to determine whether steel or iron would be the proper material of which to form the lining. Four ten inch Rodman smooth bores were converted two into 8" rifles and the other two into 9" rifles, one of each caliber with a wrought-iron, and the others with a steel tube. The wrought-iron tubes were inserted as has already been described for the Navy gun. The steel tubes were 2" in thickness, reinforced on the breech end to a short distance in front of the trunnions by a steel jacket 2" thick, shrunk on, and still further supported in the rear by a steel screw plug through the jacket. The whole was inserted from the breech end and held in place by a coarse screw thread on the jacket which worked in a corresponding thread in the cast-iron. The only difference in the manufacture of the 8" and 9" steel lined guns, was that in the 9" gun the cast-iron casing was expanded when the tube was screwed in and then allowed to shrink on it. The wrought-iron tubes were made at Sir William Armstrong's works at Newcastle-upon-Tyne, England; and the steel tubes and jackets were manufactured by the Bochum Manufacturing Company, Bochum, Prussia.

- No. 1, 8" *wrought iron* tube, has fired, up to the last reports published, seven hundred and sixty-one rounds; some small weld marks are noticeable in the bore, but the gun is still considered as serviceable as it was in the beginning.
- No. 2, 8" *steel* tube. At the one hundred and seventy-first round, a small crack was noticeable, which increased as the firing progressed; at the four hundred and fifty-sixth round, or two hundred and eighty-five fires after the tube split, the gun blew to pieces.
- No. 3, 9" *wrought iron* tube, has been fired five hundred and two rounds in all, and is still in perfect condition.
- No. 4, 9" *steel* lined, no reports.
- No. 5, 8" *wrought iron* tube, manufactured by Paulding Kemble and Co., Cold Spring N. Y., has been fired five hundred rounds,

and shows less erosion of the bore than either No. 1 or No. 3 experimental guns, for the same number of rounds.

During the proof of the Navy guns, the average internal pressure, using thirty-five pounds hexagonal powder, the battering charge, was thirty thousand pounds per square inch. This at the surface of the cast iron bore, would only give, at the very greatest, a pressure of eleven thousand pounds per square inch or a strain a little over one third of the tensile strength of the cast-iron. It is evident from these figures and from the tests for endurance to which the experimental guns were subjected, that this system of conversion is a very strong one; also that wrought iron is a more reliable material than steel for the tube. The Army experiments have fully proved that American coiled tubes are fully equal if not superior to the English coiled tubes.

More work has been obtained from the Navy 8" rifle, than from the English 8.9" ton gun, or the Army 8' rifle, firing the same charge of powder and the same weight of projectile. This is probably due to its greater length of bore.

Navy 8" rifle,	caliber to length of bore,	16	to	1.	I. V.	1466.7	ft.
Army 8"	"	"	"	14.6	to	1	" 1374.0 "
English 8"	"	"	"	14.7	to	1	" 1413.0 "

The projectiles for the 8" rifle are of two kinds; a cored, cast-iron, chilled head shot of one hundred and eighty pounds; and a long cast iron shell of one hundred and eighty pounds. The points are ogival, struck with a radius of  $1\frac{1}{4}$  calibers. The rifle motion is imparted by means of an expansion ring. This ring—the invention of Capt. Butler, U. S. A.—is double-lipped, and either screwed or cast on a reduced portion at the base of the shot. When the charge is ignited the gas enters the annular groove between the lips, expands the outer lip uniformly all around into the rifling, while at the same time the inner lip is made to grip the shot more closely; thus insuring its receiving the proper twist and effectually preventing stripping. This expansion centers the base of the shot. The ring is purposely made sufficiently stiff so as not entirely to fill the grooves and cut off all windage. The forward end of the projectile is centered by the pressure of the gas escaping through the grooves surrounding and supporting the shot during its passage along the bore.

The foregoing description has been compiled from various Army and Navy Ordnance publications at the disposal of the writer, and also much increased by valuable information kindly given by Commander F. J. Higginson, U. S. Navy.



# THE RECORD

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U. S. NAVAL ACADEMY, ANNAPOLIS,

May 8, 1877.

Captain JAMES A. GREER in the Chair.

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NAVIGATION, A. D. 1594.

<sup>1</sup> BY LIEUTENANT COMMANDER ALLAN D. BROWN, U. S. N.

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We who live in this latter half of the nineteenth century, and are furnished with such excellent means of navigating the trackless ocean that we are able to appoint a rendezvous for vessels in a given latitude and longitude, with the certainty of there meeting our fellow navigators, are apt to forget under what difficulties our predecessors labored less than three centuries ago.

It is my design to call the attention of the Institute briefly, to the state of the Art of Navigation at the close of the sixteenth century. For my ability to do this and to thus take a hasty glance at the condition of this branch of maritime knowledge at that day, I am indebted to a rare work which has recently been placed in the Library of the Naval Academy, through the kindness of Lieutenant Colonel JAMES H. JONES, U. S. Marine Corps. This volume bears upon its title page the following:

“M. BLUNDEVILE.

His Exercises, containing six Treatises, the titles whereof are set down in the next printed page, which Treatises are very necessary to be learned by all young gentlemen that have not been exercised in such discipline and yet are desirous to have knowledge as well in *Cosmography*, *Astronomy* and *Geography* as also in the *Art of Navigation*, in which Art it

is impossible to profit without the help of these, or of such like instructions.

To the furtherance of which

ART OF NAVIGATION

the said M. BLUNDEVILE specially wrote the said Treatises and of mere good will doth dedicate the same to all the young gentlemen of this realm.

LONDON.

Printed by John Windet, dwelling at the sign of the cross keys, near Paul's wharf and are there to be sold.

1594."

I have here as in all other cases of quotations modernized the spelling.

The book is arranged somewhat like our modern Epitome of Bowditch, containing treatises upon Arithmetic, Cosmography and the use of the globes and astrolabe.

In looking over the Arithmetic which, as M. Blundevile is careful to inform us, was written "for a virtuous gentlewoman and his very dear friend Elizabeth Bacon," we are at once struck with the absence of all mention of Decimal Fractions: but we do find a very elaborate description of Astronomical Fractions and many rules for the different operations to be performed upon them; these fractions, so called, were the arcs of degrees, minutes and seconds according to the sexagesimal system. We also find methods for the extraction of the square and cube roots of any number, with the following practical application of the square root. "The knowledge of finding out the square root of any number is very necessary for a Sergeant Major in the field, that he may the more readily set and arrange his squadrons of battle:" thus showing that even at that day some knowledge of Mathematics was by no means deemed amiss, in him

"Who'd set a squadron in the field."

Next follows a table of natural sines, tangents and secants with appropriate directions for taking out the function of any given arc, together with several applications of the uses to which these functions serve: one of the most notable of these is the finding of the distance (great circle) between two places whose latitudes and longitudes are given: this was of course simply the solution of a spherical triangle, but it was done in rather a roundabout manner. These tables were constructed by MONTE REGIO, and are credited to him by our author. Among the other uses for them, were the ascertaining of the sun's right ascension and declination having given his place in the Ecliptic, the

computation of the sun's Meridian altitude, of the time of his rising and setting and the solution of various other astronomical problems, into none of which however does the question of Equation of Time enter. The table of secants is further designated as the *Beneficial Table*: and that of tangents as the *Fruitful Table*.

Having thus given a brief glance at these first Mathematical principles, of which, by the way, nowhere does the author attempt the slightest explanation, our attention is next directed to the *Nautical Astronomy* or, as it is here called, *Cosmography*. This treatise has for its motto these words, which, as time goes on and astronomical research extends its domain, are found to be as true now as when first uttered by the Psalmist three thousand years ago, "The heavens declare the glory of God, and the firmament showeth His handiwork." This is, perhaps, the most interesting portion of this quaint work, for we are here brought face to face with opinions and theories which we have been accustomed to consider as belonging to a time anterior to the date of the publication of this book.

"The world is round" says the author, "by these reasons: first by comparison, for the likeness it hath to God's mind; secondly, by aptness, as well of moving as of containing; for if it were not round of shape, it should not be so apt to turn about as it continually doth, nor to contain so much as it doth, for the round figure is of the greatest capacity." And this round world "turneth like a cart wheel about a right imaginative line through the Poles, called the Axletree of the Earth." "The world is divided into two essential parts, the celestial part and the elemental part. The celestial part contains the eleven heavens or spheres, which in ascending orderly upward from the elements be these; first, the sphere of the Moon; second, the sphere of Mercury; third, the sphere of Venus; fourth, the sphere of the Sun; fifth, the sphere of Mars; sixth, the sphere of Jupiter; seventh, the sphere of Saturn; eighth, the sphere of the fixed stars commonly called the firmament; ninth, the second movable or crystal heaven; tenth, the first movable; and eleventh, the Æmpyreal heaven, where God and His angels do dwell. The elemental part contains the element of fire, which is next to the sphere of the Moon, and next to that, more downward, is the element of the air, and next to that is the earth, which is lowest of all." Accompanying this description is a plate with fourteen concentric circles to represent these several spheres, the earth being at the centre of revolution. This was the Ptolemaic theory which had held undisputed sway for centuries: and although Copernicus had written

his treatise "*de Revolutionibus*" half a century before, his theory had not yet overthrown the more ancient one. Blundevile says in this connection; "Copernicus affirmed that the earth was movable, by way of supposition, *and not that he thought so indeed*: who affirmed that the earth turneth round and that the sun standeth still in the midst of the heavens; by help of which false supposition he hath made truer demonstrations of the motions and revolutions of the celestial spheres than ever were made before. But Ptolemy, Aristotle and all other old writers do affirm the Earth to be the center of the world, which I think few or none doubt thereof." The text next proceeds with a description of these several spheres, the eleventh or empyreal heaven being immovable: the tenth moves about the center from East to West in twenty-four hours, carrying all the others with it; while the ninth has its own proper motion as well, in a reverse direction, completing an entire revolution in thirty-six thousand years, at which time all things should be according to Plato, as they were at the beginning of the revolution; this ninth sphere also contains "the waters that be above the firmament." It is quite evident that the so called conflict between science and religion had even then begun, for the student's attention is called to the fact that "the natural philosophers allow no water to dwell above the heavens:" to which the reply is made, "That is true, yet, notwithstanding, if the holy scriptures manifestly affirm that there be waters above the firmament, it behooveth a Christian man to believe it; but question perhaps may be moved what manner of waters they are that are above the firmament, whether they be such as breed rain, or whether they are only to be referred to the crystal heaven to assuage its heat, which otherwise, owing to its swift moving, would set all the heavens on fire." A note opposite this paragraph, in faded ink and in a quaint handwriting, has these words "not very good." The eighth heaven is described as containing the fixed stars, so called because "they are fastened in this heaven like knots in a knotty board:" this had the motion from East to West in twenty-four hours, common to all the remaining heavens, but it also had the motion of the ninth heaven in the opposite direction; its own proper motion was a tilting one, causing the precession of the equinoxes. The heavens of the planets, sun and moon are then noticed and the term of the revolution of each from West to East given: the same period of three hundred and sixty-five days being assigned to the Sun, Venus and Mercury. "The reason why all these several heavens seem to the eye as one entire body is, because they are all clear and transparent like fine glass or crystal through which the sight doth easily

pierce, though there were never so many coats of such clear substance, covering one another like the scales of an onion, for so the heavens do cover and enclose one another, and every one is of an exceeding great thickness." As our author is nothing, if not accurate, he proceeds to give the thickness of these several heavens as follows:

"The Heaven of the Moon,	105,222 $\frac{2}{33}$ miles.
of Mercury,	253,372 $\frac{2}{3}$
Venus,	3,274,494 $\frac{6}{11}$
Sun,	343,996
Mars,	26,308,800
Jupiter,	1,899,654 $\frac{6}{11}$
Saturn,	19,604,454 $\frac{6}{11}$ ."

He further says, "The stars be of the same substance that the heavens are wherein they are placed, differing only from the same in thickness; they are bright and shining bodies, the thickest part of their heaven, apt both to receive and retain the light of the sun; and in like manner the galaxy is visible to the eye, by reason it is thicker than any other part of the heaven. These stars have no moving of themselves, but by reason of the manifold moving of the firmament wherein they are placed they seem to change their places: and whereas the planets do change their places now here, now there, that chanceth not of their own moving, but by the moving of the heavens wherein they are placed; for a star being round of shape hath no members meet to walk from one place to another."

Having thus disposed of the celestial sphere we turn to the four elements earth, air, fire and water: it will be remembered that fire comes next inside the heaven of the moon, and it is here defined as "most hot and dry, pure and subtle, and so clear as it doth not hinder our sight looking through the same to the stars: and it is turned about under the sphere of the moon like a celestial sphere. The air is divided into three regions, the highest of which being turned about by the fire is made hotter, wherein are bred lightnings, blazing stars and such like; the middle region is extremely cold *because* it is placed between two hot ones, and in it are bred frost, snow, ice and hail and such like; and lastly the lower region, which is hot by reflex of the sun, whose beams first striking the earth do rebound back again; and in this region are bred clouds, dews, rains and such like moderate watery impressions." The water is considered to be of itself round; and that this is so is proven by the familiar illustration of a ship sailing from port and losing sight of low objects, while elevated ones remain in sight; but it never seems

to occur to the author that by this the spherical shape of the globe may be proven.

The small globes used for purposes of instruction, having upon them different circles as the meridian, ecliptic, &c., next claim the attention. Then follow instructions for obtaining the sun's place in the ecliptic and thence his declination, with tables to facilitate the operation: the subject of eclipses is briefly touched upon, as is also that of the precession of the equinoxes and the need for a reformation in the calendar; the names of the principal stars are given with directions as to finding their right ascension and declination. The division of time is noticed and the different kinds of years are defined, and a reason assigned for the inequality of the days and nights, and rules given for "finding what planet reigneth at any hour of the day or night." Longitude and Latitude are defined as follows; "The longitude of the earth in general is that space or upper face of the earth, which extendeth from West to East and again from East to West; and the Latitude in general is that space which extendeth North and South even from one pole to the other." The prime meridian passes through the Azores, which are  $5^{\circ}$  to the Westward of the Fortunate (or Canary) Isles, where was the prime meridian of Ptolemy: this change was made "because, say the Cosmographers, the Mariner's Compass will never incline to the true North pole but when they sail either by the Isle St. Mary or St. Michael; affirming that in every other place the compass doth vary from the true North either by Northeasting or Northwesting." Next follows the method of obtaining the latitude by the meridian altitude of the sun, with the statement that the altitude must be measured at intervals and the highest altitude taken. The problem of determining the longitude is disposed of very briefly by directions for observing the beginning of an eclipse, the time to be compared with the computed time of such beginning at some other place. The germ of our modern method is found in the tenth chapter of this treatise, which is taken from Gemma Frisius; he says, in effect, "this is done by the help of some true watch or horologe, which is to be set to local time before leaving a place, and is to be compared with the local time at the place of your arrival; the difference of which times will be the difference of longitude. "This method," he further states, "is applicable only on land, as watches made of iron or steel will soon rust at sea: the twenty-four hour glass is therefore used at sea, to keep the local time of the port of departure." A further method of obtaining the longitude by Lunar distances, is also given: this was

liable to very great errors, owing not only to the imperfection of the Lunar tables but also to great lack of instruments of precision for measuring the distances.

Next follow directions for obtaining the distance between two places by taking the difference of latitude and difference of longitude: the latter being converted into *departure* by means of tables which give the length of a degree in every parallel of Latitude; and this departure used in the solution of the problem is reckoned on the Middle Latitude between the two places: nowhere, however, is anything said about the course, nor is any explanation of the problem given. With a few sections devoted to the seasons and their characteristics, and a short article on the winds and their names as derived from the different points of the mariner's compass, the book ends: these being the closing words: "I heartily pray all those that shall vouchsafe to read this my treatise of the sphere, to take my labor therein bestowed in good part, and where any fault is, friendly to correct the same without any scorn or disdain."

The next treatise is upon "the use of the globes": these were the invention of Mercator, and were used for the solution of spherical triangles, especially in those cases involved in Navigation: the celestial globe had the horizon and meridian, declination circles, the equinoctial and ecliptic; as also an hour wheel at the pole, by means of which the hour angle of a body was readily determined. As a proof of the old saying that "History repeats itself" and of that equivalent aphorism of Solomon that "there is nothing new under the sun," I would here state that within the last six months there have been put forth the drawings of an instrument called the Automatic Navigator, which in all its essential parts is but a reproduction of Mercator's celestial globe, the very existence of which was probably entirely unknown to the inventor of this latest improvement. Among the many problems, rules for the solution of which are given, and which are thus solved mechanically may be mentioned the finding of the latitude; first, by the meridian altitude of any heavenly body (two methods); and second, by altitudes of two different bodies at the same time; also the finding of the longitude by means of a lunar distance. Following this is a description of a large terrestrial globe then lately put forth, being an improvement upon the original one of Mercator, with a brief account of the voyages of Drake and Cavendish, whose tracks in their then recent voyages of circumnavigation are put down upon this globe.

Next follows a description of the map or chart of *Plancius*, which

had but just been published. In this map (it was not a projection), the meridians and parallels were at right angles, and the degrees of latitude were of the same length from the equator to the pole. Tables were annexed showing the value of a degree of longitude in miles at each latitude, but the fact that these parallels were expanded in the ratio of the secant of the latitude, is entirely lost sight of, although Mercator's chart had then been before the world for a quarter of a century. In another place commenting upon this last fact, the author says "that *Cogniet* hopeth to find out some more perfect rule for making charts when time shall serve: in the meantime *Mercator* hath made the spaces of the parallels of latitude to be wider every one from the other, by what rule I know not, unless by such a table as my friend Master Wright of Caius College, Cambridge, hath sent me"; which table is Wright's Table of Meridional Parts, computed on the supposition that the earth is a sphere; and it is to Wright rather than to Mercator himself, that we are indebted for the elucidation and demonstration of the true principles involved in the construction of Mercator's Chart. But to return to the chart of Plancius; from this we learn that Symmes' Hole is not by any means a modern idea; for Plancius tells us that "there are three islands next the pole, between which the North ocean sea rushes with swift stream and is continually carried under the North pole and there is swallowed up by the bowels of the earth; but," says Blundevile, "I marvel how any ship durst enter through these straits to discover the North sides of any of those islands, and how and where it came out again." The magnetic pole is placed in longitude  $0^{\circ}$  (corresponding to our longitude  $25^{\circ}$  W.) in latitude  $75^{\circ}$  North. Then follows a description of the various countries of the world, with an account of some of their remarkable curiosities. Next follows an article devoted to the South circumpolar stars with a description of the Southern cross, the star in the foot of which is stated to be thirty degrees distant from the South pole, so that when the meridian altitude of the star is taken, by subtracting thirty degrees therefrom, the latitude is at once given. The method of determining the distance between two places on the map, is given; and our author closes his review of Plancius' work with these feeling remarks; "Truly I must needs confess that it is not so easy to make a scale for a map drawn *in plano*, as for that which is drawn upon a round body or globe: and therefore it is no marvel that the scale of maps drawn *in plano* do not always show the true distance of places; which true distance is to be found by rules which depend upon the knowledge of the quantity of the angles and sides of spherical triangles, which



kind of working is indeed *more troublesome and tedious, than ready or pleasant.*"

We next have an elaborate account of "Blagrave's Astrolabe or Mathematical Jewel." This astrolabe was not of the kind generally used for taking observations at sea, though it might so be; it was essentially a planisphere, having upon its face or *Mater*, the various meridians, parallels &c., projected stereographically; upon this, and concentric with it, was a movable plate styled the *rete*, having altitude and azimuth circles projected upon it, in the same manner as were the others upon the *Mater*; Chauvenet's great circle protractor is constructed upon the same general plan; and is used in the same general way as was the astrolabe of Blagrave. Upon the face of the *rete* was also an oval figure containing the signs of the zodiac in order, and also the names of seventy-one fixed stars, for convenience in using the instrument in finding the places of those heavenly bodies. Upon the back of the planisphere, was a large circle graduated to degrees and minutes, with a diopter or ruler working upon its central pin; this ruler had a projection at either end, perpendicular to the plane of the instrument; these were each pierced with two holes which served to direct the line of sight of the diopter to the sun or other heavenly body, while the extremity reaching the graduated arc showed the altitude. The author speaks of the book of instructions concerning this astrolabe, written by Blagrave, implying that the theory of the instrument is therein discussed; he confines himself to simple rules for its manipulation, without concerning himself as to the theoretical part.

With these preparations, from the Arithmetic at the beginning of the book to the account of the astrolabe just noticed, the author now takes the student into his "New and Necessary Treatise of Navigation, containing all the chiefest principles of that art. Lately collected out of the best Modern Writers thereof, by M. Blundevile, and by him reduced into such a plain and orderly form of teaching, as every man of a mean capacity may easily understand the same." The title page is embellished with the picture of a ship, with this motto "They that go down to the sea in ships, and occupy their business in great waters, these men see the works of the Lord, and His wonders in the deep."

Navigation is defined to be "an art which teacheth by true and infallible rules how to govern and direct a ship from one port to another safely, rightly and in shortest time. I say here safely, so far as it lieth in man's power to perform. And in saying rightly, I mean not by a right line, but by the shortest and most commodious way that

may be found; and by saying in shortest time, I mean thereby according as the ship is good of sail and as both wind and tide shall serve." The instruments which every skilful seaman should possess before undertaking a long voyage, are said to be "a perfect Calendar or Ephemerides; the Mariners Ring or Astrolabe; the Cross-staff; the two Globes, celestial and terrestrial; an universal horoige, to know the hour of the day in every latitude; a Nocturnlabe, to know the hour of the night; the Mariner's Compass; and lastly, the Mariner's Card or Chart. "But" says Blundevile "all these instruments serve to little purpose unless you know also the North star with his guards, and divers other stars with their latitude, longitude and greatness, to kuow thereby the latitude of any place and the hour of the night; also the course of the sun and his declination; and finally you must know the course of the moon, whereon dependeth the knowledge of the tides in all places." With these as his subjects, he proceeds to discourse upon them in the order just rehearsed. The perfect Calendar or Ephemerides to which he refers was by no means the article known to us as the Nautical Almanac: it contained merely the place of the sun, moon and planets in the signs of the zodiac and their place in those signs, for every day in the year: the declination of the bodies was otherwise obtained. In his remarks upon the calendar, our author directs us how to find the golden number, the epact, the full and change of the moon and the various fast and feast days throughout the year. We here find in the chapter devoted to the Epact, a paragraph which shows the probable origin of our modern term "*thumb-rule*." As I have never before met with any plausible theory as to the origin of this phrase, I have here transcribed a portion of

### "CHAPTER III.

How to know the Epact by the Mariner's Rule *upon your thumb*.

First, you must suppose the inside of your left thumb to be divided into three spaces, and the nethermost space to contain ten, the middle space twenty, and the highest space towards your thumb's end to contain thirty: and knowing first the golden number, begin to tell the same at the nether space, saying there one, at the middle space two, at the third space three, then begin again at the lowest space and then say four, and so continue your account still after that manner, until you have the full sum of the golden number, and mark upon what space it falleth, for the golden number added to the number of that space doth show the Epact."

*Cogniel's* cross staff consisted of a piece of hard wood, three quarters of an inch square and four feet long with three transoms or cross pieces of different lengths sliding upon it; the first of these was twelve inches, the second six, and the third three inches, in length; the long piece or staff was graduated to degrees by means of a simple triangle; the altitude was taken by placing the end of the staff at the eye and then moving the transom until the sun was visible at the upper extremity thereof and the horizon at the lower; the longest transom was used for altitudes exceeding thirty degrees, the second for altitudes between thirty degrees and ten degrees, and the shortest one for altitudes less than this. This instrument also appeared in another form, known as *Hood's* cross staff; in this there were two pieces of wood three quarters of an inch square, and about a yard in length: these were set at right angles to each other in a metal socket, in which each one moved readily, being retained at any desired point by a set screw. The horizontal part was called the yard, the vertical one, the transom; each was graduated to degrees and minutes, the least count being ten minutes; the transom was marked from  $0^{\circ}$  to  $45^{\circ}$ , and the yard from  $45^{\circ}$  to  $90^{\circ}$ . This graduation was made in the ratio of the tangent of the angle from  $0^{\circ}$  to  $45^{\circ}$  and of the cotangent from  $45^{\circ}$  to  $90^{\circ}$ ; although *Blundevile* says nothing about it; from his text it would readily be inferred that the graduations were equal, which of course would have given extremely incorrect results. At the zero mark of the transom was a metal plate, flush with the graduated surface and projecting from it about three quarters of an inch; in this plate was a notch, the bottom of the notch being in line with the zero of the scale. This instrument was made ready for use by inserting both portions into the socket, the  $45^{\circ}$  marks being together; the altitude of the sun was taken by holding the yard as nearly horizontal as possible (decidedly a difficult matter to accomplish on board ship) and observing where the shadow of the vane on the transom struck the yard, and then moving either the yard or transom in the socket until the shadow struck the  $90^{\circ}$  mark on the yard; the place of the socket was the reading of the instrument for altitude. In taking the altitude of a star the  $90^{\circ}$  mark was placed at the eye the instrument being "stayed upon the upper bone of the cheek", and when the line of sight passed through the notch of the vane and the star, the socket was clamped and the reading taken; lunar and stellar distances were measured in a similar manner. In its original and more common form the cross staff was like *Cogniel's*, heretofore described, with however but *one* transom instead of three.

The ordinary Astrolabe or Mariner's Ring was a metallic ring about

seven or eight inches in its exterior diameter, and about half an inch wide and of different thicknesses, according to the fancy of the maker. It was considered desirable to have the whole instrument as heavy as practicable, in order that it might readily retain its proper position. This ring had two perpendicular diameters of metal, at the extremity of one of which was a swivel, by means of which the instrument was suspended when in use; one quadrant was graduated to degrees and minutes, the least count being ten minutes. A diopter, reaching from limb to limb and turning upon a pivot in the centre, was furnished at each extremity with a square plate perpendicular to the plane of the instrument; these plates were each pierced with two holes, the smaller for use in observing the sun, the larger for the stars and moon. The instrument was suspended from the fore-finger or thumb of the right hand, while the left hand directed the line of sight through the diopter to the body whose altitude was desired, the altitude being read off the graduated arc.

The division of the Compass Card into thirty-two points is then explained, with the manner of attaching the card or fly to the needle or wires; which are figured as of elliptical shape, the major axis being prolonged to make the North and South poles: the method of imparting the virtue of the lodestone to the iron needle is also mentioned. The further statement is made that "it is well known by good experience that the North point of the compass declines always from the true North, either to the East or West, more or less, according to the latitude of the place wherein you are, unless you be right under the meridian of the Azores. And therefore most men in these parts of the world do use to set the North point of the wires not right under the flower de luce (or North point of the card) but rather somewhat inclining toward the East, half a point or thereabouts to avoid the Northeasting and Northwesting of the compass." As an additional illustration or proof of Solomon's saying as to the want of novelty of anything under the sun, I would here state that within the last year there has been patented in this country an instrument called a Variation Compass, the principle involved in its construction and its method of manipulation being precisely the same as that here noted by Blundevile; viz., the alteration of the card and needle according to the Variation. Assuming the line of no variation as being coincident with the Meridian of the Azores (or longitude  $0^\circ$ ), Mercator placed the magnetic pole in longitude  $180^\circ$ , and in latitude  $73^\circ 30'$  North; and he thought that at this pole was a "great rock of adamant whereunto all lesser rocks or needles touched with the lodestone do incline as to their chief fountain;" cou-

cerning which Blundevile declares that "he rather believes with Robert Norman, that the properties of the loadstone are secret virtues given of God to that stone for man's necessary use and behoof, of which secret virtues no man is able to show the true cause." Cogniet's proof that Easterly variation is found in the hemisphere from longitude  $0^{\circ}$  to  $180^{\circ}$  East, and Westerly variation in the other hemisphere, is shown; as also his statement that of two places having the same longitude that one will have the greater variation, which is the nearer to the pole. Instructions for finding the variation are then given; the first method was by observing the bearing of the sun at his rising and again at his setting, when half the difference of these two bearings in points from the Meridian would give the variation; the second method is a modification of the first, the bearing of the sun being taken when at the same altitude on both sides of the Meridian, the variation being found in the same way; a third method was to note the sun's bearing at the instant of taking the Meridian altitude, and the fourth method was by observing the bearing of the North star.

Next follow directions for constructing a chart by the old method which was followed by Plancius: but the author prefers Mercator's Projection as being more suited to the uses of the mariner. For this purpose he gives Wright's Table of Augmented Latitudes with full instructions as to the mechanical portion of the operation, including the insertion of compass cards in convenient spots. Although the text discusses the question of the loxodromic curve and shows that it must necessarily be a spiral, yet no where is it noted that on Mercator's chart this curve is projected as a right line; although the fact is stated that the direction of the right line between two places will be the course between them. The compass course was obtained not by parallel rulers, which seem to have been then unknown, but by a system of guessing, using a pair of dividers as an assistance thereto: the distance was to be measured at the side of the chart.

The dead reckoning, in contradistinction to the reckoning by observation, did not exist; they were not independent of each other: nor is there any mention of the log or of any other appliance for measuring the speed of the ship at any time. When sailing upon a meridian, the distance made good was known by the change in latitude, sixty miles, or seventeen and a half Spanish leagues, in which distances were generally reckoned, being allowed to a degree: the means of determining the distance when sailing in any other direction than due North or South had but recently been published by Cogniet. His method was

briefly as follows: "if in sailing to the Northward or Southward the course declined one point or rhumb from the meridian and the ship sailed so far as to change the altitude of the pole one degree, then the distance was seventeen and five-sixths Spanish leagues"; and a table is given containing the distances in leagues necessary to be traversed to change the latitude one degree on the remaining courses between the cardinal points. This method of reckoning was of course good, only when the ship sailed on one course from latitude to latitude; but if there were any shift of wind necessitating a change of course "the pilot was by skilful conjecture either to add to or to subtract from this distance as such should require." In like manner the change of longitude was determined, and a table was given for this purpose, showing the change of longitude for a change of one degree in latitude when sailing upon a given course or rhumb: this change was given in leagues and also in degrees and minutes of the equator: this was to be used in all latitudes which was of course greatly incorrect, for the distance given in this table was the *departure*: although the principle of changing *departure* into *difference of longitude* was known, as we shall presently see, yet the idea of applying it in this particular case, seems to have been entirely unknown; at least it is not mentioned in the text: in the example given by the author, the error amounts to about four degrees of longitude in thirty. That this principle was known is seen from the next chapter, in which we are told "How to account the leagues in sailing East or West without changing the latitude." It is here stated that "in sailing thus, most men think it impossible to make any true account of the leagues, but only by conjecture: for remedy whereof Cogniet hath invented a rule most certain:" which was briefly this: "Knowing the difference of time between two places in the same latitude, this difference was to be multiplied by the number of leagues which were equal to fifteen degrees or one hour, in that latitude:" this number was tabulated for all latitudes from  $0^{\circ}$  to  $90^{\circ}$  and was practically the length of a degree of longitude in every parallel of latitude. The difference of time between the two ports was to be obtained as follows: a large sand glass made to run twenty-four hours was hung in gimbals: this was set running at noon by the sun on the day of leaving port: it was to be carefully turned every twenty-four hours and on arriving at the port of destination the time at which the glass ran out was to be carefully noted either by the horologe or universal dial, or obtained from the celestial globe or from Blagrave's planisphere, first obtaining the sun's altitude with the astrolabe: the difference between this time and the local noon

gave the difference of longitude of the two places in hours, which was reduced to distance as above stated.

Next follow detailed directions for finding the North star by means of the pointers or *guards* as they were called, and also for determining the latitude and the local time by observations of this star. To effect this there was given a table showing the degrees and minutes to be added to or subtracted from the altitude of *Polaris* according to the compass bearing of the pointers from the star; this correction was given for the four cardinal and four intercardinal points. To enable this correction to be found more accurately, an instrument called the Rectifier of the North Star was devised: this was the invention of Cogniet so often quoted in the text and was quite an elaborate affair: under ordinary circumstances it might produce tolerably accurate results. It consisted essentially of a compass card containing at each point the degrees and quarters of a degree to be applied to the altitude of the star according to the bearing of the pointers: a ruler turned upon a hollow spindle in the centre, through which the line of sight passed. When in use, the instrument was raised in front of the face by means of the handle (which was situated at the south point) until the star was visible through the central spindle: the ruler was then moved until the nearest pointer could be seen in line with it and the correction was read off the arc where the ruler intersected it. Directions are also given for using any other star than the nearest pointer, provided the difference of right ascensions was known. This instrument was also used as a Nocturnlabe or determiner of time at night: the inner circle of the compass card was divided into three hundred and sixty five equal parts, which were named and numbered according to the number of days in each month, the days upon which the star crossed the meridian at noon and midnight being placed opposite the North and South points respectively: a small circle divided into twenty-four equal parts or hours moved also upon the central pivot, and the twelve hour mark was placed opposite the day of the month before using the instrument: the reading of the point at which the ruler before mentioned cut the hour circle gave the hour of the night. Provided that the North and South line could be held in the plane of the meridian, this instrument would give very good results. The concluding chapters of the work are devoted to the subject of tides and the finding of the time of high water.

From this brief glance, we see that the mariner of three centuries ago was able to obtain results, which only by a very liberal stretch of the term could be called approximative. With the instruments at his disposal,

it could not have been possible to obtain the altitude of the sun within twenty minutes: to say nothing of the probable error of the declination owing to want of proper tables, there were no corrections made for semi-diameter, dip or refraction, and hence the latitude could not have been reliably determined within thirty minutes; probably if the result came within forty or forty-five minutes of the true one, it would be doing very well. As upon the determination of the latitude rested, as we have seen, the subsequent approximation to the distance and difference of longitude made good, it follows that these latter results must have been very far from the truth. And yet, before the close of the sixteenth century, even with such inferior means of determining the ship's position, the great voyages of discovery had been made. Prince Henry the Navigator had largely increased the existing knowledge of the west coast of Africa; Vasco de Gama had rounded the Cape of Good Hope and the African continent had been circumnavigated; Columbus had brought to light the New World; Cabot and a host of others had followed in his foot steps; Balboa had crossed the Isthmus of Panama and discovered the Pacific Ocean; Magalhaens had discovered the strait that still bears his name and sailing through it had entered the Pacific Ocean; stretching boldly across which, he reached the Philippine Islands, his vessel being the first to accomplish the circumnavigation of the globe.



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Commander W. T. SAMPSON, U. S. N., in the Chair.

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PRESERVATION OF WOOD.

By PROF. CHAS. E. MUNROE, U. S. N. A.

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*Mr. Chairman, Gentlemen,*

Wherever life exists we find a constant struggle for its maintenance. In every animal and vegetable substance, so soon as the vital force ceases to act, we see that there is at once a tendency toward the resolution of the atoms of the highly organized structure into simpler compounds. All nature seems to lend its aid to effect this change. The chemical affinities of the constituent substances encourage it, the lower forms of life assist it, and the combined influence of air, moisture and heat complete the change. Everywhere these forces are active and decay and destruction threatens.

All of the products of life which we employ either for food or clothing or for constructing our habitations, our ships, or our tools are exposed to this danger; and one of the most important industrial problems, which man has had to meet, has been the protection of these substances from decay.

It is my intention to-night to confine myself to an examination of the methods proposed for the preservation of one of these substances, wood, and especially as it is employed in ship-building. Though it may seem unnecessary to you that I should give any statistics to show the great value of employing some means for attaining this result, yet

it will I believe impress the importance of it more strongly upon our minds if we give a moment to their consideration.

The first fact which attracts our attention is the rapid destruction of our forests which is diminishing the supply and increasing the cost of lumber. While, for instance, a single acre of pine land yields on an average only six thousand feet of timber, billions of feet are annually sold in the United States. In 1855 lumber sold for about \$18 per M.; in 1860, for \$24; and in 1865 for \$45, (Hunt's Merchant's Mag. Feb. '66, p. 106). Excellent authority states that in New England the cost of oak, ash and hickory has doubled during the past twenty years, being now \$50 per M., to \$25 then, and if the demand were as great as ten years ago it would be difficult to supply it. Certainly prudence demands a less rapid expenditure.

But when we come to estimate the loss, which results from decay, the necessity for preservation becomes still more apparent. It was calculated in 1866, that the loss by the decay of sleepers on American Railroads, amounted annually to \$1056 pr. mile, and that if they were preserved by cupric sulphate at a light expense there would be an annual saving of over \$4,000,000, (Lewis) and if we included bridges and all the wooden parts of railways subject to decay, it is stated that \$20,000,000 would be saved annually, by impregnating them with coal tar (Robbins p. 67). Processes have been devised by which the durability of many kinds of wood can be doubled; hence if we consider how much timber is employed in the United States alone, in buildings, bridges, fences, ships, carriages and machines, we can readily see that a great saving would be effected, that our wealth would be increased, and that a large part of the labor, which is now employed in making good the losses from decay, could be used in production.

It is more to our purpose, however, and it was my desire, to collect some statistics concerning the decay of ships; but such as I have obtained are quite meagre and unsatisfactory.

In 1833 Mr. Edye, (Calculations relating to the Equipment of Ships by John Edye, London), stated that the quantity of wood required annually to keep the five hundred and seventy four ships of the British Navy seaworthy was one hundred and twenty five thousand loads, while only one million loads was required to build them—twelve and one half per cent. Mr. Wm. Chapman, (Preservation of Timber from premature decay, &c., by Wm. Chapman), gives several instances of the rapid decay of ships of the Royal Navy about the commencement of the present century. He mentions three ships of seventy four guns decayed in

five years, three of seventy four guns decayed in four years, and one of one hundred guns decayed in six years. Pering, (Brief Enquiry into the causes of the Premature Decay), says that ships of war are useless in five or six years. And he estimates the average duration to be eight years, and that the cost of the hull alone of one of these ships was nearly £ 100,000.

When we come to our own service we find that here also the loss by decay is enormous. Our live oak ships are exceptional, their average life being, probably, a half century, but I find from an examination of the data given by Emmons (p 23 and 86, et seq.) that the average cost per ton per year for repairs, was \$ 6.00 amounting in the case of a vessel like the Ohio to \$ 16,569.57. Up to 1850 the Ohio cost for repairs \$ 471,673.\* If now we estimate the loss upon the basis of actual sea service we find that the average cost per ton (O. T.,) per year of service was \$ 16.19. The cost of repairs to the Ohio per year of service was over \$ 89,000, and the United States, Potomac, Brandywine &c., average about \$ 35,000 while the Constitution, which was an exceptionally good ship, cost over \$ 15,000 per year of service.†

To gather any information about our present Navy is more difficult, and we must wait for some one to record for it what Emmons has so thoroughly done for the Navy previous to 1850. Such as we do find however shows that of late the loss from decay is greater than before. We find vessels built of white oak costing from a quarter of a million to over a million dollars thoroughly useless in eight to ten years. Indeed this is a large estimate, for it is stated by some authorities that the average age of a white oak ship is six years. The difficulties met with in getting any certain knowledge on the subject are best shown by the following extract from a letter from the late chief of the Bureau of Construction and Repairs, Chief Naval Constructor I. Hanscom. He says, "I believe you will only be able to obtain approximate data as to the relative durability of Live and White Oak, White and Yellow Pine timber, as it varies so much, caused by the difference in quality and degree of preservation, either by stowage or by the use of chemicals, that the condition of the timber at the time of using it can hardly be known. Still the contrast in the durability of the timber used in the construction of the "Franklin" and that of the "Delaware"—the former in good condition at the present time (twenty three years), and the latter generally rotten in eight years, each costing nearly the same,

\* While the cost of building her was only \$ 547,889.

† See Appendix.

(cost of Del. \$1,178,000) is so great that a general idea may be obtained by which to judge of the durability of timber used before and after thorough seasoning. I judge that the loss to the Government in using unseasoned timber during six years from 1861 was at least \$20,000,000."

Incomplete as these statistics are they give us a partial idea of the magnitude of the loss, which we sustain by decay, and they fully warrant our devising means for arresting it.

One of the chief difficulties which presents itself, when we resort to chemical processes to effect the preservation of wood, lies in its very complicated structure. Being the product of vital processes and also the individual in which these processes are taking place, a tree necessarily contains very many different chemical substances arranged in a complicated manner. It is to the character of the constituent substances and the manner of their arrangement that wood owes the properties which render it so well suited to the purposes to which it is applied.

A brief description of the structure of a tree and the way in which it is formed will more clearly explain these difficulties. If we examine a section of the stem of a tree we observe that it consists; 1st, of the pith or its remains, at the centre; 2nd, of the wood surrounding the pith; and, 3rd, of the bark.

In Fig. 1 is represented a section both vertical and horizontal of a branch of a tree, two years old, as it appears in December. The portion included in the lines marked A is of the first year's growth; those marked B indicate the wood of the second year; while those marked C inclose the three layers of bark; D represents the pith of loose cellular tissue; E represents the pith rays or silver grain of hard cellular tissue connecting the pith with the green or middle layer of bark, which consists wholly of cellular tissue; F marks the outer or corky layer of the bark, which is composed of dry, dead cells, which are formed of consecutive layers from the outer portion of the living green layer; G is the green layer of cellular tissue; H shows the liber or inner bark, made up of cellular tissue penetrated by long bast cells, arranged parallel with the axis of growth; I represents the place of the cambium or growing layer of organizable material which descends from the leaves between the liber and the sap wood during the period of growth; K is a woody fibre, which gives strength to the stem and through which the crude sap rises; L indicates the vessels or ducts, with various markings, such as dots, rings and spirals, which are formed most abundant-

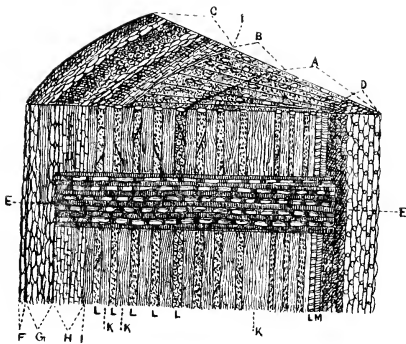


Fig. 1.

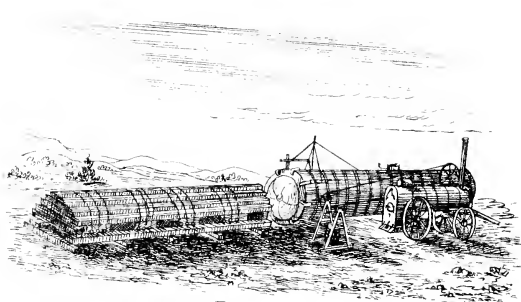


Fig. 2.

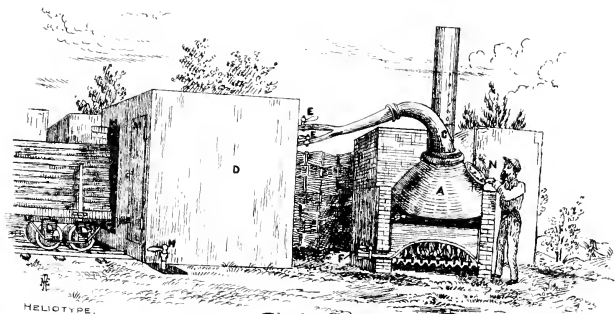


Fig. 3.



ly in the spring and usually contain no fluid. They convey gases and aqueous vapors, and it may be that a large proportion of all the water ascending from the roots to the leaves passes through them as vapor; M is the layer of spiral vessels or ducts, which always inclose the pith and in the young shoot extend into the leaves and unite them to the pith during its life, which ceases with the first season.

Though the assertion has given rise to much discussion it seems now to be well determined that a circulatory system exists in vegetables. For convenience it is divided into the vascular circulation and the horizontal or cellular circulation. In the first the sap from the roots passes up through the woody fibre and the elaborated sap or cambium passes down between the liber and the sap wood. In the second the fluids pass between the pith and the bark. The food for the growth of the tree is secured by the roots and the leaves. The roots absorb water and the nitrogenous and mineral substances which the tree requires. The leaves store up carbon from the decomposition of carbonic acid in the numerous stomatae with which they are provided. From these various substances the several constituents of the tree are formed and by the circulatory system they are conveyed to the part of the individual where they are to perform their functions. Thus we see that while the tree lives, in a healthy state, by means of its roots and leaves, it holds communion with the earth, water, and air, and that the fluids, juices and deposits depend for their movement upon the presence and action of these parts. When this communication is interrupted by drought or exhaustion of the soil, by the stripping of the bark or the felling of the tree, growth ceases. The circulation still continues however, but waste a of tissue begins, decomposition sets in, and the tree becomes the prey of fungoid growth. If however, after felling, we lop off the top of the tree, the vascular circulation ceases, and, if we remove the bark, cellular circulation stops. If now the tree is exposed to dry air at a moderate temperature, all vital processes are arrested and the wood is for the while preserved. Especially is this so if the sap wood is cut away and the pith is laid open.

From this sketch we realize how very complex the physical structure of the tree is. A narration of but a portion of the constituent substances will show that its chemical structure is still more diversified. In all plants we find woody fibre or cellulose, and this is covered with incrusting substances formed from the decay of the cells. The following substances are also found in quantities varying with the season and the locality, the species and the age of the plant. They are the constit-

uents of the sap such as albumenoidal substances, starch, grape sugar, cane sugar, gum, tannic acid, coloring matters, pectose, resins, and volatile oils and the ordinary mineral constituents of plants, &c.

From the composition and structure of the healthy material our discussion naturally turns to the consideration of the manner in which the decay (*Eremacausis*) takes place and of the conditions most favorable to its progress. When wood in a moist state is exposed to air it undergoes decomposition; a species of fermentation is occasioned by the nitrogenized constituents, in consequence of which oxygen is absorbed, carbonic dioxide and water are exhaled, and the wood crumbles down into a blackish brown vegetable mold called humus, ulmine or geine. This decay occurs most rapidly in young, spongy wood, which admits the air most freely and at the same time contains a proportionately larger quantity of the albuminous substance, than the harder and older portions. The decomposition of these albuminous constituents favors the growth of lichens and fungi and encourages the ravages of insects, to which the albuminous portions in particular afford nutriment. Pure woody fibre by itself, is only very slightly affected by the destructive influences of weather as we see in cotton, linen, paper and other materials, formed from nearly pure cellulose. The decay arises wholly from the presence of the substances in the wood that are foreign to the woody fibre, but are present in the juices of the wood while growing, and consist chiefly of albuminous matter, which, when decaying, causes the destruction of the other constituents of the wood also. Since resinous woods resist the action of damp and moisture for a long time, they are quite lasting; next in respect to durability follow such kinds of wood as are very hard and compact and contain some substance, which like tannic acid, resists decay.

The conditions which obtain then are these; a limited supply of air, a moist atmosphere, and a moderate temperature. Change either of these conditions and decomposition ceases. You will recall that these conditions air, moisture and heat are the very same as were shown by our eminent associate, Dr. Gibon, to exercise so baneful an effect upon the health of those who live in ships. Remove the moist atmosphere and while the health of the inhabitants is benefited the destruction which assists in polluting the air is delayed.

Mr. Finchau, formerly Principal Builder to Her Majesty's dockyard, at Chatham, tried an experiment to show that the presence of all these conditions was essential to decay. He bored a hole in a perfectly sound timber in an old oak ship. The admission of air to the central part of



the wood, moisture and heat being already present, caused the hole to be filled up in the course of twenty-four hours with mold which speedily became so compact as to admit of being withdrawn like a stick.

Other cases may be cited of the remarkable freedom of wood from decay when any of these conditions are changed. For instance, when there was free circulation of air and an absence of moisture as in the roof of Westminster Hall we find well preserved wood over four hundred and fifty years old (1866). The carvings in oak at Stirling Castle are also over three hundred years old (1866), and Scotch fir was found in good condition after three hundred years, and the trusses of the roof of the Basilica of St. Paul, Rome, sound and good after one thousand years. Instances of longevity where there was an absence of air, and the wood was submerged in water, are found such as the piles from the foundation of the old Savoy Palace perfectly sound after six hundred and fifty years, the piles from Old London Bridge perfectly sound after eight-hundred years, &c.

#### PRESERVATION.

In accordance with these observations, Wagner, (Chem. Tech. p. 474, Am. ed.), divides the methods adopted for the preservation of wood as follows: 1. the elimination, as much as possible, of the water from the wood previously to its being employed; 2. the elimination of the constituents of the sap; 3. by keeping up a good circulation of air near the wood so as to prevent its suffocation as it is termed; 4. by chemical alteration of the constituents of the sap; 5. by the gradual mineralization of the wood and thus the elimination of the organic matter; and to these may be added 6, by the use of antiseptic agents.

The first of these is the most universally employed method, i. e. by seasoning. As formerly carried on, the wood, carefully protected from sun and rain, was stored away for years. An active circulation of air was permitted and by the slow action of this air all the moisture was extracted from the wood. As the presence of moisture is essential to the fermentation of the albuminous and saccharine constituents of the sap this fermentation is thereby prevented. But beside the loss of interest on the capital invested and the time required for this result to be attained this method has other objections. If the timber is in the log it is liable to become rent, and if the pith is not bored out it is liable to decay at the heart before the moisture can be evaporated from it. If cut into lumber great care must be taken to prevent warping and cracking. Consequently various processes have been proposed for hastening

the drying, while yet it is so controlled that cracking and warping are avoided. Several of the processes of seasoning depend too upon the removal of the sap. We have water seasoning, seasoning by steaming and boiling, seasoning by smoke drying and stove drying, seasoning by scorching and charring, seasoning by extraction of sap, &c. Water seasoning, which is effected by submerging the wood for some time in water, renders it brittle. Seasoning by steaming and boiling also diminishes the strength and elasticity of the wood, for at temperatures somewhat below the boiling point, that is at 140° F., the albumen is coagulated and this seals up some of the water or sap in the wood and thereby weakens the cohesion of the particles. The process of smoke drying answers quite well but the same result is more easily attained by the Bethell or Robbins process to be described farther on. Stove drying renders the wood quite hygroscopic and leaves the pores open. Scorching and charring are only applicable to wood already thoroughly seasoned. If green wood is treated in this way the outside only is protected; the sap is sealed up in the interior and ferments and then decomposes. It may be well to mention here that the same unfortunate result is brought about if the green wood is covered with a coat of paint. The protection is wholly superficial and is very deceptive. It is far better to leave the wood uncovered for then if there is a free circulation of dry air, the wood will gradually season as the sap is evaporated. Owing to the belief that paint or varnish will protect wood under any circumstances it is no unusual occurrence to find the painted wood work of old buildings completely rotted away while the adjacent naked parts are quite sound. But the preservative action induced by charring seasoned wood is undoubted, for by the destructive distillation of the superficial layer various antiseptic agents are formed which find their way into the interior of the wood and the charcoal left upon the surface acts to destroy all fungoid germs which seek an entrance. This process has been long employed for preserving piles &c., and has been used in the Portuguese and French Navies. M. de Lapparent makes use of a gas blowpipe, the flame from which is allowed to play upon every part of the timber in succession. By this means the degree of torrefaction can be regulated at will. Instances of the efficiency of this process are cited as follows. Charred wood has been dug up which must have lain in the ground fifteen hundred years, and was then perfectly sound. At Herculaneum, after two thousand years, the charred wood was found to be whole and undiminished. The methods proposed for seasoning by the extraction of the sap alone have been abandoned as impracticable.

## PROCESSES DEPENDING ON THE CHEMICAL ALTERATION OF THE SAP.

The first of these processes that went into general use was Kyan's process, patented in England in 1832, and soon after in this country. This process, called Kyanizing, consisted in immersing the wood in a dilute solution of mercuric chloride (corrosive sublimate) until it was thoroughly saturated, or if time was an object, injecting the solution by pressure in a closed vessel from which the air was first partially exhausted. In England a solution of one kilo. of the salt to eighty to one hundred liters of water is employed for railway sleepers. They are laid in an open tank. In Baden they remain in the solution, when they are to be impregnated to a depth of 82 m. m., for four days, 85 to 150 m. m., for seven days, 150 to 180 m. m., for ten days, 180 to 240 m. m., for fourteen days, 240 to 300 m. m., for eighteen days, the solution consisting of one kilo. of salt to two hundred liters of water. When taken out the wood is washed and dried.

The use of the mercuric chloride depends upon the fact that it converts the albumen into an insoluble compound, while the salt itself becomes reduced to the mercurous chloride. This process was extensively adopted in England, and to some extent in this country. The objections urged are that the salt employed is costly, that when open tanks are used the process is tedious, and when closed vessels are employed the method is very costly, that the mechanics who shape the wood are liable to be poisoned by the salt, and that the bolts which hold it are liable to corrosion. But the process when faithfully executed seems to effectually arrest the rapid decay of timber in exposed situations.

Zinc chloride has an effect upon wood somewhat similar to that of mercuric chloride while it is a much cheaper salt. In 1838, Sir Wm. Burnett was granted a patent for preserving wood by this material and the process was known as Burnettizing. A solution of one kilo. of zinc chloride to ninety liters of water is employed. The wood is placed on a car and run into a large, air-tight, cylinder of iron and the solution is forced in under pressure. Although this method is not a sure preventive of decay the advantages which result from using it are more than sufficient to justify its application to most kinds of timber in common use, and in situations favorable to rapid decay. It has also a distinct effect in rendering wood less liable to warp and crack when placed in dry situations. It is open to the same objection as the mercuric chloride that the salt will act upon the iron or copper fastenings. This

process has been quite thoroughly tried in this country by Mr. J. B. Francis of Lowell, Mass., and its preservative power in many cases was quite well shown. Pieces of various woods treated by Burnett's process were partially buried in the ground side by side with unburnettized similar pieces of the same woods. They were kept there for over five years, and at the end of that time while the unprepared specimens were thoroughly decayed most of the burnettized ones were in good condition. Especially was this the case with birch, beech and poplar.

In the same year in which Burnett secured his patent another patent was granted in England to Bethell for the use of the heavy oil of tar for impregnating wood. This material is obtained as one of the by-products in the manufacture of coal gas. Although its composition varies considerably it always contains carbolic and cresylic acids, which are among our best known antiseptic agents together with various resinous, empyreumatic and asphalt forming substances. The preservative influence of these substances is well known.

Bethell placed the wood in an air tight cylinder (See Fig. 2) and first produced a vacuum, by which means the air and moisture were extracted from the wood. Then the liquid was forced in until a pressure of one hundred and fifty pounds to the square inch was obtained, and the pressure was continued until the wood was sufficiently saturated. This process was very successful, specimens which were treated in this way having remained unchanged when buried for over eleven years. Dr. Ure says of this process, "the effect produced is that of perfectly coagulating the albumen in the sap, thus preventing its putrefaction. For wood that will be much exposed to the weather, and alternately wet and dry the mere coagulation of the sap is not sufficient; for although the albumen contained in the sap of the wood is most liable and the first to putrefy, yet the ligneous fibre itself, after it has been deprived of all sap, will, when exposed in a warm, damp situation, rot and crumble into dust. To preserve wood, therefore, that will be much exposed to the weather, it is not only necessary that the sap should be coagulated, but that the fibres should be protected from moisture, which is effectually done by this process.

The atmospheric action on wood thus prepared renders it tougher, and infinitely stronger. A post made of beech, or even of Scotch fir, is rendered more durable, and as strong as one made of the best oak, the bituminous mixture with which all its parts are filled acting as a cement to bind the fibres together in a close, tough mass, and the more porous the wood is, the more durable and tough it becomes, as it im-

bibes a greater quantity of the bituminous oil, which is proved by its increased weight. The materials which are injected preserve iron and other metals from corrosion; and an iron bolt driven into wood so saturated, remains perfectly sound and free from rust. It also resists the attack of insects; and it has been proved by Mr. Pritchard, at Shoreham Harbor, that the *teredo navalis*, or naval worm, will not touch it."

In this country a patent has been granted to Robbins\* for an improvement in Bethell's process. He employs the oil of tar and drives the sap from the wood. Then he forces the tar in, in the form of a vapor, in which condition it is claimed that it penetrates more deeply into the wood and in a shorter time. It is claimed also that the wood is cleaner than when prepared by Bethell's process. One side of the Vandalia was treated in this way and it is proposed to compare its durability with the wood of the other side, both being manifestly under similar conditions.

The objections which have been urged against the use of coal tar compounds are that they impart a disagreeable odor to the wood; that the wood is difficult to work, as it clogs the tools, and that it renders the wood more inflammable.

One of the most interesting methods devised for introducing preservative agents into the pores of wood is that suggested and applied by Boucherie. Deep cuts were made in the trunk of a living tree near the roots, a sort of tank built around them, and the tank filled with the solution. (See Fig. 4.) Sometimes the tree, immediately after felling, was placed upright in the solution. In either case the solution was drawn up by the aspirative force of the tree, and penetrated even to the leaves. According to Hyett (Parnell's Chemistry) a poplar tree, ninety feet high, placed with its lower end in a solution of acetate (pyrolignite) of iron of specific gravity 1.056, absorbed about ten feet cubic in six days. Afterward the method was modified by applying a rubber cup to the larger end of the log as it lay on the ground with the top lopped off. Then the solution was allowed to flow from a height, in order to exert

\* For form of apparatus see Fig. 3.

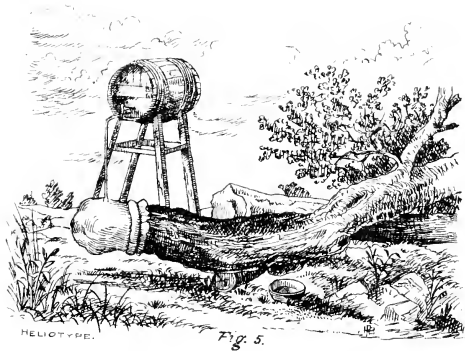
#### DESCRIPTION OF FIG. 3.

A, represents a retort in which the coal tar, resin or oleaginous substances or compounds are placed and subjected to the action of heat. B is the man-hole for reaching the interior. C the pipe with branches E E which connects the retort with the wood chambers D. F discharge pipe for retort. H discharge pipe for vapors condensed in chambers.

pressure, into the cup. (See Fig. 5.) By this means the sap was forced out and the solution flowed in. When the solution began to issue from the opposite end the operation was completed. Boucherie tried various substances but the one which he decided upon as the best was cupric sulphate. The solution used is one kilo. cupric sulphate to one hundred litres of water.

The testimonials to the efficacy of cupric sulphate are quite numerous. In some of the German mines it has given better results than zinc chloride. (Dingler's Poly. Jour. 1871, Vol. 202, p. 174.) But on certain German railways where it had been employed to protect the sleepers it was found to attack the iron. It is said in defense of the process that if the wood is thoroughly dried after impregnation, the iron will not be acted upon. However this may be, in ships where copper fastenings are used there would be no action. In 1855, the jury of the French Exposition made an extremely favorable report upon Boucherie's process, asserting not only its value, but its superior cheapness over the plan of creosoting. (Jour. Frank. Inst. 1856, vol. 32, p. 1.) In 1846, about eighty thousand sleepers saturated with cupric sulphate together with some that were unprotected, were laid down on the Northern railway of France. In 1855 that is, nine years afterward, the prepared sleepers were as good as ever, the others having long been decayed and replaced by new ones. For preserving telegraph posts, the cupric sulphate has been similarly effective. The saving to the French lines alone, up to 1855, was estimated at two and a half millions of francs (Compte Rendus 1868, vol. 67 p. 713.) By the report of the commission to the exposition at Vienna we learn that this process is still resorted to for this purpose and that telegraph posts are made to last from fifteen to twenty years. (Vol. II, L. 2, p. 18.) Examples of the preservative value of cupric sulphate could be easily multiplied, but one more will suffice. In 1868, Boucherie Jr. exhibited to the French Academy specimens of wood which had been prepared according to his father's process and exposed since 1847. These specimens were as sound, as elastic, and as strong as when new, and readily yielded the reaction of the copper they still retained. Here was a test of twenty years standing.

The rationale of the action of cupric sulphate has been stated by Koenig. (Am. Jour. Sci. 2 series, Vol. XXXII, p. 274.) The action is first the union of cupric sulphate with the resinous and albuminous constituents and next the dissolving of the albuminous compounds by the excess of the cupric sulphate solution. By long immersion it is said to be pos-







sible to remove all of the nitrogenized bodies. Resinous woods retain the most basic salt.

The process is useful only for green wood, and best adapted to light, porous, easily perishable woods.

Beside the substances mentioned a multitude of others have been suggested but they have generally been abandoned. Some have aimed to introduce solutions of different substances so that the interchange of their atoms shall take place in the pores of the wood and an insoluble deposit will be formed there. But the tendency is to some extent to petrify the wood and thus to destroy those characteristics which adapt wood to its uses. You can easily realize how useful a carpenter's tools would be in shaping stone.

I will speak of but one other method and that you are all somewhat familiar with. It is the preservation of wood by salting. This method of treating ship frames is imperatively required by the lake underwriters in new vessels of the first class. The American Lloyds recommend it but do not make it an absolute condition.

"The mode of salting is to fix stops of boards between the timbers of the frames about the height of the load line, and when the ceiling and planking are worked and the plank-sheer ready to go into place the spaces between the timbers are filled with salt. Near the end of the vessel the salt is sometimes put between the frames quite down to the deadwood. A vessel of five hundred tons will take one hundred bbls. of salt applied in the usual manner." (W. W. Bates Ag. Rept. 1866.)

The use of salt depends upon the fact that it incrusts the timbers and prevents the fermentation from taking place at the surface, but if applied to unseasoned wood its action being only superficial it does not arrest the decomposition of the interior. It has been used by Boucherie as a substitute for cupric sulphate but it could not compare with it. The use of it is objected to because being a deliquescent salt it keeps the atmosphere moist. Beside it is corrosive. For instance so long ago as "between 1768 and 1773, the practice prevailed of saturating ships with salt; but this was found to cause a rapid corrosion of the iron fastenings and to fill the vessels between decks with a constant damp vapor." (T. A. Britton, p. 112.)

As we examine the various processes which are in use we observe one fact, that they are all of them adapted only to light, porous, easily penetrated woods. Only the sap wood of oak and denser woods can be reached, but this is the part which is most liable to decay and most in need of a preservative agent.

The conclusion to which I have come then is the following.

The preservative processes enable us to use an inferior quality of wood with great safety. When vessels must be built in great haste and of inferior material, the wood should always be subjected to the action of a preservative agent.

It would no doubt be advantageous to treat the hard varieties of wood after they have been thoroughly seasoned, for although the treatment would be only superficial, in thoroughly seasoned wood, this would be sufficient. Of the materials employed the use of cupric sulphate appears to me to be the best applicable for ship timber as regards cost, inflammability, freedom from odor, corrosive properties, poisonous action, deliquescence, durability and ease of application.

## APPENDIX.

Table showing the cost of repairs per ton per year of life and per ton per year of sea service up to 1850 of vessels of the U. S. Navy.

	Rate Guns.	Tonnage.	Commenced Building.	Launched.	Cost.		Time from launching. yrs.	Time Building. yrs.	Sea service to Jan. 1850. y. m. d.	Repairs pr. ton pr year of life.	Repairs pr. ton pr. year of sea service.
					Building complete	Repairs to 1850.					
Franklin,	74	2257	1815	1815	438,149	27,487	35	1	8,9,8	.35	1.38
Columbus, 2	74	2480	1816	1819	426,950	260,468	31	3	8,1,20	3.36	12.97
Ohio, 2	74	2757	1817	1820	547,889	471,673	30	3	5,3,10	5.70	32.65
North Carolina,	74	2633	1818	1820	431,852	369,176	30	2	4,9,16	3.07	29.33
Delaware,	74	2633	1817	1820	513,368	459,199	30	3	6,9,2	3.59	25.31
Independence, 2	54	2257	1814	1814	421,810	538,392	36	1	7,5,26	6.60	31.89
United States,	44	1697	1796	1797	299,356	658,106	53	1	29,5,17	7.73	20.07
Constitution,	44	1697	1796	1797	302,719	495,236	53	1	32,0,24	5.82	9.61
Potomac,	44	1726	1819	1821	350,000	390,244	29	2	10,8,23	7.80	20.93
Braudywine,	44	1726	1821	1825	399,217	644,496	25	4	17,4,9	14.93	21.58
Columbia, 2	44	1726	1825	1836	336,891	136,339	14	11	6,5,12	5.65	12.25
Congress, 4	44	1867	1839	1841	399,088	122,631	9	2	6,1,2	7.39	10.86
Cumberland,	44	1726	1825	1842	357,475	114,802	8	17	4,10,21	8.31	13.58
Savannah,	44	1726	1820	1842	400,739	78,260	8	22	4,7,27	5.67	9.86
Raritan,	44	1726	1820	1843	406,087	81,663	7	23	4,4,6	6.76	10.88
Constellation,	36	1778	1796	1797	314,212	400,982	53	1	22,5,17	5.92	13.97
Macedonian, 2	36	1341	1832	1836	258,872	67,135	14	4	0,2,7	3.58	8.15
Average cost,										\$6.02	\$16.19

The first nine columns are compiled from Emmons' Statistical History. The last two are added by me.

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 Preservation of Wood—“ “ “ “  
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First Forms of Vegetation—*Hugh Macmillan.*

# THE RECORD

OF THE

## UNITED STATES NAVAL INSTITUTE.

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A GENERAL DESCRIPTION OF THE ORDNANCE AND  
TORPEDO OUTFIT OF THE U. S. S. "TRENTON" (2nd Rate).

By Lieutenant CHARLES A. STONE, U. S. Navy.

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The Spar deck battery of the "*Trenton*" consists of two eight inch converted Rifles on the forecastle, and one aft. The forward guns are mounted on Ericsson pivot carriages, shifted and trained by tackles. The recoil is controlled by friction compressors, attached to the front of the top carriages. Attached to each slide are two bronze compressor plates, the length of the recoil allowed, placed horizontally, one above the other. The gun is run in or out by direct gearing on the inside of the brackets of the top carriage, which is geared into a longitudinal rack, inside of and close up to one of the rails of the slide. The rear trucks of the top carriage are on eccentric axles, but the depth of the cogs of the gearing is sufficient to prevent their being entirely separated by heaving the rear trucks into action. These forward guns can be fired both on the same side of the ship, or one on either side. They can be trained from right ahead to about two points abaft the beam.

The after pivot gun on the Spar deck is mounted on what is called the "Circular Brake Carriage." Placed longitudinally, and attached to the slide, are two heavy cogged racks of bronze. Engaged in these are two bronze pinions on a heavy steel axle extending between the brackets of the top carriage. On this same axle is a drum, with an iron strap extending around it, acting as a circular friction brake on the recoil. The strap is tightened on the drum before firing, by means of an eccentric worked by a lever. There is also a simple automatic

NOTE. This paper has not been read before the Institute, but is inserted by direction of the Executive Committee.

device by which the compressor is tautened still more during the first foot of the recoil. This device consists of an arm on the same axle with the compressor lever; on the end of this arm is a stud, or pin, which, during the first foot of the recoil, travels along and down an inclined plane attached to the slide, thus heaving the compressor lever up, and tautening the compressor. The inclination of this plane is adjustable. But little initial compression need be given when this automatic device is used, thus easing the first strain on the pivot bolts, &c. On the same steel axle with the pinions above mentioned is a wheel, engaged in which is a pinion on a crank shaft passing through the brackets of the top carriage, with a crank on either end. When the compressor is slackened the gun is run in or out by means of these cranks. Previous to firing, the pinion on the crank shaft is disengaged from the wheel on the main axle by a longitudinal movement of the crank shaft. There are two wheels and two pinions on the crank shaft, of different sizes, giving different rates of speed and power, in running in and out. This after pivot gun has three fighting pivots, one astern, and one on either quarter. The gun can be trained from about four points forward of the beam on one side, around to the same angle on the other side, or through an angle of about  $270^\circ$ . Owing to the elliptical form of the stern, the three fighting pivots cannot be reached from one shifting center; two are required.

In the Gangways on the Spar Deck are two twenty pounder Bronze Breech Loaders, converted from Dahlgren muzzle loading rifles. They are mounted on iron Marsilly carriages, and are fitted with directing bars, on which are arranged friction compressors. These guns are used for saluting. The charge is two pounds of cannon powder. An eight or nine second salute can be fired from them without difficulty. They were converted, at the Washington Navy Yard, by cutting off the breech of the gun a short distance in rear of the base ring, cutting a score around the gun at the base ring, centering the breech in a mould, and casting on to it the masses to which the collar is attached, and then turning out the plug recess &c. They have the same system of breech mechanism as the three inch B. L. Rifles.

On the Gun Deck are four 8 inch converted Rifles in each broadside, divided into two divisions of four guns each. The guns of the First Division are mounted on Ericsson carriages with friction compressors, similar to those of the forward pivots. They are run in and out by similar gearing. The rear trucks of the top carriage are not on eccentric axles, but are always in action. The rear training trucks

of the slide are geared into training racks on the deck. Above one of these trucks is placed the training crank, geared to the truck by direct gearing. This gearing is locked by a screw, which presses hard, when desired, against one of the axles of the gearing, and thus holds the slide when there is motion on the ship. In port the guns can be trained fore and aft, close out to the ship's side. They are first trained sharp on the bow, when a securing pivot bolt is put in and the fighting pivot bolt withdrawn, they are then trained fore and aft. As the friction compressor plates occupy the central part of the slide the securing pivot is placed on one side. To allow the rear transom of the slide and training gear to accommodate itself to this new center, the transom is not riveted to the rails of the slide but is pivoted in its center to another transom, which is riveted to the rails. The first transom, carrying the training gear, has therefore a movement under the slide similar to that of the front axle under a carriage.

The guns of the Second Division are mounted on the Hydraulic Buffer carriage, a description of which, written by Commander M. Sicaud, will be found in the Ordnance pamphlet on the 8 inch converted Rifle. The 8 inch Rifles have two sets of sights; side sights on the left side of the gun, the rear sight being set at a permanent angle ( $1^{\circ} 47'$ ) for drift; and central sights, the breech sight having an adjustable head for drift and wind.

There are four boat guns supplied to the ship, all of which are of bronze. Two 12 pounder smooth bores, and two 3 inch B. L. Rifles, one of 500 pounds, and one of 350 pounds. The shell and shrapnel for the 3 inch Rifles are fitted for the Boxer fuse, slightly modified, a description of which will be found in the Ordnance pamphlet on the 3 inch B. L. Rifle.

#### ELECTRICAL APPARATUS.

On the bridge is an electrical instrument, called the Annunciator, for firing the guns and torpedoes by electricity. In shape and size it somewhat resembles a standard compass. Inside, along the sides are two rows of four ports each, corresponding to the guns in broadside. At either end are two more ports corresponding to the bow and quarter spar torpedoes. Outside of the instrument, but protected by a brass shield, abreast of each of the ports above mentioned, is a firing key. There is also a firing key for each broadside. Overhead, in rear of each gun on the Gun Deck, is an instrument called a tell tale, which shows when a current passes through the electrical circuit of that gun.

The two wires leading from the tell tale are terminated by an instrument called the Primer Connection, which furnishes a ready means of putting the electric primer into the circuit. On one of the wires between the tell tale and primer connection is a simple make circuit connection, which is held by the Captain of the gun. When the primer is connected, and the circuit completed by the Captain of the gun, the current passes, causes the tell tale to work, and also revolves in front of the port corresponding to that gun in the Annunciator on the Bridge, a red signal bearing the number of the gun. This current passes through sufficient resistance in the Annunciator to prevent its firing the primer; but when the corresponding key is pressed the firing current is shunted into the circuit, and the primer is fired. The object of the tell tale is to show the Captain of the gun that his primer is good, that is that there is a current through it, and it also shows him that the officer on the bridge knows that his gun is ready to fire. It also takes the place of the order "Ready" to the crew, as it is in plain sight of the mall, and without the tell tale indicates it, they know that the gun cannot be fired. If the Captain of the gun loses his aim, or does not for any reason wish his gun to be fired, he breaks the circuit in his hand, which makes it impossible for the officer on the bridge to fire the gun. Upon breaking the circuit the tell tale shows no circuit, and in the port in the Annunciator his number disappears, showing that the gun is no longer ready. If the keys in the Annunciator are kept pressed, then upon the captain of the gun completing the circuit, the gun is instantly fired. By means of the keys in the Annunciator for the broadsides the officer can fire simultaneously all the guns that are ready, and moreover he sees before firing just what guns are ready. The tracks of the gun deck battery are being marked for concentration of fire, and a Director is being made to ship on top of the Annunciator, so that the broadside can be concentrated and fired from the bridge.

The electrical circuits for the Spar Torpedoes are similar to those for the guns, except that there are no tell tales. The connections being made on the spar deck and in sight of the bridge, none are required. The Spar deck guns can be fired by electricity by using such of the torpedo circuits as are not in use. There are three galvanic batteries in use on the ship. The cells of the batteries on board the *Trenton* are the La Blanché, modified by Lieut. Converse. The testing battery is composed of twelve cells, arranged in two groups of six each. This current works the tell tales and the annunciator, and tests the primers. The firing battery is composed of twenty cells, arranged in groups of five each.



This fires the gun primers and torpedo fuses. There is a large excess of power in this battery, as a single cell, in good condition, will fire a primer on short circuit. These batteries are in walnut boxes, under lock and key, standing on brackets on either side of the main mast on the berth deck. The third battery is the Bell Battery. It rings all the electric bells, and also supplies the current for the Thermostat circuits. The Thermostats are set to give warning when the temperature of the place they are in rises above 140° F. This instrument consists of a cylindrical metallic case within which, and insulated from it, is a metallic spiral spring, composed of two strips of metal of different expansibilities under heat, soldered together, and coiled into a spiral. The most expansible metal is on the inside of the spiral. As the temperature rises the spiral uncoils; and when the temperature for which the instrument is set is reached, the end of the spiral comes into contact with a point on the inside of the case; this point is adjustable.

One wire, insulated from the case, is connected to the spiral, the other wire to the case. In the same circuit, near the cabin door, is the Thermostat Annunciator, similar to the Electric Annunciators in use in Hotel Offices, in which, when any of the Thermostats completes its circuit, a shutter bearing the name of the place in which it is placed, is dropped; and at the same time an electric bell rings continuously to attract attention, as long as the Thermostat keeps the circuit closed. The Thermostat Annunciator is directly under the eyes of the orderly at the cabin door. There is a Thermostat in each of the coal bunkers, and one between the Yeoman's Storeroom and the Paint Room. Besides the Spar torpedoes, there are two Harvey torpedoes of the Service pattern supplied to the ship.



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## NOTICE.

At the April meeting of the Institute the following amendment to the Constitution was adopted, to take effect January, 1879.

“Members, who are two years in arrears for dues shall be dropped; and the Proceedings shall not be furnished to members one year in arrears for dues.”

All correspondence in regard to dues and publications must be addressed to the Treasurer.

All papers and correspondence referring to papers, applications for membership and resignations of membership must be addressed to the Secretary.

General correspondence in regard to the Institute and its affairs must be addressed to the Corresponding Secretary.



THE RECORD.  
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UNITED STATES NAVAL INSTITUTE.

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U. S. NAVAL ACADEMY, ANNAPOLIS,

OCTOBER 11, 1877.

Chief Engineer CHAS. H. BAKER in the chair.

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In the absence of the author, P. A. Engineer W. L. Nicoll read the following paper on

THE U. S. SHIP TRENTON.

BY GEO. W. BAIRD, PASSED ASSISTANT ENGINEER, U. S. N.

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An Inspection of this fine vessel will show that our Naval Authorities have well improved their time since the termination of our late war, and have profited by the costly experiments which have so advanced the great Navies of Europe.

The "*Trenton*" is one of the "eight sloops" recently completed, and like all modern unarmored ships of war, is intended for a commerce destroyer.

Indeed, the high speed and great weight of armor now demanded have rendered inevitable the division of ships into several classes. This, however, our own Naval Authorities were the first to recognize and to put in practice. The principal improvements in the "*Trenton*" are in the steam machinery and the ordnance, the former of which I am invited to write about; but that this paper may be more comprehensive I will introduce the dimensions of the hull and other data on which depends the performance of the machinery.

THE HULL.

The vessel has by no means a sharp model, being designed to carry four guns in the bow, all of which can bear directly forward. Amidships she has scarcely a perceptible dead rise, but her keel increases in depth from 1 ft. 8" for'd to 2 ft. 8" aft.

She has great breadth of beam in proportion to her length. The hull is of wood, is coppered, is rigged as a ship, and has the following dimensions.

Length over all, in feet and inches,	271-6
Length on the load water line in feet,	253.
Depth of hold from throat of gun-deck, in feet and inches,	23-4
Draught of water at launching	} forward, 10-2½ } aft, 14-4½
Displacement per inch of draught,	
Displacement at deep load line, in tons,	{ 8 in. draught, } 3900
Extreme breadth of beam, in feet,	48
Area of greatest immersed transverse section in square feet,	780.
Area at load line (at 20 ft. 8 in. draught) in square feet,	9576.
Center of gravity of displacement aft of greatest immersed transverse section, in feet and inches,	10-4
Distance of greatest immersed transverse section from stern-post, in feet and inches,	137-10
Ratio of length to breadth on the load water line,	5.271 to 1.000
Ratio of displacement to its circumscribing parallelopedon,	0.6131 to 1.000

#### ENGINE.

There is, for the propulsion of the ship, a compound engine having one high pressure and two low pressure cylinders. The two latter are connected to cranks, which are placed upon the shaft at right angles to each other, while the crank of the high pressure cylinder bisects the angle between them, or is placed at an angle of 135 degrees with either low pressure crank. The low pressure valve chests, the exhaust passage of the high pressure engine, and the pipes connecting them, form the receiver, the aggregate volume of which is 90½ cubic feet, or 1.21 times the volume swept by the high pressure piston.

Each low pressure cylinder exhausts into a separate condenser, but the condensers can be connected if desired.

The cylinders are arranged on the starboard side of the hold, the high pressure being in the middle. The engine is of the horizontal, back acting type. The valves are double ported slides, with lap on both the steam and exhaust sides. The steam lap is sufficient to cut off the steam at 6-10 of the stroke of the pistons. The high pressure has an independent cut off on the back of the valve and the point of cutting off is varied by the usual right and left hand screw arrangement. The valves are worked by Stephenson's links and eccentrics.

Air, feed and bilge pumps are worked from arms on the side rods.

The air pumps are double acting piston pumps, packed with lignum-vitae and hemp, and have rubber valves.

The cylinders are steam-jacketed and felted. The valve chests are felted and lagged.

The condensers have brass tubes, well tinned, placed horizontally and in two nests; the circulating water passing once through the tubes of each nest. The tubes are  $\frac{5}{8}$  of an inch outside diameter and the steam is condensed on the outside. They are secured in cast iron tube sheets by wood packing.

### THE DESIGN.

The compound engine and high pressure boilers were designed for the purpose of giving the vessel the highest mean rate of speed, and the greatest possible length of voyage. The unit of measurement of a vessel is her displacement. A certain definite space is allotted for battery, for machinery and fuel, for stores, ammunition etc., and within the weight and space allotted for machinery and fuel the Bureau of Steam Engineering has so distributed the constituents, as to approach very nearly the highest possible mean.

The increase in the economic efficiency of the marine engine has advanced with the increase of steam pressure, higher grades of expansion, and velocity of piston. In each of these three essential advances, our own countrymen have been foremost. There appears, from the most reliable experiments, to be a certain degree of expansion due to each definite steam pressure, if the maximum economy would be obtained, and as far as the unqualified *economy* of the fuel goes, it is not probable that any fair-minded engineer will claim supremacy for the compound, over the simple, arrangement of engine, or, *vice versa*. Other functions enter, which will probably be interesting to the Institute, and will be shown. For non-jacketed simple condensing engines, using steam at 25 lbs. pressure above the atmosphere, Chief Engineer Isherwood found that the economic point of cutting off was four tenths (4-10), from the commencement of the stroke of the piston. A non-condensing engine would need follow about one-half stroke, in order to attain its greatest economy. At 75 pounds pressure these figures would be about one-fifth (1-5) for the condensing, and about one third (1-3) for the non-condensing engine.

The use of a steam jacket, by which the cylinder is enveloped by steam of the boiler pressure and temperature, changes the conditions sensibly. The saving by this means is elaborately set forth in the

Bureau's report for the year 1875, which, being in the archives of the Institute, does not require comment here.

The two features which make the compound engine superior to the single expansion (or simple) engine are, 1st, the lighter working parts ; and, 2d, the greater uniformity of its turning forces.

As an example of the former, we may take the engines of the *Trenton*. It is intended to attain a piston velocity of 448 feet per minute, to use 80 lbs. of steam, above the atmosphere, with 2.75 expansions in the high pressure cylinder, or a total range of 14 expansions.

There are three cylinders, and each is intended to be of equal power. The two low pressure cylinders are 78 inches in diameter and the high pressure is 58½. The pistons have a stroke of four feet.

Now it must be borne in mind that all parts of machinery are proportioned to the maximum strain. In a steam engine this occurs at the commencement of the stroke of the piston.

The power is made up of the mean weight upon the pistons multiplied into their velocity. A single cylinder, single expansion engine, which carried the same initial pressure and same mean pressure as the high pressure engine of the *Trenton*, and which exhausted into the condenser with the vacuum attained here would require to be 63½ inches in diameter, or nearly 15 per cent. larger than the present H. P. cylinder. This would increase the sizes of the piston and connecting rods in the same ratio. Indeed it would carry a large increase of size and weight throughout most of the engine.

It was the intention of Chief Engineer Wood, late Chief of the Bureau of Steam Engineering of the Navy Department, to design for two vessels of the "*Miantonomah*" class (now re-building) compound engines and for two others simple engines, all of the vessels having hulls, boilers and propellers exactly alike. Indeed he intended to have had all the engine framing, working parts of the engine, condensers, pumps etc., exactly alike ; the same aggregate volume of cylinder and the same grade of expansion ; but on calculating the strain on working parts, the area of piston needed, etc., it was ascertained that the maximum weight (or pressure) upon the pistons would be twenty four (24) per cent. greater in the simple engine than in the compound.

#### UNIFORMITY OF THE TURNING FORCES.

Figure I is a diagram of the turning forces of the engine, with the three cylinders in use. a, a, a, represent the variation of pressure in the high pressure engine, and b, b, and c, c, that in the two low pres-

ure engines. The curve A, A, is the combined resultant, and its variation shows the variation of torsion on the shaft, leaving inertia out of consideration. Had the cranks been connected at  $120^\circ$  (or equidistant) then the torsion would vary as the line B, B. It will be observed that though the engine has three cylinders, there are but two distinct and decided increments during a complete revolution.

It will also be observed that the turning force is more uniform with the cranks in their present relative positions. It will be remembered that the crosstail of the after, (low pressure) engine was broken on the 10th of March, since which time the after engine has been disconnected and out of use. With only two engines in use it is more difficult to start or reverse them, than if the cranks were placed at  $120^\circ$  from each other. To ascertain what relative effect this would have on the turning forces, Fig. 2 has been constructed, in which the curved line, A, A, A, shows the variation of torsion upon the shaft with the cranks, as at present arranged, and the dotted line shows what the torsion would have been, had the cranks been arranged at an angle of  $120^\circ$  apart.

In this diagram, as in the other, there are but two definite pulsations per revolution, and they follow the variations of the high pressure engine. The sharp angles which occur in these diagrams, or, in other words, the sudden change in the intensity of the turning forces would be greatly modified, had the inertia of the moving parts of the engine been considered; but inasmuch as these diagrams are merely comparative, and refer only to the distribution of the work, so far as the piston pressures are concerned, they have been confined exclusively to that purpose.

It may not be out of place to compare a diagram\* of our most successful single expansion engines, with those of the "*Trenton*." Fig. 3 is a diagram of the turning forces of the engines of the "*Pensacola*," using 40 pounds pressure and expanding four times. This is a higher grade of expansion than this class of engines usually employed, though it is the exact point at which the Bureau proposed to cut off, in adapting the engines of the "*Worcester*" to the "*Lancaster*." (Vide Report of Sec. of the Navy for 1876), though it is not nearly so high a grade as is employed in the compound engines generally. These have been unanimously accorded to be the best working, simple screw propeller engines in the Navy; though it will be observed that the variation,

\* I am indebted to Asst. Engineer I. A. Henderson, U. S. N., for the construction of these torsion diagrams.

even at so low a grade of expansion, is considerable, and the number of pulsations per revolution is just double that of the "*Trenton's*." These sudden, though uniform, variations in the extent of torsion on the shaft, have, in my opinion, a decided influence on the shaking of the ship. If one of the blades of the screw propeller pass the stern post at the instant of the greatest torsion (and velocity) of the shaft, and if this number of beats per unit of time accords with the natural vibration of the vessel, it is natural that the latter should respond to the former, until great motion ensues: exactly as the march of infantry over a bridge endangers it, unless they break step. If, however, the blades of the propeller be so arranged that they are not opposite the rudder post at the instant of greatest torsion, this danger is reduced. However, I am of the opinion that where a propeller with an odd number of blades is used, this difficulty is partially overcome.

I have prepared Fig. IV. to show the variation in torsion of a three cylinder, single expansion (or simple) engine using the same initial pressure, the same total unbalanced pressure, the same number of expansions and the same velocity of piston as are employed in the "*Trenton*."

This example is theoretical, and is calculated for the full power of the engine, while Fig. I. has been draughted from indicator diagrams taken before the after engine was placed out of use, (with broken cross-tail) at which time, unfortunately, the power developed was only about two thousand (2000) horses. In the example given in Fig. IV, it is assumed that the engines are connected at  $120^\circ$  with each other. A comparison of Figs. I. and IV. will show, graphically, the merits of the two systems in regard to their uniformity in turning forces.

#### REVERSING GEAR.

A pair of oscillating engines, under the engine-room platform, raise and lower the links through the intervention of a spiral gear. The motion of the oscillating cylinders upon their trunions opens and closes the ports, and the motor is reversed by a two-way cock, which changes the steam-port into an exhaust-port, and *vice versa*. This arrangement essentially deprives the machine of "lap or lead," and keeps the exhaust open up to the termination of the stroke, which gives the advantage of always clearing itself of water; and no matter how suddenly a signal is received to stop, or reverse, the engines, no fear need be entertained of damaging the reversing engine by the water that is certain to accumulate in the steam pipe.



On leaving the Navy Yard, New York, on the 5th of March last, I gave this system a trial, and found that the time required to throw the links from full ahead to full back gear was only six seconds. This was with the boiler pressure of 75 pounds on the valves of the main engine. An automatic arrangement shuts off the steam when the links reach full throw.

#### BOILERS.

The boilers are eight in number, and cylindrical in form. They are arranged in rows (with their axes athwart-ship), four on each side of the hold, and discharge their products of combustion into a common smoke-pipe, which latter is telescopic.

Each boiler is 12 feet in diameter and 10 feet 3 ins. in length, on line of axis, and contains three furnaces. The furnaces are cylindrical, 36 inches internal diameter, exposing a length of grate of 6 feet and 11 inches. The tubes are of brass, are arranged in nests, horizontally, above the furnaces, and are  $3\frac{1}{4}$  inches outside diameter, and 8 ft.  $2\frac{1}{2}$  ins. in length. Each boiler has a safety valve, a check valve, a bottom, and a surface, blow valve, a stop valve, and steam and water gauges. They discharge their steam into a common pipe which enters the uptake, and passes twice its length. The pipe thus acts as a super-heater.

The boilers are entirely below the water, their highest points being about 24 inches below the water level when the coal bunkers are empty. All the coal is carried outboard of the boilers, there being no forward bunkers. A shot would have to pass through twelve feet of coal, even on the berth deck, before it could reach the boilers, so they can be considered as being well protected. It is a fact, patent to all, that no vessel in our Navy, the boilers of which were masked by the water, has ever received a shot into them.

#### STEAM PUMPS.

The circulating pumps for the condensers are independent, centrifugal ones, and are two in number. They are driven by a pair of vertical steam engines, and are upon the same shaft. The estimated capacity of these pumps is five thousand (5000) gallons of water per minute. They are situated about eight (8) feet below the water level, and have, therefore, that head to assist them. They are provided with bilge valves; but inasmuch as they would have to lift the bilge-water, it is estimated that their capacity as bilge pumps would not be more than half the above figure.

The auxiliary (or Donkey) pumps are two in number, and are of the

Blake patent. They are horizontal, double acting, and have a capacity of three hundred and fifty (350) gallons per minute. These pumps may be used for pumping water out of, or into, the boilers, for pumping the bilges, for fire purposes, or, as auxiliary air-pumps to the main condensers. They have, so far, proved themselves to be the best auxiliary steam pumps I have ever used, the only thing not in their favor being that there is no means of working them by hand. The combined capacity of the steam bilge pumps of the vessel is estimated at three thousand two hundred (3200) gallons per minute.

#### STEAM WINDLASS.

This machine was built by the Providence Steam Engine Company, from the plans of the ingenious engineer, Mr. Frederick Sickles. It is essentially a horizontal revolving shaft placed athwartships on the forward part of the berth deck, and upon which shaft is secured the "wild cats" for carrying the chains, drums for carrying ropes to be used in catting and fishing the anchor, and at the middle of the drum a spiral gear wheel is placed which is driven by a pair of engines placed beneath the deck. The "wild cats" are secured to the shaft by means of movable keyes, which enable the attendant to veer chain on one anchor and hoist the other at the same time. A friction gear enables the attendant to check the chain when veering, at any moment.

The steam cylinders are 14 inches in diameter of bore and have 14 inches stroke of piston. An automatic valve, placed on the steam pipe near the engine, prevents the pressure from rising above 30 lbs. per sq. in. on the pistons, no matter what excess we have in the boilers. In usefulness and in convenience this machine is admirable. The sharp angle at which the chains pass the hawse pipes increases the resistance to such an extent that the thrust bearing of the spiral gear heats, and when breaking the anchor out of the mud the hand gear is used, to assist the engines, as a precaution. The hand gear is an ordinary pump brake, and may be used with the steam gear or independently of it. The "wild cats" may be unkeyed and the engine used to "cat" and "fish" the anchors.

#### STEERING ENGINE.

This machine is from the same builders and designer as the Windlass. It is placed on the gun-deck between the steerage and ward room hatches, with its axis fore and aft, and its drum is connected to the tiller by means of hide ropes. The engine consists of a pair of cylinders, inclined at an angle of 45° and connected to the same crank.

The drum which carries the tiller ropes is keyed to the crank-shaft. That which distinguishes this from the ordinary steam engine, and makes it particularly valuable for the purpose of steering, is its valve gear. This system is mounted upon the engine frame in front of the engine, and is actuated by a hand wheel, which in turn is moved by a similar wheel, on the spar-deck, through the intervention of a drum and cord. Any motion of the valve gear admits steam to the engine, and any motion of the engine tends to bring its valves to the middle position, and the mechanism is so graduated that every degree of angular motion given to the hand wheel is responded to by exactly the same amount of angular motion in the engine. The steam cylinders have a diameter of 24 inches and a stroke of piston of one foot, and though the hand wheel may be worked by a child, yet the turning force of the engine, which responds to it, is enormous. The working of this machine is not smooth and can never be made so. The pressure of steam upon the pistons urges them forward until the motion has brought the valves to their middle position. Here the ports are all closed and there is no pressure to impel nor to impede the motion of the engine. But the inertia of the moving parts of the engine is sufficient to move it a short distance past the dead point, and this motion, communicated to the valve gear, admits steam on the opposite side and brings the engine back. Instead of stopping exactly upon the dead point it passes and repasses several times and is only brought to rest by a friction brake which the builders have attached.

#### STEAM WINCHES.

In the boiler hatch, and secured to the coamings on the gun-deck, are placed two rotary engines of the Lidgerwood patent. They each drive a drum through the intervention of a friction gear and are reversed on the same principle as the *reversing engine*. The drums carry cords for the purpose of hoisting ashes, or for coaling ship. These rotary engines were intended by the superintending engineer to hoist the smoke pipe; but, as at present arranged, cannot be employed for that purpose.

#### DISTILLING APPARATUS.

This machine is of the kind patented by the writer, and has been too long in use in the Navy to warrant any comment here.

#### SPEED OF THE VESSEL.

The accident to the crosstail of the after engine, on the day the ship left New York, (five months ago), made it necessary to disconnect that

engine and run with the other two. By this arrangement but one condenser is in use and, therefore, more than half the power cannot be employed. With half the power the ship has frequently logged  $11\frac{1}{2}$  knots under steam alone, uninfluenced by wind or current. The preparation of this paper has been postponed in the vain hope of seeing the damaged engine repaired, and a test made for speed. Supposing that the power varies as the cube of the speed, the vessel will attain a maximum rate of  $14\frac{1}{2}$  knots per hour, on the estimated full power of 3000 indicated horses. Although there is every indication that a maximum of 3000 indicated horse power will be attained, yet, with the full model of the "*Trenton*," it cannot be expected that the speed will vary exactly as per the law above cited, and if 14 knots is ever attained, the most sanguine hopes of the designers and builders will be realized.

#### EFFECTIVENESS AS A RAM.

The great strength and peculiar construction of the bow, and the great power of the vessel, will make her very effective as a Ram. Steaming at 14 knots, and striking another vessel at rest, the energy exerted would be  $\frac{w}{g}V^2 = 25,868$  foot tons, or sufficient to raise the whole weight vertically a little over six and a half feet.

This is equal to the concentrated fire of ten of the eleven 8-inch rifle guns (that compose the battery) of the vessel, with the projectiles having a striking velocity of 1450 feet per second. Such a blow would crush in the armored side of any vessel yet built. The "handiness" of the vessel, which is truly remarkable, will make it not difficult to strike her adversary when, and wherever, her commanding officer wishes.

#### WARMING, LIGHTING AND VENTILATING.

The vessel is warmed by steam heaters, known as Walton's "Radiators," which are supplied with steam from the main boilers, and discharge their condensed water through a Nason's trap into a tank from whence it is taken for washing purposes. These heaters being *noiseless*, merit a special mention. The device consists of an upper and lower chamber which are connected by iron pipes  $1\frac{1}{4}$  inches in external diameter, the lower chamber being used for the purpose of collecting the water. As each pipe empties itself freely, and there is no flow of steam to retard or back up, the flow of water, that objectionable noise (which resembles a hydraulic ram) is entirely avoided.

The exposed surface of these heaters is nearly one square foot for each one hundred (100) cubic feet to be warmed, and the mean temperature of 74° F. was maintained in the ward room, when both hatches were open, and the temperature of the external atmosphere was 30° F. The temperature near the radiators was, of course, much greater; but the mean of six thermometers, placed at equal distances apart, on the centre line of the ward-room, gave the above quantity.

The large area and convenient arrangement of the hatches of the "*Trenton*" do not compensate for the diminutive size and unequal spacing of the air ports. It is true that all holes in a wooden ship should be cut equally between the timbers, and that the timbers may be spaced in reference to the location of the guns and other weights; but there is no apparent reason why the air ports should not have been more numerous and of greater size. Most of the officers' staterooms have each one air port; but some of them have only half a port, and others have one and a half. No one air port gives sufficient light to enable one to write ten feet from it. The vessel is lighted, at night, by oil lamps, and, except in the cabins, ward room and the offices of the Admiral and Captain, where argand burners are used, the vessel is as dark and dismal as the average U. S. ship of war. Special attention has been paid to the lighting of the engine room, where the most approved oil lamps are used; but the light is insufficient.

The danger and labor of trimming lamps that illuminate the most important moving parts of engines have usually prevented their sufficient use.

With the improved apparatus for manufacturing gas from the products of petroleum which are within our reach, there are many reasons why we should use it. It gives a better and a cheaper light than oil lamps; the labor of manufacturing it on board is less than that required to fill, clean and trim the lamps, and it is much more cleanly, and, for fixed lights, it is safer.

There are no unusual means for ventilating the ship, except two 8½ inch pipes extending from the after end of the shaft alley, up and out through the stern of the ship, and a number of oblong openings between the beams under the gun and spar decks. The latter were made for the purpose of ventilating the bilge. Those which were in the staterooms of the ward-room officers have been stopped up. The Constructor has stated that the openings into the officers' quarters were not intended to be permanent, but were for use only during the long period required to build and fit out the ship.

The two small pipes from the after end of the shaft alley are doing good work. With a wind aft, a current is forced in, and is felt in the alley; also, when the wind is ahead, there is an inward current caused no doubt by the wind eddying round the stern; but in a calm, or when the wind is a-beam, the pipes act as chimneys, and the current is strong enough to deflect the flame of a lamp very decidedly. Under any and all conditions there is a current of air through these tubes, either one way or the other. There is one other unusual means of ventilation (though not intended for that purpose), which merits mention. In order that room might be given on the gun deck to permit two guns to bear directly forward, the chains were brought in on the berth deck. The hawse pipes, through which the chains pass, are most excellent ventilators, when the ship is swinging head to the wind. The ship is supplied with the usual windsail, and the stationary ventilators for the fireroom. The berth deck, though warm when the vessel is under steam, is by far the most pleasant that I have seen. Inside the smoke pipe, and running as high as the standing part, there is a pipe which opens into and discharges the air from the fireroom. This arrangement was first devised for the "*Richmond*," in 1867, by the Chief of the Bureau of steam Engineering; but, as it impeded the draught, it was abandoned. The boilers of the "*Trenton*" have so strong a draught, that the use of the pipe is permissible, and from it benefit is derived. In the event of using full power, where it would be necessary to force the fires, the lower opening of this pipe will be closed by a suitable door. On the gun deck there are no bulk heads around the boiler hatch, and, as most of the crew are berthed on this deck, and the temperature near the boiler hatch is high when there is steam, Rear Admiral Worden directed that a curtain be hung around the hatch. To determine the benefit of this curtain, a thermometer was hung on a hammock hook on the gun deck, another in the hatch just above the gun deck, another in the hatch just above the berth deck, and one in the fire room level with the uptake doors, out of the draft of the ventilators, at which place the temperature was greatest. The two thermometers in the hatch, and the one in the fire room were in the same vertical line. The readings were as follows:

LOCATION OF THERMOMETER.	CURTAIN HUNG.	CURTAIN REMOVED.
Suspended to a hammock hook on the Gun-deck adjacent to the boiler hatch,	80	87°
Suspended in hatchway above level of gun-deck,	129	110°
Suspended in hatchway above level of berth-deck,	138	142°
Suspended in fire-room out of draught of wind sails.	145	160°

A lighted candle placed in the opening under the curtain, indicated an inward draught. It is not to be supposed that the temperature recorded in the last line is "the temperature of the fire room" of this fine ship: it is the temperature at a point in front of the uptakes, the warmest place in the fireroom, and from 30° to 40° warmer than that in which the firemen live. Under the ventilators, or the windsail, the temperature is as low as it is on deck.

#### THE BILGES.

In the design and construction of the *Trenton*, attention appears to have been given to this subject. The limber holes are the largest I have observed in any of our sloops, and the floors, from the fore hold aft, are high enough for a man to pass under. One of the bulkheads of the shaft alley, which rested on the main keelson, prevented the space under the after shell room from being cleaned, but the bottom part of it has been cut away, and the offensive matter which had accumulated there has been removed, and it is now cleaned with the rest of the bilge, semi-weekly. Owing to leaks in the bow (probably some of the bolts that secure the ram) a small stream of water is constantly flowing aft, that being the lowest part. From this moisture there arises, at times, a most unpleasant bilge odor, but it is becoming less and less all the time. On the trip across the Atlantic, where the ship encountered bad weather, a quantity of chips and shavings were removed from the bilge strainers and bilges, notwithstanding the bilges had been cleaned before the ship was placed in commission.

No doubt these chips were washed down from between the timbers and it is highly probable that the intensely disagreeable stench from the bilges which came through the openings into the officers' rooms, in the early part of the cruise, arose from the decay of these shavings and chips. Forward of the boilers there is a water tight bulk head, which is provided with sliding gates. These gates are raised, and the bilge of the fore hole is washed semi-weekly, the water flowing into the fire-room bilges, which is pumped dry, scraped and whitewashed.

The regulation inspection of the bilges of a ship upon going into commission has not in all cases been satisfactory, and unless some precaution be taken during the building of our vessels, we may expect to have stinking bilges for the first three months of the cruise.

#### FIRE PUMPS.

The two auxiliary steam pumps discharge, each, into a vertical copper pipe which has a hose coupling on the spar, gun and berth decks and in the engine rooms, making an aggregate of eight connections for hose.

These hose are of the regulation size, and the muzzles are 1" inch in diameter of opening. There are three hand pumps on the berth deck, which are used at fire quarters and are used also, for washing decks when the ship is not under steam. These pumps, which were built at the New York Yard, do most excellent service. There are nine pumps of the "Rogers" patent situated in different parts of the ship, all of which are deficient, and six of them have already been condemned by survey. There is one point which I observed in the French ship "Richelieu," which I will take the liberty of mentioning. At the forward end of the fireroom, and recessed into the forward coal bunker, there is a large niche containing troughs in which the firemen wash. A grating forms the floor and under it there is a tank for receiving the soapy water. An opening from the bottom of this tank to the suction side of a donkey pump, permits it to be emptied without the necessity of the soapy water going into the bilge. A shower bath is also here provided for these men. It appears to me that this is a valuable improvement and that the space occupied by this wash room might be slightly enlarged to accommodate a steam fire engine. As it requires two hours, under favorable circumstances, to raise steam in the main boilers, and with the inadequate deck pumps that are supplied, a steam fire engine of such size that it could be carried in the launch, would be valuable, not only to the ship carrying it, but to other shipping in the harbor. For use on board, the machine need be brought only to the middle of the fire room, where its gases would be discharged into the main smoke pipe, while its discharge could be coupled to the vertical hose pipe already described, and its suction to couplings that could be easily improvised.

#### LENGTH OF VOYAGE.

On examination of the steam log book for the quarter ending June 30th, 1877, we find that there were six hours during which the ship's steaming was not influenced by wind or sea. This occurred during the run from Gibraltar to Villefranche. The length of voyage depends directly upon the economic performance of the machinery and weight of combustible carried in the bunkers.

This six hours run furnished all the data that I have for estimating the distance the vessel can steam. When working at high powers the engine works more economically than at low powers. What the exact difference will be, I am, of course, unable to say, but from the performance of other engines, the data of which are in my possession, I have estimated this rate.



The power is estimated to vary as the cube of the speed, and is calculated from the six hours performance, with half boiler power, the record of which run is as follows :

## PERFORMANCE OF THE ENGINE.

Number of hours,	6
Mean speed in geographical miles per hour,	11.44
Mean pressure in the boilers in pounds above the atmosphere,	64.
Mean pressure in the receiver in pounds above zero,	18.84
Mean number of revolutions of the engine per minute,	43.6
Mean vacuum in the condenser in inches of mercury,	20.
Mean number of holes of the throttle open,	2.
Distance travelled by the pistons in inches when the steam was cut off,	{ High pressure, 21. Low pressure, 30.
TEMPERATURES IN DEG. FAHR.	{ Engine room, . . . . . 77.
	{ External atmosphere, . . . . . 65.
	{ Injection water, . . . . . 62.
	{ Discharge water, . . . . . 113.
	{ Feed water, . . . . . 127.
DRAUGHT OF WATER.	{ Forward, . . . . . 19 ft. 7 in.
	{ Aft, . . . . . 21 ft. 5 in.
	{ Mean, . . . . . 20 ft. 6 in.
Mean number of pounds of coal consumed per hour,	2773
Indicated horse power developed by the engine,	1300
Mean number of pounds of coal per I. H. P. per hour,	2.133

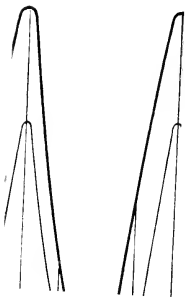
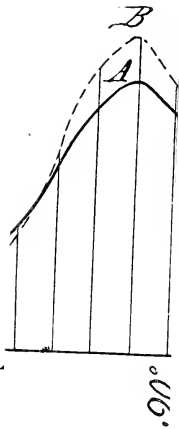
The bunkers can be stowed with 316 tons of coal and  $\frac{316 \times 2240}{2773} = 256$  hours, or  $10\frac{2}{3}$  days, or 2929 nautical miles at the rate of speed above recorded.

## LENGTH OF VOYAGE AT DIFFERENT SPEEDS.

Speed in geographical miles per hour.	Pounds of coal per I. H. P. per hour.	Indicated horse power devel'p'd by the engine.	Total no. of hours steam-ing.	Total no. of days steam-ing.	To'l steam-ing dis. in geographical miles.
14.50	2,000	2,647	133	5.54	1,928
14.00	2,000	2,383	148	6.16	2,072
12.50	2,000	1,695	209	8.71	2,611
11.44	2,133	1,300	256	10.66	2,929
10.50	2,250	1,015	310	15.40	3,255
9.00	2,750	633	406	16.90	3,654
8.33	3,250	503	469	19.12	3,824

The vessel has been usually underlogged, and there is good reason to believe that the speed of 11.44 knots was attained fairly, during the period above referred to. The passage from Gibraltar to Villefranche was favorable, so far as weather is concerned, for whenever the wind blew at all it was favorable.

TIME.	Total time the engines were in operation in hours and minutes,	71-23
REVOLU- TIONS.	{ Total number, . . . . .	179759
	{ Mean number per minute, . . . . .	42.7
SPEED.	{ Total number of geographical miles per log-line,	765.5
	{ Total number of geographical miles per chart,	806.0
	{ Mean num'r of geographical mls. per hour, per log-line,	10.8
	{ Mean number of geographical mls. per hour, per chart,	11.29
COAL.	{ Total number of tons of coal consumed,	89 $\frac{1710}{2240}$
	{ Mean number of pounds of coal consumed per hour,	2970
DRAUGHT.	Mean draught of water for the run, in feet and inches,	20-5



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Fig. 1.

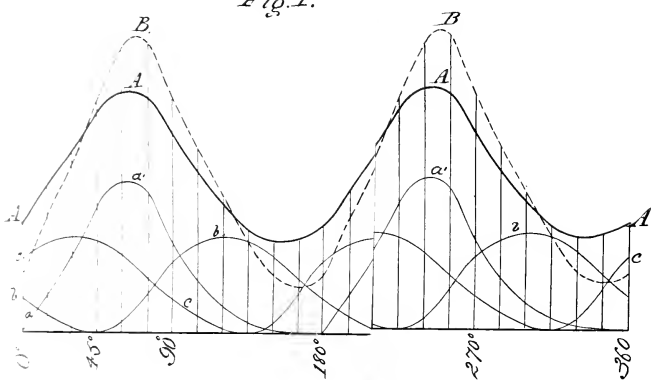


Fig. 2.

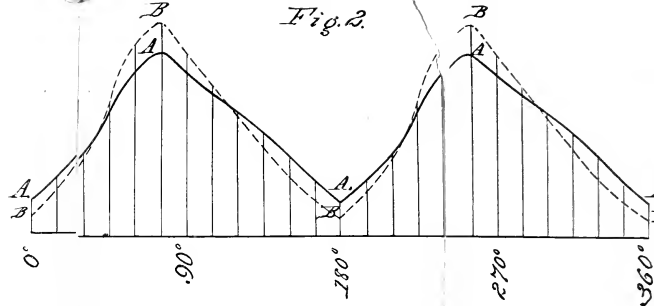


Fig. 3.

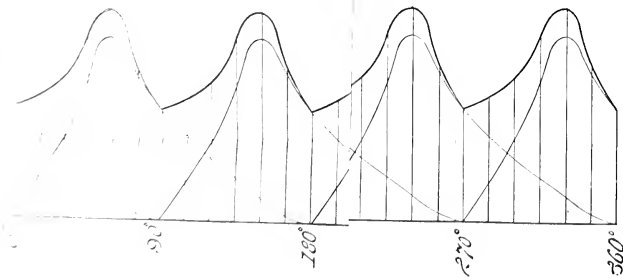
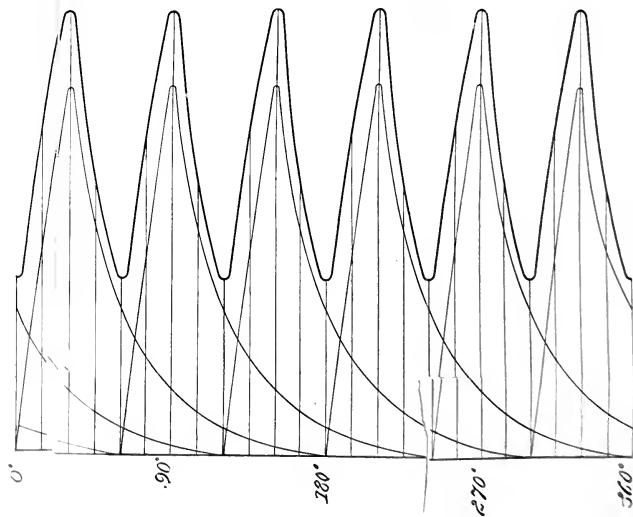


Fig. 4.



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# THE RECORD.

OF THE

## UNITED STATES NAVAL INSTITUTE.

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Vol. IV.

1877.

No. 2.

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U. S. NAVAL ACADEMY, ANNAPOLIS,

NOVEMBER 8, 1877.

Commander W. T. SAMPSON in the Chair.

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AN EXPERIMENTAL LECTURE.

UPON THE

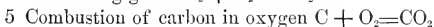
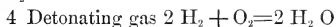
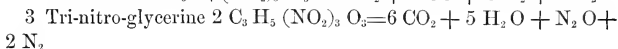
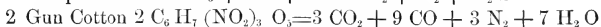
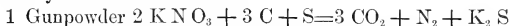
CAUSES OF AND CONDITIONS WHICH PROMOTE  
EXPLOSIONS.

BY CHAS. E. MUNROE, PROF. OF CHEMISTRY, U. S. N. A.

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In treating of the subject of explosion I shall deal only with those explosive bodies which are in general use as projectile or blasting agents and whose explosive properties result from the re-arranging of their constituent atoms.

To learn the nature of the changes which take place during an explosion it is necessary that we should know the composition of the explosive body and of the products of the explosions. The apparatus used in determining these facts is so elaborate and the analytical processes occupy so long a time that it is impossible for me to undertake them before you but I have brought together these facts in the diagram before you which is as follows :



As gunpowder is a mechanical mixture the relative proportions of the nitre, charcoal and sulphur in the mixture may of course vary to almost any extent, but the above formula closely represents the compo-

sition of the U. S. Regulation powder. There has been considerable discussion as to the composition of gun cotton, but the formula given in the diagram is the one which is accepted by Abel in his paper (Researches on Gun Cotton, Phil. Trans. Vol. 156, pg. 269), and which will I believe find general acceptance among chemists. The formula given for tri-nitro-glycerine is undisputed.

When, however, we come to consider the products of the explosion we find great difficulty in arriving at any exact knowledge of their composition. If we alter the conditions of temperature or pressure under which a chemical change takes place we alter materially the character of the resulting products and hence it is obvious to any one that the substances that will be produced when an explosive is burned under great pressure in a gun will differ very much from those which will be formed when it is burned in an open tube or only under such slight pressure as obtains generally in laboratory experiments. Especially is this so with gunpowder, for from a complex mixture much more complex products must result. We have but to examine the experimental results obtained by Bunsen & Schischkoff, by Karolyi and several others, but especially those obtained by Noble and Abel in their elaborate and exact Researches on Fired Gunpowder, (Phil. Trans. Vol. 165, pg. 49.) to learn how very complex and variable these products are. So complex are they that it is well-nigh, if not quite, impossible to formulate them.

Granting then that the formulæ for the products given in the diagram do not ever represent what takes place in practice, they do represent what would result if certain theoretical conditions obtained, and these conditions have been secured for gun-cotton and nitro-glycerine, and they answer our purpose in showing the principal and most efficient substances that are present in the products of every explosion of the bodies we are studying.

Accepting then these formulæ as representing approximately what takes place, let us inspect them and our attention is called to the fact that in every case we have carbon and oxygen present in the explosive and a compound of carbon and oxygen ( $\text{CO}_2$ ) resulting from each explosion. These are the substances which we employ in our ordinary processes of combustion and the products of the processes are similar compounds of carbon and oxygen. Let us expose one of our explosive agents freely in the open air and ignite it, and it will exhibit all the phenomena of the combustion of charcoal, only more markedly. Hence it is probable that from a study of the phenomena of combustion under such conditions that we may be able to control their operation, we may



gain some insight into the cause of the explosion and the source of the energy of these explosive bodies.

I will perform the well known experiment of burning charcoal in oxygen. You now observe how much more readily the charcoal burns and how much more brightly it glows than when burned as usual in the open air. The change that is going on is identical with what takes place when the charcoal is burned in a grate, but whereas in this last case the oxygen comes to it diluted with four parts of inert nitrogen, in the experiment we are witnessing the charcoal is in contact with oxygen only. The chemical change is represented in reaction (5) on the diagram.

As we witness this experiment this question naturally arises; what is the cause of this manifestation of energy? The experiment shows that when ignited carbon is brought in contact with oxygen combustion takes place, but how is the development of heat and light accounted for?

The doctrine of the conservation of energy teaches us that whenever motion is arrested the energy of the moving mass is not lost, but is converted into some other form of energy. When we bore a piece of iron, friction arrests the motion of the bit, but the mechanical energy of the bit is converted into heat and the bit becomes warm. When a ball is fired against a target which it cannot penetrate, its motion of translation is arrested but the mechanical energy of the mass is converted into molecular energy and the ball becomes heated. If it is moving with a high velocity at the time of impact its temperature may become so high that the shot will glow and be fused. So if we place a nail upon an anvil and strike it with a hammer we are able to heat the nail by the conversion of the mechanical energy of the falling hammer into the energy of heat, and the greater the energy of the blows which fall upon the nail, and the greater the number of the blows which fall in a given time, the higher will be the temperature of the nail. Since the mass of the nail cannot be moved its molecules are set in motion thus producing the phenomena of heat, and the more rapid these molecular motions are, and the greater the distance over which the molecules move the more intense will be this manifestation of energy and the higher will the temperature produced be.

We see from these examples that when the molecules of a body are set in rapid motion heat is produced, and that when the motion of a body is arrested it communicates its motion to the body against which it strikes and causes either the body struck or its molecules to move.

Keeping these principles in mind let us return to the combustion of the charcoal in the jar of oxygen. When we introduced the charcoal into the jar it was heated up to such a point that it could combine with the oxygen.

As the oxygen was in a gaseous state its molecules had great freedom of motion and hence could come in sufficiently close contact with the molecules on the surface of the charcoal, to be influenced by the force of chemical attraction. Urged on by the force of chemical attraction the atoms in these molecules rushed against each other in order to unite and as these motions were arrested by impact heat was produced. As these sub-divisions of matter were very small the energy of any one was insignificant but they were myriad in number, and as they were moving with a very high velocity the sum of their energies was very great and was sufficient to produce the intense heat and light emitted by the charcoal.

This explanation is, of course, largely hypothetical, but if it be at all a true one, it follows that if we can increase the number of blows delivered in a given time against a mass of charcoal we shall be able to increase the velocity of the motion of the molecules of the charcoal and hence raise their temperature, and consequently the manifestation of energy will be more intense. The most obvious way to do this is by increasing the surface of the charcoal and this can easily be done by powdering it. When we now throw this glowing powdered charcoal into the oxygen gas we have a vivid combustion which is much more brilliant and much more intense than in the first experiment.

In the ordinary process of combustion we observe that the different substances used ignite at different temperatures. Thus phosphorus we know is heated up to the point of ignition by simple friction, sulphur burns at a higher temperature, soft wood still higher, charcoal next and then hard coal, and we make use of all these, in the order given, in building fires, for we cover a piece of dry, soft wood with sulphur and tip this with phosphorus. Then by friction the phosphorus is ignited, this fires the sulphur, this heats the wood so it burns, then the paper or shavings are lighted, next the charcoal and finally the anthracite. We can show this difference in the ignition point by placing a piece of phosphorus one of sulphur and one of wood upon an iron plate and putting a lamp beneath. In a short time the phosphorus takes fire, after some time the sulphur, and the wood does not burn at all.

Since phosphorus burns so readily we may expect it to unite very

readily when exposed to pure oxygen. When the experiment is performed you see how rapidly the union takes place and how brilliant the experiment is. If we subdivide the phosphorus or increase its surface it combines even more readily with oxygen, so readily indeed that it will take fire in the open air without the aid of friction, simply by the heat generated by the condensation of the oxygen in the interstices between the particles. This experiment is performed by dissolving the phosphorus in bisulphide of carbon. A piece of bibulous paper is moistened with the solution and exposed to the air. The bisulphide evaporates and leaves the phosphorus distributed in a finely divided thin layer, quite over the surface of the paper. The oxygen unites with phosphorus and owing to the large surface of the phosphorus this union goes on very rapidly and the heat generated raises the uncombined phosphorus to its point of ignition and it takes fire.

I wish to call your attention to but one other instance of this kind, viz. the union of hydrogen with oxygen. Hydrogen is as you see by the diagram one of the constituents of both gun cotton and nitro-glycerine and a compound of hydrogen and oxygen is found in the products of the explosion. As they are both gases I will cause them to unite by igniting them at this jet. Since they are both gases we should expect the mixture to be very intimate and the energy developed in a given time to be greater than if one was a solid or liquid. That the energy developed is very great is shown by placing a file in the flame when we see that it is rapidly burnt, or by turning it against a piece of lime when we see that the lime becomes so highly heated as to emit an intense white light. That the gases are *intimately* mixed is shown by blowing soap bubbles with a mixture of the gases and touching these bubbles with a lighted taper. They combine instantly throughout their whole volume and an explosion is the result. The chemical change is represented in reaction (4) on the diagram.

We have seen that in all these cases intense energy is developed and I have explained that this is due to the impact of the atoms against each other and have compared them to the impact of a shot against a target or a hammer against a nail resting on an anvil. But you may ask how do these atoms acquire their energy of motion? We have seen that the shot acquires its energy from the energy of the explosive with which the gun was charged, and we have seen that the hammer acquires its energy from the arm of the man that wields it, whence then is the source of the energy of these atoms? My answer is that their energy is due to the force of chemical attraction and their energy

is acquired by being separated from each other just as a weight acquires its energy by being raised from the earth against the attraction of gravitation. Take the case of the union of the carbon with oxygen. The product is a compound of the two, known as carbonic acid gas. This exists in the air and when it comes in contact with the leaves of plants in the presence of the sun's rays it is decomposed; the carbon is stored up in the plant and oxygen is given off to the air. To effect this decomposition just as much energy is employed as is developed in the union of this carbon with the same amount of oxygen and this energy came from the sun. And we may consider that the heat and light emitted by the piece of carbon we burnt to-night was the heat and light of the sun, for the separation of this carbon and oxygen was effected by the sun's agency. Just as a weight in falling will do as much and no more work than was required to raise it, so the atoms of our elements in combining will generate as much and no more energy than is required to tear them apart. But we have seen that more energy is developed when oxygen combines with hydrogen than when it combines with carbon. Chemical affinity is in this respect unlike the attraction of gravitation, for, whereas in the latter the attractive force is proportional to the masses attracted, in chemical affinity the attraction varies with the *kind of matter* between which the attraction takes place. Therefore since the attraction between hydrogen and oxygen is greater than between carbon and oxygen more energy is required to separate the first two, and when they combine more energy is developed. Hence, when comparing two explosive bodies which are under the same conditions and in the same state, that one will develop the greatest energy which contains the largest amount of hydrogen together with sufficient oxygen to completely burn it, provided also there is sufficient oxygen to unite completely with the other combustible substances present.

Let us now turn our attention to some of the means by which combustion may be induced. We have seen that carbon burns by union with oxygen and that this union goes on most readily when the oxygen is pure and when the contact between the two is quite intimate. I have here the substance from which our oxygen was produced, potassic chlorate. We have simply to heat it and it gives off its oxygen readily. If we now powder some of this and mix it thoroughly with powdered charcoal and heat them on a glowing metal plate, we see that the charcoal burns very readily. Why? because the potassic chlorate furnishes it with a supply of pure oxygen. Let us make another mixture of the same but adding to it some powdered sulphur. When this is

heated, we observe that it takes fire at a lower temperature and burns more rapidly. Why? because the sulphur has a lower point of ignition, as shown in a former experiment, than the other substances in the mixture and when it ignites it rapidly heats the others to their point of ignition and fires them. We have in this mixture a type of the usual explosive mixtures. Compare it with the gunpowder on the diagram and we see that it differs from the gunpowder only in containing potassic chlorate in the place of potassic nitrate. But the potassic nitrate serves the same purpose in the gunpowder as the potassic chlorate in our mixture, it yields oxygen when heated though not so readily or at so low a temperature as the potassic chlorate does. With such a mixture as this we can produce a combustion without requiring the presence of the oxygen of the air, and hence we can burn such a mixture in a confined space such as the chamber of a gun or a hole in a rock. Indeed some of these mixtures will burn when submerged under water and when in direct contact with the water. All that we have to do is to liberate the oxygen from its state of combination by suitable means and the combustion is effected at once. This may be shown as follows. A few crystals of potassic chlorate are placed in this glass which contains water, some small pieces of phosphorus are then dropped upon the potassic chlorate and finally strong sulphuric acid is added to it. By the union of a part of the acid with the water sufficient heat is developed to heat the phosphorus to its point of ignition, and by the action of the rest of the acid the potassic chlorate is decomposed and compounds of chlorine and oxygen are formed which readily yield their oxygen to the phosphorus and the vivid combustion which you witness ensues.

If now we again return to our diagram we shall see that what is true of the potassic chlorate mixture and of the gunpowder is true of all the others, they contain sufficient oxygen to combine with the carbon or hydrogen which they contain and to form oxygen compounds of these substances, hence they too will burn when confined if we only employ some means to effect their decomposition. The energy developed by the combustion of the carbon and hydrogen under these circumstances will be even greater than when burned to the same degree in pure oxygen gas because the elements are in a nascent state. We mean by the nascent state the condition of the atoms when just liberated from a state of combination. They then possess their greatest energy of chemical separation, and they exert the entire power of chemical attraction which they possess. For we believe that when we brought the hydrogen and

oxygen together in their free state the atoms of the hydrogen were united with a certain force with each other and so likewise the atoms of the oxygen were united with one another and before the hydrogen and oxygen atoms could combine a certain amount of energy was employed in separating these elementary atoms from each other, but at the moment when the hydrogen and oxygen are separated from the compounds of which they form a part the atoms exist independently and are in their freest state and are very ready to enter into combination. Hence when they unite the energy developed is the greatest which is possible in the formation of the new compound.

The violence of the explosion of one of these substances depends upon various circumstances. The most important of these are the manner in which the decomposition is effected, the degree of confinement, the readiness with which decomposition takes place, and the character of the product.

The most common way of effecting the explosion of a substance is by flame or a spark, or by contact with a heated surface. Heat is in all these cases the agent which causes the decomposition and liberates the atoms. Another method is in vogue of employing some chemical substance which will decompose the compound in the mixture which contains the oxygen. Sufficient heat is thus generated to raise the phosphorus, carbon or other substance of a similar nature in the mixture to its point of ignition and at the same time the oxygen is liberated in such a form that it may combine with them. We produced combustion in this way when we burned phosphorus under water. In the Harvey torpedo the fuse consists of a mixture of potassic chlorate and sugar ( $C_{12}H_{22}O_{11}$ ). A bottle containing strong sulphuric acid is placed in contact with this mixture. By a suitable contrivance when any object such as a ship, comes in contact with the torpedo the bottle is broken and the acid runs out and decomposes the potassic chlorate, thus liberating its oxygen which then combines with the carbon of the sugar and an explosion results. I have here such a mixture and we see the result of adding the sulphuric acid.

Still another method of producing explosion is by a blow. The percussion cap, which is charged with mercuric fulminate, is exploded in this way. I have here some crystals of potassic chlorate and I will put with them a small piece of phosphorus, wrap them in paper and place them on the anvil. When the paper is struck we have a sharp explosion. The agent which caused this becomes evident. It is again heat, heat caused by the impact of the hammer on the anvil,

heat resulting from the conversion of the mechanical energy of the arm into molecular energy. Nitro-glycerine and gun cotton may be exploded in this way.

In the case of the explosion of the priming of a percussion cap still another cause may operate; for we find that if we touch dry mercuric fulminate in the slightest it will explode, and the same is true of argentic fulminate and nitrogen iodide. This may be due to the heat generated by friction.

When the bodies which are decomposed by a blow or by friction explode, the explosion of the whole is apparently simultaneous. Such complete and instantaneous explosions are called detonations.

Abel (in a paper which will be referred to again) speaks of these detonations as follows, "The readiness and certainty with which gunpowder, gun cotton, and nitro-glycerine and other explosive substances may be detonated through the agency of a blow from a hammer or falling body are regulated by several circumstances; they are in direct proportion to the weight of the falling body, to the height of its fall, or the force with which it is impelled downwards, to the velocity of its motion, to the mass and rigidity or hardness of the support or anvil upon which the body falls; to the quantity and mechanical condition of the explosive agent struck and to the ready explosibility of the latter. Thus a sharp blow from a small hammer upon an iron surface will detonate gunpowder with very much greater certainty than the simple fall of a heavy hammer or a comparatively weak blow from the latter. It is very difficult by repeated blows, applied at very brief intervals, to ignite gun-cotton, if placed upon a support of wood or lead, both of which materials yield to the blow, the force set in operation by that blow being transferred through the explosive agent and absorbed in work done upon the material composing the support. If, however, the latter be of iron, which does not yield permanently to the blow of the hammer, the detonation of these substances is readily accomplished. If the quantity of the explosive agent employed be so considerable as to form a thick layer between the hammer and support, the force applied appears to be to so great an extent absorbed in the motion imparted to the particles of the compressible mass, that its explosion is not readily accomplished; and if the material be in a loose or porous condition (as e. g. in a state of powder or loose wool) much work has to be accomplished in moving particles of the mass through a comparatively considerable space and a second or third blow is therefore required to determine explosion.

These circumstances would appear to afford support for a belief that the detonation of an explosive material through the agency of a blow is the result of the development of heat sufficient to establish energetic chemical change, by the expenditure of force in the compression of the material or by the friction of the particles against each other, consequent upon a motion being momentarily imparted to them. It is conceivable that, from either of these causes, sufficient heat may be accumulated, with almost instantaneous rapidity, in some portions of the mass struck, to develop sudden chemical change."

A peculiarity of the explosion of such substances is that by detonating one portion of the substances the explosion may be communicated to another portion which is near to it. To avoid igniting the second portion by ignited particles of the first being projected against it, it may be separated in the experiment by a glass plate. Since there is apparently no source of heat present in this case to cause the decomposition of the body, what is the agent which produces the explosion of the second portion? Abel (Phil. Trans. Vol. 159, 489) investigated very thoroughly the subject of detonation and obtained some very interesting results. He showed that not only would a detonating body cause the detonation of another mass of the same body but that it would cause also the detonation of other explosive bodies. For instance, by detonating mercuric fulminate in contact with gun cotton or nitro-glycerine these bodies were also readily detonated. Only a small quantity of the fulminate was required, .32 of a gram (5 grains) when confined in a sheet metal cap and placed in direct contact with the nitro-glycerine or compressed gun-cotton being sufficient to cause the detonation of the latter. He found that a mass of nitro-glycerine by its explosion would cause the explosion of another mass of nitro-glycerine even though both were immersed in water. His experiment further showed that a peculiar kind of detonation was required in order to cause the detonation of an explosive. For instance, while the detonation of gun cotton would cause the detonation of nitro-glycerine in close proximity to it, the detonation of nitro-glycerine would not cause the detonation of gun-cotton. This shows that this property of causing detonation does not depend alone upon the violence of the detonation, for we all know that nitro-glycerine is much more powerful than gun-cotton. Again argentic fulminate which explodes more violently and sharper than mercuric fulminate is no more efficient in producing the detonation of nitro-glycerine or gun cotton than mercuric fulminate, and nitrogen iodide and nitrogen chloride which are the most



violent explosives we possess are very much less efficient in causing-detonation than mercuric fulminate. In the course of his investigations Abel was led to the conclusion "that a particular explosion or detonation may possess a power of determining at the instant of its occurrence similar violent explosions in distinct masses of the same material, or in contiguous explosive bodies of other kinds, which power is independent of or auxiliary to, the direct operation of mechanical force developed by that explosion; that as a particular musical vibration will establish synchronous vibrations in particular bodies while it will not affect others, and as a chemical change may be wrought in a body by its interception of only particular waves of light, so some kind of explosions or powerful vibratory impulses may exert a disturbing influence over the chemical equilibrium of certain bodies, resulting in their sudden disintegration which other explosions, that develop equal or greater mechanical force, are powerless to exercise.

I venture to offer the following as being the most satisfactory explanation of the remarkable differences pointed out. The vibrations produced by a particular explosion, if synchronous with those which would result from the explosion of a neighboring substance which is in a state of high chemical tension, will, by their tendency to develop those vibrations, either determine the explosion of that substance, or at any rate greatly aid the disturbing effect of mechanical force suddenly applied, while, in the case of another explosion which produces vibrations of a different character, the mechanical force applied by its agency has to operate with little or no aid; greater force, or a more powerful detonation must, therefore, be applied in the latter instance, if the explosion of the same substance is to be accomplished."

That vibrations will induce the decomposition of chemical compounds whose atoms are in a state of unstable equilibrium is a well recognized fact in science, and numerous instances can be cited where advantage is taken of this fact to induce chemical change. The effects of the vibrations which produce heat are too well known to need illustration here. The most marked instances of the action of the vibrations which produce light are the decomposition of the silver salts on the photographic plate, and the decomposition of carbonic acid gas in cells of leaves. The vibrations which produce electricity will cause the decomposition of chemical compounds, as is seen in the process of electroplating, etc. Why, then, should not the vibrations which produce sound be also capable of inducing chemical change?

The condition of a compound whose atoms are in a state of unstable

equilibrium, is probably somewhat similar to that of a Prince Rupert's drop, in which the molecules are in a state of unstable equilibrium. Separate but the smallest bit from the end of the drop, and the whole drop flies to pieces, as you see. So with a chemical compound, if by means of vibrations we can increase the amplitude of the vibration of any of its atoms, so that the force of chemical attraction is overcome, the molecule breaks up with violence; and in explosive bodies this violence is increased by the character of the compounds which are formed by the re-arrangement of the atoms.

Abel's theory was examined experimentally by Champion and Pellet (*Compt. rendus*, lxxv. 110). They took a tube seven meters long, made in two lengths, and joined by a paper band. Small quantities of nitrogen iodide were placed in each end, and when one was exploded it immediately caused the explosion of the iodide at the other end. But if the paper band connecting the two lengths was removed, this result was not produced. By a suitable apparatus it was shown that the effect produced was not due to the action of a puff of air, but to vibrations of the air such as are caused by a sounding body. When they attached nitrogen iodide to the strings of a double-bass, and bowed the strings, the iodide exploded when placed on the string giving the highest note, but not when on the two lower strings. The lowest number of vibrations which would cause explosion was found to be thirty per second. Similar results were obtained with other musical instruments.

A further set of experiments was made to determine the difference between the vibratory motion excited by various detonants, and thus to account for the difference in their power of causing, by means of the intervening air, the explosion of other detonants placed at a distance. A series of sensitive flames was arranged corresponding with the complete scale of *g* major and 0, 03 gm. of mercuric fulminate and, nitrogen iodide were exploded near them. The nitrogen iodide produced no effect; but the mercuric fulminate excited the flames *a*, *c*, *e*, *f* and *g*. This showed that the vibrations excited by the two explosives were very different; and also that the vibrations excited by the mercuric fulminate act on flames belonging to some notes of the scale, to the exclusion of others. On exploding these bodies nearer the flames than in the former experiment, while the nitrogen iodide excited only flames corresponding with the higher notes of the scale, the mercuric fulminate affected all of them. On exploding 20 grms. of nitrogen iodide near the flames, it excited all of them. In these experiments it was observed that acute sounds predominate in explosions.

Abel (*Proc. Roy. Soc.* xxii. 160), continued these investigations on the transmission of detonation by means of tubes—using explosive agents which were less highly susceptible; such as gun-cotton, dynamite, etc., and the results tended to confirm his theory.

The second condition governing the violence of an explosion, to which I have referred, is the degree of confinement. Abel, in the paper cited, (*Phil. Trans.*, vol. 159, 489), shows this by numerous experiments. In these he found that .32 grains of mercuric fulminate, when confined in a sheet metal cap, will do the work as a detonator which it requires 2 grm. of the unconfined mercuric fulminate to do.

The readiness with which a body may be decomposed depends upon various circumstances. If we apply fire to gun-cotton in a mass, as it is a poor conductor, heat enough may be stored up in one portion of the cotton to cause its explosion, while with gun powder, on the contrary, the heat is conducted through the mass, and the heating body is cooled down; hence the temperature of the igniting body must be greater for gun powder than for gun-cotton. I can show this in the following way: In this cup I place some gunpowder. A fine platinum wire is passed through it, and it is heated by the current from a battery. Now the wire begins to glow; but where it is in contact with the powder it is cooled down on account of the heat being conducted away. Let me now drop in a piece of gun-cotton, and it at once ignites and fires the powder.

We have learned what the general character of the constituents of our explosives is, and we have seen how they can be exploded and by what means the violence of the explosion may be controlled. The next point to be considered is the manner in which the energy developed by the explosion is communicated to the projectile or to the body which is to be moved. Our first experiments taught us that when carbon and hydrogen unite with oxygen the products are gaseous. The nitrogen in these explosives is also liberated in the gaseous state, either as free nitrogen or combined with oxygen. It is a distinguishing property of gases that they exert pressure in every direction and this property is explained by the theory that the molecules, of which they are composed, are constantly moving at a high velocity and that the pressure which the gas exerts is due to the impact of these molecules against the walls of the chamber in which they are held. We daily meet with numerous examples of the effect of this molecular motion and we can show that the gases formed by the combustion of the powder exerts a similar pressure, by the aid of a simple apparatus sim-

ilar to that used for showing the pressure exerted by steam. A mercury gauge is fitted to the top of a stout iron cylinder. Through another opening in the top a gram of powder is passed and then the opening is closed tightly by a plug. The wires from a battery pass through this plug and connect with a fine platinum wire passing through the powder. The apparatus is now exhausted and you will observe the level of the mercury in the gauge. Now we connect the battery and fire the powder and we see the mercury rapidly rising in the gauge thus proving that pressure is exerted by the gaseous products. If any part of this vessel were movable of course it would be forced aside, for the molecules would move in the direction of the least resistance, and if they came in contact with a movable body they would impart their motion to this body just as one billiard ball imparts motion to another. When the volume of a gas is constant the pressure is proportional to the density, therefore the greater the quantity of gas developed by the explosion of the same quantities of different explosives, in the same space, the greater the explosive effects.

There is another property of gases which comes into play here also and that is the property of augmenting their pressure when heated, if they are confined. The heat increases the velocity of the molecules and consequently a greater number of blows is delivered upon the same surface during the same time when the gas is heated than when it is at the lower temperature. Hence we find that not only does the force developed by an explosive depend upon its condition, i. e. whether a mechanical mixture or chemical compound, but also upon the number, kind, and arrangement of the atoms in the explosive and the character of the products of the explosion. From the observations already made we should conclude that of two explosives that one would be the most powerful in which the atoms, which are united in the product, are most widely separated from each other and in which the combustion is most complete, for under these circumstances the greater amount of heat would be developed and consequently the products would exert the greater pressure.

I hoped to be able to develop this part of the subject much more fully but I find that I have already occupied more of your time than I am entitled to and I must rest here.

To sum up, then, we learn that an explosion is an instance of chemical decomposition wherein the constituent atoms of a solid or liquid substance re-arrange themselves and yield products which are gaseous and which occupy a very much larger volume than the explosive substance ;

that all useful explosives are mechanical mixtures or chemical compounds containing carbon, hydrogen and oxygen, and that they owe their energy to the fact that by the union of the carbon and the hydrogen with the oxygen, gaseous products are formed which exert pressure and are capable of doing work, and to the fact also that by this union of the elements the potential energy of chemical separation becomes kinetic and, heat being developed, it very much increases the energy of the resulting gases. We learn also that the work which an explosive is capable of doing depends upon the kind of atoms composing it, upon the intimacy of their contact, upon the ease with which the decomposition can be effected, and upon the manner in which it is induced.



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Rear-Admiral C. R. P. RODGERS in the Chair.

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DEEP SEA SOUNDING.

BY LIEUTENANT-COMMANDER THEODORE F. JEWELL, U. S. N.

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MR. PRESIDENT, GENTLEMEN :

It is within the last thirty years only that any material addition has been made to our information as to what lies beneath the surface of the sea. For centuries men had speculated as to the depth of the ocean, but so far as accurate knowledge is concerned, they were completely ignorant. It was long held for instance, that analogy indicated that the deepest parts of the ocean were not deeper than the height of the highest mountains. But early experiments with long lines and heavy weights, seemed to show that the ocean's depths were unfathomable. Indeed, many exceedingly intelligent persons, among whom I may cite the late Vice-Admiral Fitzroy, of the Royal Navy,\* were of the opinion that a lead could not be made to sink to the bottom of the deepest seas, on account of the increased density of the water under the enormous pressure;—notwithstanding the fact that water had been shown, long before, to be practically incompressible. Irrational conceptions, such as this, of the difficulties attending deep-sea soundings seem to have prevented the accomplishment of much that, otherwise, might have been done. Yet Scoresby, writing in 1817 or 1818, recognizes clearly that the principal difficulty is the uncertain intimation given when the lead strikes the bottom; and he even suggests

\* Fitzroy—Voyages, Adventure & Beagle, Vol. II. p. 674.

that this could be remedied if some method could be devised for determining the tension of the sounding line throughout its descent.\* The earlier devices for sounding all involved the use of a heavy sinker, with a correspondingly large line, and while they answered very well in depths not exceeding a few hundred fathoms, beyond a thousand fathoms they were valueless. If a large line were used the sinker would not carry it rapidly and vertically downward, while a lighter line was incapable of drawing up its own weight along with that of the lead. With a large line no impulse was felt when the lead reached the bottom, and the line would go on running out by its own weight, coiling itself over the lead. Indeed this would happen with any line, and, in most cases, any attempt to check it was attended by its parting. The record of deep sea soundings previous to 1850 is consequently not only meagre, but entirely untrustworthy. It was but a natural sequence to such uncertainty that all sorts of devices should have been resorted to in order to dispense with the use of a line as a measuring instrument. The impregnation of wood by water under the greatly increased pressure was one of these devices, but it was found that the impregnation was practically complete at three hundred fathoms. Ericsson invented a lead in which air was compressed by the pressure of the water, and by the amount of compression the depth was to be estimated, but the instrument failed at great depths. Explosions were resorted to, the velocity of sound in water to be the means of measurement, but alike unsuccessfully.

But great strides have been made in the last thirty years in the development of deep-sea work, and instead of being unable to sound at all, we can now not only sound in deep water, but can do so with ease, certainty and astonishing rapidity. Among those to whom we owe this extraordinary advance, officers of our Navy stand in the foremost rank. I am, therefore, about to present a short and, necessarily, an imperfect account of the process of this development, confining myself generally to the achievements of our own countrymen.

In October, 1849, the schooner *Taney*, Lieut. J. C. Walsh commanding, sailed from New York equipped for deep sea research. Her arrangements for sounding seem to have been made with great care, but she was small and unseaworthy—a vessel of but one hundred tons, that could not keep at sea to complete her cruise. In this little vessel steel wire was first used as a sounding line. I do not know whether the idea of using wire was original with Walsh or not, but it

\* Scoresby—*Arctic Regions*, Vol. I, p. 189.



is interesting to note that this, the first attempt at the employment of this material with which the greatest feats of deep sounding have since been done, was by an American Naval officer.

The *Taney* was supplied with 14,300 fathoms of the "best English steel wire," in five sizes, No's 5, 7, 8, 10, and 13, Birmingham gauge. The wire was tested to one third more strain than it was estimated would be brought upon it. I give Walsh's language in describing how it was marked and prepared for use.\* "Of this an extent of 7,000 fathoms, weighing eighteen hundred lbs, (the remainder, consisting of the smaller sizes, No's 10 and 13, being stowed away as spare wire,) carefully measured and marked with small copper labels, was linked into one piece, and wound upon an iron cylinder 3 feet in length and 20 inches in diameter—the larger sizes being wound first so as to be uppermost in sounding. Two swivels were placed near the lead, and one at each thousand fathoms, to meet the danger of twisting off by the probable rotary motion in reeling up. The cylinder with the wire was fitted to a strong wooden frame, and machinery attached,—fly-wheel and pinions, to give power in reeling up. Four men at the cranks could reel up with ease, with the whole weight of the wire out. Iron friction bands, which proved of indispensable importance, were connected to regulate the running off the reel. One man, with his hand upon the lever of one of these friction bands, could preserve a uniform, safe velocity, checking or stopping the wire as required. The whole apparatus could be taken apart, and stowed away in pieces (being so large and massive, this was indispensable in so small a vessel as the *Taney*.) When wanted for use the frame was put together and secured to the deck by iron clamps and bolts, near amidships, the reel hoisted up from below and shipped in its place; a fair leader was secured to the taffrail, being a thick oak plank, rigged out five feet over the stern, having an iron pulley, 18 inches in diameter, fitted in its outer end, and two sheet iron fenders 3½ ft. long, of semicircular shape fitted under it to guard the wire from getting a short nip in the drifting of the vessel. The wire was led aft from the reel, over the pulley which traversed freely in the fair leader, and passed between the fenders into the water."

The first trial of this apparatus was made on Nov. 15th, 1849. The sinker used was a ten pound lead, and attached to the wire was an instrument, weighing six pounds, invented by Maury for recording the

\* Maury's *Sailing Directions*—5th Ed. p. 167, The diameters of wire (B. W. G.) were as follows: No. 5, 0.22 in., No. 7, 0.18 in., No. 8, 0.165 in., No. 10, 0.134 in., No. 13, 0.095 in.

depth descended by the sinker. The cast was made under the most favorable circumstances; the sea was smooth and there was hardly a breath of wind. The wire went down vertically, "preserving," says Walsh, "the exact plumb-line throughout the sounding." When fifty-seven hundred fathoms had run out, the wire broke at the reel, but from what cause we are not informed. It was probably owing to the imperfection of the method used in joining the different lengths of wire together.

Walsh considered that in this sounding he had proved that the depth of the ocean at the point where it was made (Lat.  $31^{\circ} 59'$  N. Long.  $58^{\circ} 43'$  W), about four hundred miles east of Bermuda, was not less than fifty-seven hundred fathoms. This depth was marked upon the chart with the sign of "no bottom." After a few years, however, Maury caused the sounding to be marked "doubtful," and finally in 1857 it was erased from the chart. Walsh's mistake was in using a sinker of too little weight for such large wire. A weight of sixteen pounds became insignificant in comparison with that of the wire (which in water was more than two hundred pounds to the thousand fathoms) when two or three thousand fathoms had run out, and consequently the shock when the sinker touched the bottom was inappreciable. The depth at the point where the sounding was made is between twenty-five hundred and twenty-eight hundred fathoms.

Several other unsuccessful attempts were made by the Taney to sound with the wire, but in every instance the wire broke when about two thousand fathoms had run out. This material was, therefore, deemed unfitted for the purpose and its employment was discontinued. Lt. M. F. Maury, who was very active in the study of the ocean at that time, came to the conclusion that no reliance was to be placed upon soundings made in great depths with wire. But the experiments of Walsh incited the Navy to new exertions. Sounding twine was substituted for wire; instructions for its use were prepared and issued, and a supply of twine furnished to every vessel in commission. This twine was of two sizes—the smaller was capable of supporting a weight of seventy pounds, the larger would bear one hundred and fifty pounds. Ten thousand fathoms of the small twine, and five thousand of the large was supplied to each ship. The sinkers to be used were one or more 32 pdr. shot. The smaller twine was to be employed in great depths where there was little probability of recovering the shot; the larger, when it was probable the sinker might be recovered.

Among the first to use the twine was the sloop-of-war Albany, Com-

mander Platt, which proceeded to sea in 1850. The officers of the ship entered heartily into the work, but the experiments were conducted under the direct supervision of the first Lieutenant, Wm. Rogers Taylor. The twine was wound upon a "delicately constructed reel which would turn with as little friction as possible." It was at first thought that this light line, weighing but a pound to 160 fathoms, would cease running out when the shot struck the bottom, or that it would, at least, move so much more slowly that the instant could be determined. This supposition was afterwards proved in error and consequently the first soundings, which, indeed, were little better than guesses by the feel of the line, were subsequently discredited. Many discouragements were encountered, but they persevered. The twine proved of bad quality breaking frequently when two or three hundred fathoms had run out, and we find recorded as lost in making one cast, as many as eleven shot. The line was overhauled fathom by fathom; weak portions were weeded out; and so at the end of six months they had made thirty-six casts. During this period the Albany expended forty thousand fathoms of twine, and in no instance where the depth exceeded one hundred fathoms was the shot recovered. In December 1851, the ship was supplied with new twine, which had been very carefully made. One thousand fathoms of this weighed  $8\frac{3}{4}$  pounds. It was overhauled as before, the lengths were reknotted and parts of it were waxed. Notwithstanding these precautions, the line continued to part, but still much good work was done, and the experience thus gained was of great value to those who were to follow. As a result of these soundings it was demonstrated that the line would not cease running out when the sinker touched the bottom and that the feel of the line was an uncertain indication as to whether the sinker was on the bottom or not. It was also found impossible to make a cast from the vessel in any except the calmest weather. It was shown that the waxed twine would go down more rapidly than when unwaxed; and it was found that the twine, although tested to 70 pounds, would not weigh a 32 pound shot, owing to weak places, and the frictional resistance of the water.

Near the close of the Albany's work Taylor adopted a suggestion of Maury's and noted the time of running out of each hundred fathoms. The result is remarkable as indicating for the first time a means of determining with some degree of accuracy the instant when the sinker touches the bottom. It was found that from the beginning of the cast the time of running out of each hundred fathoms gradually increased, so that if at any particular hundred fathoms the time interval was in-

creased more than its due proportion it was an indication that bottom had been reached. This was, probably, the most important fact developed by this cruise. So important did it seem to those interested in deep sea soundings at that time that the method was immediately adopted, and in nearly all, if not all subsequent casts it has been used. In the recent Challenger expedition it was the only method adopted for determining when the sinker was at bottom.\* The neglect in observing this time interval properly or the failure to interpret it correctly led Lieut. J. P. Parker of the Congress to report, in 1852, a sounding of eighty-three hundred fathoms; Capt. Denham of H. M. S. Herald, one of seven thousand, seven hundred six fathoms, the same year; and Berryman, in 1853, one of sixty-six hundred fathoms. Denham did observe the time of running out of each five hundred fathoms, but an examination of his record shows that the bottom was reached at between twenty-three hundred and twenty-eight hundred fathoms. Parker did not observe his time intervals regularly, nor did Berryman. Maury estimates that Parker reached bottom in about twenty-eight hundred fathoms, and Berryman was afterwards satisfied that his sounding was incorrect.

Such was the state of affairs when the first really successful deep sea sounding expedition was organized. This was in 1852, in the Brig Dolphin, under the command of Lieut. S. P. Lee. Profiting by the experience of the Albany, Lee caused his sounding twine to be carefully examined as it was received, and rejected thousands of fathoms. Notwithstanding his supervision, much of the line was still defective, and of the first seventeen casts made, only the last was successful. Lee soon repeated the experience of Walsh and Taylor—only in the smoothest states of the sea, and in calm weather could good casts be made from the vessel. He, therefore, adopted the expedient of sounding from a boat, which by means of an oar on either side could be kept over the line. By doubling his line for the first two or three hundred fathoms he prevented its carrying away, and after that there was little trouble in obtaining quite reliable casts. Lee always noted his time intervals, though he did not always correctly interpret them. With a heavy sinker and a light line the shock when bottom is reached can usually be detected by those experienced in the work if proper care be used. But this method is uncertain and the officers of the Dolphin were frequently led into error by adopting it.

The problem of deep sea soundings was so far solved. The depths

\* Naval Science—Vol. II. p. 410.

of the ocean could be determined at the expense of a 32 pound shot and a little inexpensive twine. The conditions necessary were a heavy, though not excessive, weight; a smooth, light line; some means of keeping the sounding vessel over the line; and an accurate record of the time required for running out of each fifty or one hundred fathoms.\* The soundings of the Dolphin under Lee, and his successor Berryman, are universally recognized as the first ever made in the deep sea with any degree of accuracy.

But the subject was not allowed to rest at this point. Hitherto when a cast had been made the line had been cut or parted, so that no specimen of the bottom had been brought to the surface from any great depth. In order that a more complete knowledge of the bottom of the sea could be obtained, some contrivance for bringing up

\* To show the absolute necessity of this last requirement, when rope is used, I subjoin a record of a cast made by Lee in Lat. 26° 32' N. Longitude, 60° 06' W., and reported by him as 3825 fathoms.

Time of descent of each 100 fathoms after the first 300 fathoms.

Depth.		Interval.		Depth.		Interval.		Depth.		Interval.	
Fathoms.	m.	s.	Fathoms.	m.	s.	Fathoms.	m.	s.	Fathoms.	m.	s.
400	1	41	1600	2	36	2800	3	08			
500	1	49	1700	2	43	2900	3	09			
600	1	51	1800	2	41	3000	3	10			
700	1	58	1900	2	44	3100	3	10			
800	2	02	2000	2	44	3200	3	10			
900	2	10	2100	2	46	3300	3	12			
1000	2	14	2200	2	51	3400	3	13			
1100	2	26	2300	2	53	3500	3	20			
1200	2	32	2400	2	59	3600	3	23			
1300	2	32	2500	3	07	3700	3	28			
1400	2	34	2600	3	07	3800	3	34			
1500	2	42	2700	3	08						

This table shows that the line ran out for the first twenty-four hundred fathoms at a gradually increasing rate. After the twenty-five hundred fathom mark passed out, the rate at which the line ran out remained almost constant for nearly a thousand fathoms. This indicates either that the under surface current was carrying the line out, or that the weight of the line was doing so. In my opinion bottom was reached at about twenty-five hundred fathoms. Soundings of the Challenger, made near the reported position of this cast, show from twenty-five hundred to twenty-eight hundred fathoms. It is about three hundred and thirty miles south and west from the position of Walsh's cast of fifty-seven hundred fathoms, and this circumstance may not have been without its influence in causing the error.

a sample of the soil became requisite. Heretofore this had been done only by weighing the sinker, to which some form of cup was attached, and, indeed, it had never been accomplished at depths exceeding a thousand fathoms.\* The sounding twine was not strong enough to weigh the shot, and some other device was necessary. At this stage, about 1854, Passed Mid'n Jno. M. Brooke appears with his apparatus, by which the shot could be detached when it reached the bottom, and the instrument with a specimen of the bottom could be lifted again to the surface. I need not describe this invention, every one present is familiar with it. With some modification of its original form it remains to this day the most successful instrument of the kind ever invented. With it Berryman obtained specimens from depths exceeding two thousand fathoms, and Belknap has repeatedly brought samples of the bottom from more than four thousand fathoms.

Brooke's invention gave a new impetus to the work of sounding. Equipped with this instrument Berryman again (in 1856) put to sea in the Arctic, and sounded all over the North Atlantic. One result of this cruise was the discovery of what has since been called "the telegraphic plateau." Berryman's soundings showed that between Newfoundland and Ireland, there existed a remarkably uniform depth of water not differing much from two thousand fathoms. As soon as this discovery was announced the project of connecting the two countries by a submarine telegraph cable was agitated. Berryman made twenty-four casts on a great circle between St. Johns and Valentia, with a view to determining the practicability of the scheme. He was followed, in 1857, by Capt. Dayman of the Royal Navy who in H. M. S. Cyclops went over the same ground, making thirty-four casts. Dayman used Brooke's detaching apparatus with Massey's sounding machine, by which the depth was recorded. Brooke's original invention had already been modified by Berryman, who replaced the shot by a long leaden cylinder† thus to diminish the resistance to the descent, and also adapted a valved-cup to the end of the sounding rod. Capt. Dayman made similar modifications, and in addition replaced the rope slings of Brooke's original device by wire ones which were more readily detached. Massey's sounding recorder was found to be useful as a check upon the soundings, but for some reason, difficult to explain, it is not a reliable instrument in deep water.

From the time of Berryman's soundings in the Arctic, the U. S. Na-

\* Wyville Thomson—*Depths of the Sea*, p. 210.

† Coast Survey Report. 1857.

vy took but little part in deep sea work, for several years. The English Navy, however, continued the work with great activity. Brooke's detaching arrangement was universally employed. Its use had gradually introduced the intervention of larger lines, but in 1860 we find H. M. S. Bulldog adopting the old plan of a cod line and an iron sinker, the line being cut at each cast. In this cruise, however, the soundings were usually repeated with a detaching sinker and larger line in order to obtain bottom specimens. Many efforts were made to invent a machine which would bring up larger bottom specimens, but the methods of sounding hardly varied. The use of steam rendered the lowering of boats unnecessary, as a steamer could be kept over the line when sounding. Small engines were also introduced for reeling in the line, thus diminishing greatly the labor of obtaining a cast.

The progress which had been made in deep sea sounding, in 1870, can best be indicated by a description of the process as practised on board the Porcupine in that year. This vessel, commanded by Staff-Commander Calver of the Royal Navy, was operating under the auspices of a committee of the Royal Society, with Prof. Wyville Thomson as scientific director. The following extract from Prof. Thomson's book, entitled "The Depths of the Sea," describing a cast made in two thousand four hundred and thirty-five fathoms presents the art of sounding in its most perfect development at that period.

"The 'Porcupine' was provided with an admirable double cylinder donkey-engine of twelve horse-power (nominal) placed on the deck amidships with a couple of surging drums. This little engine was the comfort of our lives; nothing could exceed the steadiness of its working and the ease with which its speed could be regulated. During the whole expedition it brought in, with the ordinary drum, the line, whether sounding line or dredge rope, with almost any weight, at a uniform rate of a foot per second. Sometimes we put on a small drum for very hard work, gaining thereby additional power at some expense of speed.

Two powerful derricks were rigged for sounding and dredging operations, one over the stern and one over the port bow. The bow derrick was the stronger and we usually found it the more convenient to dredge from. Sounding was most frequently carried on from the stern. Both derricks were provided with accumulators, accessory pieces of apparatus which we found of great value. The block through which the sounding-line or dredging-rope passed was not attached directly to the derrick, but to a rope which passed through an eye at the end of the

spar, and was fixed to a 'bitt' on the deck. On a bight of this rope, between the block and the bitt, an accumulator was lashed. This consists of thirty or forty or more of Hodge's vulcanized india-rubber springs fastened together at the two extremities, and kept free from one another by being passed through holes in two round wooden ends like the heads of churn staves. The loop of the rope is made long enough to permit the accumulator to stretch to double or treble its length, but it is arrested far within its breaking point. The accumulator is valuable in the first place as indicating roughly the amount of strain upon the line; and in order that it may do so with some degree of accuracy it is so arranged as to play along the derrick, which is graduated from trial to the number of cwts. of strain indicated by the greater or less extension of the accumulator; but its more important function is to take off the suddenness of the strain on the line when the vessel is pitching. The friction of one or two miles of cord in the water is so great as to prevent its yielding freely to a sudden jerk such as that given to the attached end when the vessel rises to a sea, and the line is apt to snap. A letting-go frame, a board with a slit through which the free end of the sounding machine passed, and which supported the weights while the instrument was being prepared, was fitted under the stern derrick. The sounding instrument was the 'Hydra' weighted with three hundred and thirty-six lbs. The sounding line was wound amidships just abaft the donkey engine on a large, strong reel, its revolutions commanded by a brake. The reel held about four thousand fathoms of medium No. 2 line of the best Italian hemp, the No. of threads, 18, the weight per hundred fathoms, 12 lbs, 8 oz., the circumference 0.8 inch, and the breaking strain, dry, one thousand four hundred and two lbs, soaked a day, one thousand two hundred and eleven lbs., marked for fifty, one hundred and one thousand fathoms.

The weather was remarkably clear and fine; the wind from north-west, force=4; the sea moderate, with a slight swell from the north-west. We were in Lat.  $47^{\circ} 38' N.$ , long.,  $12^{\circ} 08' W.$ , at the mouth of the Bay of Biscay. The sounding instrument, with two Miller-Casella thermometers and a water bottle attached a fathom or two above it, was cast off the letting-go frame at 2 h., 44 m., 20 s., p. m. The line was run off by hand from the reel and given to the weight as fast as it would take it, so that there might not be the slightest check or strain."

(Here follows a table showing the time of running out of each one hundred fathoms, the time intervals varying from 45 seconds for the first hundred to 1 m. 52 sec. for the last.)



“In this case,” continues Prof. Thomson, “the timing was only valuable as corroborating other evidence of the accuracy of the sounding, for even at this great depth, nearly three miles, the shock of the arrest of the weight at the bottom was distinctly perceptible to the commander, who passed the line through his hand during the descent. This was probably the deepest sounding which had been taken up to that time which was perfectly reliable. It was taken under unusually favorable conditions of weather, with the most perfect appliances, and with consummate skill. The whole time occupied in the descent was 33 minutes, 35 seconds; and in heaving up 2 hours, 2 minutes. The cylinder of the sounding apparatus came up filled with fine, grey Atlantic ooze.”

This was the sum of our experience in deep sea sounding when, in 1873, the *Tuscarora*, Comdr. Geo. E. Belknap, was ordered to prepare for soundings in the Pacific Ocean, a field hitherto unexplored. The object of the *Tuscarora's* cruise was, primarily, to determine a practicable route for a submarine cable to connect the United States and Japan. The original plan comprehended a line of soundings on a great circle, as nearly as might be, from Cape Flattery, Washington Territory, to No-Sima, at the entrance of Yeddo Bay, Japan. Returning, a line was to be run from Cape No-Sima, by the Bonin Islands, to Honolulu, and thence to San Diego or San Francisco. But a short coal supply prevented the completion of the first line, and bad weather, due to the lateness of the season, rendered it advisable to return. On the passage back to San Francisco lines of soundings were run on and off shore to determine the conformation of the bottom near the coast line. This was continued afterwards as far south as San Diego. The southern line was then run, the ship returning by the great circle route to the northward. The results of this cruise, together with a description of the apparatus employed have been published by the Hydrographic Office, in a fully illustrated volume, to which you are referred for more complete information.

The *Tuscarora* was supplied with about fifty thousand fathoms of sounding lines. Of this, some forty thousand fathoms was  $1\frac{1}{4}$ ,  $1\frac{1}{2}$  and  $1\frac{3}{4}$  inches Manilla rope, which had been treated with carbolic acid, after some patented process, with a view to its preservation. About five thousand fathoms was  $1\frac{1}{4}$  inch whale line, and there was also four thousand or five thousand fathoms of Albacore line made of untarred hemp,  $\frac{3}{4}$  inch in circumference. Fitted on the forecastle was a steam reel and a dynamometer, for use with this rope. The want of some

instrument for regulating and measuring the tension of the line in sounding had long been felt. As the line runs out the tension is continually increased by the weight of the increasing length overboard, until it is suddenly diminished by the sinker resting on the bottom. If then the tension could be measured at every instant, any sudden diminution of the strain would be an indication that bottom was reached. The dynamometer, designed by Passed-Assistant Engineer T. W. Rae, was for that purpose.\* It consisted essentially of two fixed pulleys, elevated several feet above the deck, midway between which was a third pulley attached to a rod which was capable of motion in a vertical direction, through guides which it traversed freely. The lower end of this rod, which passed through the deck, terminated in a piston, which worked in a cylinder filled with water. The sounding line passed from the drum of the steam reel over one of the fixed pulleys, under the movable pulley, which was thus made to ride upon the line, over the second fixed pulley, and thence, by means of a fair leader, over the ship's side. The rod attached to the movable pulley could be weighted and by means of a scale behind the rod the strain upon the line could be determined. By gradually increasing the weights on the rod as the line ran out, it was intended to keep such a strain on the line, that it would cease running, or nearly so, when the sinker rested on the bottom. The object of the piston in the cylinder filled with water was to prevent violent motion of the rod, when the ship was rising or falling with the sea. This machine, although constructed upon perfect mechanical principles, and notwithstanding the fact that similar instruments are used with accuracy in the laying of submarine cables, gave hardly satisfactory results. It was found that the oscillations of the rod were violent and uncontrollable when there was any rolling motion, and it was impossible to estimate with any degree of accuracy the tension of the line. It is possible that a more thorough acquaintance with this apparatus would make it valuable in sounding with rope. By an unfortunate accident it was not properly arranged in the Tuscarora, and hence did not obtain a very thorough test of its value, before the soundings with wire become so successful that its employment was unnecessary.

We have seen with what success the attempt to sound with wire had been attended in the Taney. Walsh's failure, together with that of

\* A description and sketch of this instrument may be found in U. S. Hydrog. Office publication No. 54.

other efforts made at about the same time, led to the conclusion that wire soundings were impracticable. Nevertheless that material offered great advantages and possessed the very qualities which experience had shown to be desirable in a sounding line. The small, smooth wire meeting with but little resistance from the water in descending, would sink rapidly, nor would it be deflected to any great extent by submarine currents; it would require a sinker of comparatively little weight; it could be made sufficiently strong to bear any ordinary strain; it was compact and portable, and would occupy but little room on board ship, a consideration which only those who have been embarked with great quantities of sounding rope, can properly appreciate. There were those, therefore, who did not accept the verdict rendered upon the evidence of former trials. All that was required to render the method practicable, it was maintained, was some contrivance for so regulating the strain upon the wire, that when the sinker reached the bottom, the wire should no longer run out, or should do so with such a diminished velocity as to be readily perceptible. This was the object of a machine invented by Sir Wm. Thomson, in 1872, for sounding with steel piano wire.

One of these machines, with a supply of wire, was furnished to the *Tuscarora*. At that time but a single cast had been made with the apparatus, and that by the inventor, who sounded in twenty-seven hundred fathoms from a schooner yacht in the bay of Biscay. The cast had not been satisfactory; the reel was crushed in the operation, and it was with great difficulty that the wire was hauled in. The original machine differed but little from that furnished to the *Tuscarora*, so that the method was almost absolutely untried when it was placed in Capt. Belknap's hands for experiment. The weight of opinion both in this country and in England was against the method. When the *Challenger* was fitting out in 1872, it was reported that she would be furnished with the machine. But she went to sea without it, the reason being, according to Sir. Wm. Thomson, that "innovation is very distasteful to sailors." Prof. Wyville Thomson, who was the director of the scientific staff of the *Challenger* expedition, in a paper read before the Asiatic Society of Japan, at Yokohama, said, "When we started from England this wire had only been tried once \* \* \* . I had been some years at sea and my colleagues were all sailors, so we had great sympathy with hemp." According to Sir William, the British Admiralty would not try the wire method because it was new. He states that he received a semi-official letter to the effect. "When

you have perfected your apparatus we may be willing to give it a trial."

Whether or not it was sailor's prejudice that opposed the use of wire in this country, it is certain that few had any faith in its success. Fortunately, however, among the few, was the Chief of the Bureau of Navigation, Commodore Ammen. It was his determination in the matter that enabled the *Tuscarora* to put the method to the test. He facilitated the preparation of the ship in every way; he ordered Capt. Belknap to make an experimental cruise to detect defects in his apparatus, which was the foundation of future success; and it is to his aid and counsel and constant interest throughout the work, supplemented by the ingenuity of Capt. Belknap, that the Navy owes its prestige in having made wire soundings practicable.

Thomson's machine as furnished to the *Tuscarora*, consisted of a reel *a* (Plate I.) for holding the wire, and an arrangement for regulating and measuring its tension.\* The reel was a hollow cylinder of galvanized sheet iron, with an iron axle passing through its center, and soldered to its sides. The drum of the reel was about six feet in circumference and three inches long. The ends extended two inches beyond the circumference of the drum, thus forming an annular space two inches deep and three inches wide in which the wire was wound. To one side of the drum was fixed a projecting ring of galvanized sheet iron, which formed with the side of the reel a V shaped groove in which an endless rope passed. The axle of the reel was a small iron shaft, six or eight inches long, which revolved in bearings on two iron standards, bolted to a plank of hard wood  $3\frac{1}{2}$  ft. long, 15 inches wide and  $2\frac{1}{2}$  inches thick. The shaft carried on one side of the drum an endless screw, which gave motion to a train of wheel work by which the revolutions of the reel were counted; on the other side was attached a ratchet in which worked a pawl by which the revolutions of the reel was prevented when necessary. Both ends of the shaft projected beyond its bearings and were squared, so that cranks might be applied in putting the wire on the reel.

The arrangement for controlling the tension of the wire consisted of a grooved friction wheel of iron *e*, ten inches in diameter, the groove being wide enough to carry two parts of the endless rope *b b* passing around the reel. It was capable of motion in a vertical plane, in an iron crotch fixed to the bed of the machine, but was prevented from turning by a cord *e*, passing from the lower part of its circumference

\* The reel in its original form was exhibited at the meeting.

to the dynamometer. The friction wheel was connected with the reel, when the wire was running out, by means of an endless rope *b*, of 9 thread untarred hemp, which passed around the V groove of the reel, then up, over, and once around the friction wheel, and then around a pulley *d* placed several feet in rear of the reel. This pulley was attached to a small tackle by means of which the endless rope could be made more or less taut, thus increasing or diminishing the resistance of the friction wheel. The tackle was shortly afterwards replaced by a pendant *f* rove through a tail block, and carrying hooks to which weights could be attached, an arrangement of much greater utility.

The dynamometer was an instrument similar to one form of the spring balance, secured to the bed of the machine. The force exerted upon it, which depended upon the tension of the wire, was indicated in pounds, by a pointer which moved over a graduated scale. For this dynamometer was afterward substituted an ordinary spiral spring balance, *g* which gave more satisfactory results.

The wire furnished for this machine was steel piano wire, No. 22, B. W. G.,\* of the best English make. Its weight in air was about 14 lbs., and in water 12 lbs, to the thousand fathoms. It would support a weight of 230 lbs. It was supplied in lengths of from two hundred to four hundred fathoms which were spliced together on board ship. One great objection which had been urged against the use of wire was the impossibility of making the splices strong enough. The method of splicing adopted on board the Tuscarora was to lap the ends about two feet, solder one end and lay the other end up in turns of about an inch in length until it was all expended, when the second end was soldered. The two parts of the splice were also soldered together at intermediate points, and the whole splice served with well waxed twine. The splice thus formed was very strong, not one of them having broken down during the cruise. The wire was received packed in sperm oil in cases of sheet tin; it was kept in these cases covered with oil until wound upon the reel for use. The operation of winding was one requiring the utmost care, the wire having a great tendency to kink. When, by accident, a kink did occur it was found best, as a rule, to break the wire and splice the ends. In winding, the coil of wire was taken from the oil and slipped over the end of a wooden reel, from which it was wound on the sounding reel, being kept hand taut all the time. It was carefully measured as it was wound, the lengths between the splices, as well as the number of revolutions of

\* Diameter 0.028 inch.

the drum, being noted at each splice. These were recorded in a notebook and by them the depth was determined when a cast was made. The reel held readily between four thousand and five thousand fathoms and this quantity was usually wound upon it. When it was all on, to the free end of the wire was attached a small grommet made of  $1\frac{1}{2}$  or 2 inch rope. The grommet was secured by sticking the end of the wire between the strands of the rope and then taking several round turns against the lay, the whole being finally served. A piece of cod line attached to the grommet and tied around the reel prevented the the wire from unwinding

The required length of wire being wound, the reel was unshipped and placed in a galvanized iron tank containing a solution of caustic soda, which served to protect the wire from rust. The philosophy of this method of preservation, as explained by Sir. Wm. Thomson is as follows: "The preserving effect of alkali upon steel is well known to chemists. It seems to be due to the alkali neutralizing the carbonic acid in the water, for the presence of carbonic acid in water is the great cause of iron being corroded. The fact is well established that iron will remain perfectly bright in sea-water rendered alkaline by a little quicklime. Caustic soda is a more sure material, because with it we can make more certain that the water is really alkaline. \* \* \* All that is necessary in order to made sure that the pickle will be a thorough preserver of the wire is that it should be found to be alkaline when tested with the ordinary litmus test paper.

I give Sir Wm.'s language as nearly as may be because I do not think he estimates at its true value the action by which the wire is preserved from rust. In the Tuscarora the lye in which we kept the wire was much more strongly alkaline than he says is necessary. It was found, however, that while the wire was perfectly preserved, the caustic soda solution attacked the zinc of the galvanized iron of which the reel was made, as well as the soldered splices. Now zinc and iron, or iron and tin solder, when placed in contact in caustic soda form a galvanic couple of which the zinc or the tin solder is the electro-positive element. A galvanic action is, therefore, set up by which the iron is preserved at the expense of the zinc or tin. It is probable that this action would be less with a more dilute solution of soda than with a stronger one, but still great enough to protect the sounding wire from rust. This, I think, is the true explanation of the preservative action. If so, it seems to me that a more suitable liquid than soda-lye might be substituted for it. Caustic-soda is a very disagreeable substance to

use on board ship. It spoils the clothes and hurts the hands of those working with the wire; and the lye, washing over the sides of the tank in the rolling of the ship, kills the wood of the deck, and then running through the scuppers takes the paint off the ship's side. I am inclined to think that slightly acidulated fresh water, or even sea-water alone might be substituted for it with advantage.\* So serious has the objection to the use of soda become that it has been discarded in English vessels using the wire, and sperm oil is now used in its stead.

The Tuscarora's soundings were always made under steam and with the ship stern to wind. This was found to be the best method of laying the ship and it was resorted to even when the force of the wind was as great as 8. Usually the screw held the stern of the ship up to the wind, but when the bows showed a tendency to fall off to one side or the other, which was the case only when the wind was light, the jib being set with the sheet hauled flat aft effectually prevented it. After numerous experiments Capt. Belknap fixed upon the gangway as the most convenient point from which to sound.† There the motion of the ship was least sensible, the wire was consequently more manageable, and accordingly nearly all the soundings were made there. A bridge across the deck was constructed, so arranged that it could be unshipped and stowed away in port. The machine was placed upon a slide so that it could be run out or in and compressors were applied to secure it at any point. The upper grating of the accommodation ladder being shipped, this slide was supported by a railing and securely lashed. The grating allowed room to the men who were handling the sinker &c., and served to carry the wire well out from the ship's side.

In preparing to sound, the reel was placed on its bearings at the gangway, and the bed run out to the end of the slide. The endless rope was arranged as already described. To the grommet was hitched a piece of Albacore line, twenty-five fathoms in length, and this was also wound on the reel. The other end of the Albacore line carried a small iron rod six feet long, to which was seized the upper end of the swivel-link of the Brooke detaching apparatus. The Albacore line was to prevent the wire itself from going to the bottom, thus avoiding all danger of kinking, and the rod was for the purpose of throwing

\* Experiments by the writer go to show that either of these liquids will preserve the wire. Water slightly acidulated with hydrochloric acid gives the best result. Lime water is probably the best liquid for the purpose.

† In the Challenger, soundings were made from the main yard, the ship being head to wind.

the line clear of the specimen cylinder so as to prevent fouling. The sinker, which was usually an 8 in. shot weighing 55 lbs, was placed on the apparatus for obtaining the bottom specimen, an invention of Capt. Belknap, shortly to be described. When all was ready the sinker was eased down by hand into the water, and a Miller-Cassella deep-sea thermometer, for obtaining the bottom temperature, was attached to the stray line above the iron rod. The stray line was then allowed to run out slowly until the grommet in the end of the wire was reached. To this was attached a lead weighing four pounds, which prevented the end of the wire from flying up and kinking when the sinker reached the bottom, as experience had shown it would sometimes do. Weights were now hooked to the pendant carrying the pulley around which the endless rope passed, and the wire was allowed to run out. When it had fairly started, the weight on the pendant was diminished so as to allow it to run more rapidly. The time the wire started was noted, as well as the instant at which the drum completed each hundred revolutions. When it was thought that the sinker was nearing the bottom, the weights on the pendant were increased in order to diminish the speed of the reel and to make sure that the instant of reaching the bottom should be properly indicated. This indication was usually unmistakable; the pointer of the dynamometer would fly back on the scale, and, except in very deep water, the revolution of the drum would almost instantly cease. The fact that bottom had been reached could be noted as well from the poop or the forecastle as at the gangway.

Bottom having been found, the cord holding the friction wheel was detached from the dynamometer so that the endless rope might be employed in reeling up the wire. The officer in charge of the sounding then laid hold of the endless rope and, unaided, hauled in a few fathoms to make sure that the shot had been slipped. If not, as was the case in but few instances in the early part of the cruise, fifty or sixty fathoms were reeled in and again let go, the second effort almost invariably detaching the shot. The reeling in was at first done by putting men on the bridge who hauled in hand over hand on the endless rope, an operation both tedious and laborious. For this arrangement was afterwards substituted a fly-wheel, carrying a grooved disk of wood from which a belt passed to the V groove of the reel. By turning the fly-wheel by means of long cranks, which could be manned by four or six men the wire was wound in much more rapidly and uniformly than by the old system. When reeling in the wire was guided fair on the reel by two petty officers, round sticks being used for the purpose.



In Brooke's original apparatus the device for obtaining specimens of the bottom consisted of a number of open quills placed in the lower end of the sounding rod. This arrangement, however, did not secure adequate samples, and the ingenuity of those engaged in deep sea work has ever since been directed toward its improvement. Berryman soon replaced the quills with a valved cup, which gave much better results. Many subsequent improvements in the form of the cup have been made, not a few of which have been by officers of the Navy. In the *Challenger*, the apparatus usually employed was the "Hydra," so called because it was invented on board an English surveying vessel of that name. The Hydra consists of a long cylinder of brass, closed at its lower end by a valve opening upwards. An iron piston-like rod, carrying a short arm projecting at right angles to the rod, is fitted into the upper end of the cylinder. Over the projecting arm is a curved steel spring, one end of which is fast to the rod, the other end movable. This may be pressed flat against the rod, a hole in the spring allowing the projecting arm to pass through it. The sinker is supported on the rod by a wire sling which passes over the arm and is kept there in opposition to the spring, by the weight of the sinker. When the sinker rests on the bottom the sling is pushed off the projecting arm by the spring, and the rod and cylinder are hauled up. The piston-like arrangement of the rod assists in closing the valve in the lower end of the cylinder.

This apparatus had been used very successfully in the *Porcupine*, and was highly thought of in the *Challenger*. Its weight, however, made it objectionable for use with wire, and it necessitated the use of a separate instrument, the water-bottle, when samples of the bottom water were required. In order to overcome these objections several new forms were devised by Capt. Belknap. Of these the most important and most successful are those designated as specimen cylinders, No's 1, 2, and 3 (Plate II.) In each of these the Brooke plan of detaching is adhered to.\*

Cylinder No. 1 (Fig. 1) consists of two cylinders *a* and *b*, the inside diameter of the one, *b*, being very slightly greater than the outside diameter of the other, *a*, so that the larger slides over the smaller with but little friction. The inside cylinder terminates in a cone, *d*, above which, on two opposite sides, are openings, *p p*, by which the bottom mud or sand can enter. The upper end of this cylinder screws on the iron detaching rod *c*. The outside cylinder travels on this

\* For full details and drawings of these cylinders see Hydrog. Office publication, No. 54.

rod by means of an opening in its top. It is long enough to go entirely through the shot used as a sinker and, when in its lowest position, it covers the openings in the inner cylinder. A stud on one side prevents its slipping through the shot. The inner cylinder has in its upper part a chamber, *m*, to the top and bottom of which are fitted valves, *n n*, opening upward, intended to enclose a specimen of the bottom water. In slinging the sinker this apparatus is passed through a hole in the shot, and a metal washer, *l*, is put on, which by means of wire slings is suspended to the detaching arm, *f*, of the rod. When the shot rests on the bottom, the detaching arm falls, the outer cylinder slips down and retains whatever has entered the inside cylinder.

Cylinder No. 2, (Fig. 2,) is of quite different design. To the lower end and inside of the cylinder is fitted a hollow frustum of a cone, *b*, its base downward. The upper end of the cone is closed by a valve, *h*, kept in place by its own weight in addition to a light spiral spring. Into the bottom of the valve is screwed a plunger, *p*, extending beyond the end of the cylinder. When the shot strikes the bottom, the valve is forced open and the mud or sand enters. The valve then closes, retaining the specimen. This cylinder is also fitted with a water space.

Cylinder No. 3, (Fig. 3,) consists of an auger shaped piece of iron, *a*, over which slides a brass cylinder. The brass cylinder is kept up by a stud, *l*, on its side, until the shot is detached. The auger shaped iron engages the bottom specimen which is retained by the cylinder. In the use of this cylinder it was sometimes found that the metal washer which supported the shot was caught by the cylinder in falling, and prevented the shot from slipping off. This was remedied by lacing on the shot two wire grommets of smaller diameter than the shot, to which the slings were attached.

Cylinder No. 1 was most successful in soft bottom, at moderate depths. No. 2 brought up the best specimen in hard, sandy bottom, and was always good. No. 3 answered best at great depths, when the shot on striking the bottom was not moving with great velocity.

In depths less than two hundred fathoms the sinker used was an 8 inch shot, weighing about 55 lbs. In deeper water one or more lead castings, which fitted over the top of the shot, were added, thus increasing the weight to 70 or 75 lbs, and making the total weight sent down, including the specimen cylinder and the small safety lead, about 80 lbs.

The time required for a sounding with this apparatus is much less than that required for rope, even when the rope is reeled in by steam.

The deepest sounding made by the Porcupine in 1869 and '70 was the one of twenty-four hundred and thirty-five fathoms, a description of which I have read. The sinker used on that occasion weighed 336 lbs. The time required for the descent of the line was  $33\frac{1}{2}$  minutes, and in hauling in, 2 hrs. 2 min. or 2 hrs. 35 minutes for the cast. In the Tuscarora we sounded in twenty-five hundred and sixty-five fathoms, the line running out in 31 minutes, and being reeled in in 40 minutes, the whole time occupied being but 1 hr. 11 min., a gain of 1 hr. and 24 minutes, although the depth was over a hundred fathoms greater. This is a very fair example of the speed with which a wire sounding could be made. A cast of three thousand fathoms usually required an hour and a half, and one in four thousand could be made in about two hours.\*

The Tuscarora ran lines of soundings aggregating sixteen thousand six hundred and twenty miles in length, and made in all four hundred and eighty-three casts, of which perhaps fifty, in depths generally less than five hundred fathoms, were made with rope. The depth found in one hundred and sixty of the casts was over two thousand fathoms; thirty-two were in depths of more than three thousand, and nine, in depths of more than four thousand fathoms. The greatest depth from which a bottom specimen was obtained was four thousand three hundred and fifty-six fathoms. The deepest sounding made was in four thousand six hundred fifty-five fathoms, or  $5\frac{1}{4}$  statute miles. The circumstances under which this cast was made were all the most favorable. The sea was smooth, the ship steady, and the up and down direction of the line was maintained throughout. The indication of the dynamometer that bottom had been reached was perfect. But the wire had been down four thousand fathoms three or four times on the preceding day, and it finally gave way under the strain when about four hundred fathoms had been reeled in. This was the fifth and last time during the cruise that the wire was lost.

The soundings with the wire were invariably made by the navigator of the ship, Lieut. Geo. A. Norris, and it was to his industry and intelligence that their success was in a large measure due. To Capt. Belknap, however, we owe the perfection which this method has attained. He was indefatigable in the work and every cast was made under his direct supervision. Both Commodore Ammen and Sir Wm. Thomson were, naturally, much gratified at the results of the cruise. The latter has repeatedly publicly referred to the fact that while the British Ad-

\* A sounding was made in four thousand one hundred and twenty fathoms, and a large bottom specimen brought up in 1 hour, 47 minutes, 42 seconds.

miralty hesitated, the American Navy perfected his apparatus in its own way. In his presidential address before the Section of Physics of the British Association, he speaks enthusiastically "of Commander Belknap and his great exploration of the Pacific depths by piano-forte wire, with imperfect apparatus supplied from Glasgow, out of which he forced a success in his own way, \* \* \* \* and of the admirable official spirit which makes such men and such doings possible in the United States naval service."

The great difficulty that was experienced in the *Tuscarora* and which the resources of the ship could not overcome was the crushing of the reel, especially when the soundings were in deep water. The steel wire stretching under the strain to which it was subjected, was reeled tightly on the drum. The crushing force thus brought upon the drum by the elasticity of the wire was very great, and the drum, being made as light as possible in order to keep its inertia small, invariably broke down. A drum would stand, perhaps, a dozen casts in depths below two thousand fathoms, but when the depth was much greater the life of a drum was much less. The reels on board the *Tuscarora* were constantly in the hands of the tinsmith. They were strengthened by radial pieces of wood, placed inside of them, but the crushing went on almost as fast as though the wood were not there. Other devices were resorted to but unavailingly, and the only way of keeping at work was to shift the wire from reel to reel as they broke down. Capt. Belknap recommended a steel drum for deep soundings but I do not know that any have been constructed. Sir Wm. Thomson has overcome this difficulty by the introduction of an auxiliary wheel in reeling in, the use of which is illustrated by the accompanying figure, Plate III.

The bed of the machine, B, rests on two rails, H H, so that it can be run out or in, and clutches, c c, at either end of the bed keep it on the rails. The galvanized sheet iron reel is retained, and the soundings are made directly from it as before. Under the rails, H, and midway between them are two pulleys, I and K, one of which, I, projects over the taffrail, supposing the sounding to be made from the stern as Prof. Thomson prefers. This outermost pulley is called the "castor pulley" from the manner in which it is mounted. Its bearings are in an oblique fork which turns about a horizontal axis, like the *castor* of a piece of furniture laid on its side. The other pulley, K, is inboard. The two bearings of its axle are both on the same side of the pulley so that a turn or two of the wire can be taken around it. The ends of its axle are squared so that handles may be applied in reeling in, or a

wheel having a sharp V groove can be shipped, carrying an endless rope by which the reeling in is done. When the sounding has been made the wire is stoppered and the reel run in about five feet on the slide, until it is just over the auxiliary pulley K. The wire is then led over the castor pulley and a turn, or two turns, are taken around the auxiliary pulley. The reeling in is performed by the auxiliary pulley which takes from two-thirds to nine-tenths of the strain off the wire before it reaches the sounding reel, A, on which it is wound as the reeling in proceeds. The castor pulley, by turning about its horizontal axis, in case the ship drifts during the operation, prevents the wire from leaving the groove; it performs the same office if the ship is rolling heavily. Additional security is obtained by a guard, f, to catch the wire if it should get off the pulley.

In the machine, as thus modified, the inventor has introduced a friction arrangement different from that used in the Tuscarora, and has abandoned the spring dynamometer. A rope fastened to the bed of the machine at *a* passes over the V groove of the reel and then over two small pulleys *F*. To the end of this rope weights, *g*, are applied. These are added as the wire runs out so that the friction brings the drum to rest as soon as the sinker touches the bottom. The rule is to apply a resistance greater by ten pounds than the weight of the wire out. This makes the moving force on the sinker ten pounds less than its weight in water and a sinker of thirty-five pounds is thought to be sufficient in depths less than three thousand fathoms.

The machine, as thus modified, was used in the cable ship Hooper in laying the submarine cables on the coast of Brazil; it was also used in the Faraday, in laying the direct Atlantic Cable. In these ships the sinker was always recovered, and Sir Wm. Thomson recommends that this should be done whenever the depth is not over three thousand five hundred or three thousand fathoms.\*

One difficulty remained to be overcome. When the ship is lifting in a heavy sea there are times when a very great strain is imposed upon the wire and when it would be dangerous to haul it in too fast. Prof. Jenkin, of the University of Edinburgh, who accompanied Sir Wm. Thomson in the cable laying expeditions, has invented an arrangement by which the hauling in may go on as rapidly as possible, without bringing more than a certain safe strain upon the wire. The wire will come in fast when the strain is easy, and not come in at all

\* Since this was written I learn that Sir Wm. Thomson now prefers a heavier sinker, which may be detached.

when it is too great. By this arrangement steam can be applied to reeling in the wire. I regret that I do not know the details of this exceedingly important device.

A most valuable and ingenious improvement in the Thomson sounding machine has been made by Lieut.-Commander Sigsbee, U. S. Navy, who has been engaged in sounding in the Coast Survey steamer Blake. In the Tuscarora, whenever the ship was rolling during a sounding, the revolution of the reel would almost cease when the ship rolled toward the wire; on the other hand when the roll was in the opposite direction the reel would move so rapidly that it would have thrown the wire off, if the motion had not been controlled. This was done by pressing with the hand on the endless rope, but this brought an undue strain upon the wire. Sigsbee's invention controls the motion of the machine automatically. I have never seen the machine as improved by Sigsbee, nor have I been able to obtain a drawing of it. The following description and accompanying figure, (Plate IV. Fig. 1.), are in accordance with what I have been *told* about the device.\*

On either side of the bed of the machine, at its outer end, is an upright stanchion, A. Between the two stanchions is a horizontal bar, (shown in section at B), which moves up and down in slots or scores in the uprights, A. A fixed cross-piece joins the upper ends of the two uprights, and the movable bar is connected with the cross-piece by two spiral springs, D. Attached to the under side of the movable bar is a pulley, C. To the strap of this pulley is secured one end of the brake rope *m n*. This is led around a small pulley, *p*, on the bed of the machine, then carried around the V groove of the sounding reel, and its end made fast to a small eye bolt, *u*. When there is no downward strain on the bar, B, the springs cause the rope to press tightly against the reel, and keep it from revolving. The wire, instead of passing directly from the reel into the water, is led over the pulley, C. Consequently when considerable strain is on the wire the springs are stretched, the brake rope is slacked and the reel may turn freely. Any tendency of the reel to pay out the wire more rapidly than the sinker will take it, is attended by a diminution of the strain on the wire; the springs contract and the brake-rope is applied to the reel. The changes in the tension of the wire being thus self regulating it is evident that no dangerous strain can be brought suddenly upon it.

Although not strictly within the scope of my paper, I have thought

\* The drawing and description is only intended to *indicate* the nature of Sigsbee's improvement.

it well, at this point, to speak of the most recent application of the piano wire in sounding. I refer to its substitution for rope in sounding in shoaler water for the ordinary purposes of navigation. The uncertain process hitherto adopted, involving the necessity of stopping or heaving-to the ship, and depending upon the shrewdness in guessing of the quarter master, is no longer necessary. In laying the telegraph cables on the coast of Brazil, Sir Wm. Thomson used the ordinary deep-sea machine in making approximate soundings in depths of from fifty to one hundred and fifty fathoms while the ship was running at the rate of four or five knots. The depths in these cases were arrived at by noting the length of wire out, and knowing the distance run by the ship while it was going out, and were therefore only rough approximations. He has, however, recently modified his apparatus so as to make it available for "flying soundings," and they have been made with great accuracy. The reel used for this purpose is of the same form as that for deep soundings, but it is only twelve inches in diameter and holds only three hundred or four hundred fathoms of wire. The brake arrangement differs somewhat in form from that of the larger machine. The weight, E, (Plate IV, Fig. 2), is centred at N, and at D is fastened to the brake-rope, M. The rope, M, takes a single turn around the periphery of the drum, B, and passes over the pulley, G, to which it is attached at F. H is an adjustable weight carried by the pulley, G, and, from its horizontal position, o, it can be raised to the positions indicated by n and m. When it is in the position shown, E is at its highest position against the stop, K, the maximum stress is on the rope, and the maximum friction is on the drum, because both weights, E and H, pull on the ends of the rope with their maximum effect. This is sufficient to prevent the reel from turning. When H is at the position n, the weight, E, hangs between the stop and the base of the machine, A, and the pull on the rope is about seven pounds, which corresponds to a frictional resistance on the drum of about five pounds. When H is in its highest position, m, E rests on the stand and the friction of the drum is almost entirely removed. When the sounding is made, H is raised to the position n; as soon as bottom is reached, which is shown by a sudden decrease in the speed of the drum, the weight, H, is allowed to fall to the position, o, and prevents any more wire running out. A counter is used to show the number of revolutions of the drum. The wire is reeled in by applying cranks, worked by two men, to the axle of the drum.

The sinker is a slender cylinder of iron, three feet long, weighing

twenty-two pounds, attached to the wire by a fathom and a half of log line. The depth is determined by the compression of a column of air contained in a glass tube, closed at one end, two feet long and about  $\frac{3}{8}$  in. internal diameter. The tube is coated on the inside with a colored substance\* which is discolored by contact with sea-water. The glass tube, to secure it from breaking, is inserted with its open end downward in a slightly larger tube of brass, made fast to the log-line above the sinker. As the sinker descends, the pressure of the water reduces the volume of the air in accordance with Boyle's law, the water rises in the tube, and the height to which it rises is marked by the discoloration of the chemical preparation within the tube. A graduated scale is applied to the tube by which the depth in fathoms is determined by the extent of the discoloration.†

There is no reason why such an apparatus should not be carried on board every ship. The frame of the machine could be secured to the taffrail when the ship is on soundings. "Two men," says Sir Wm. Thomson, "can take a cast with ease every quarter of an hour." It is not necessary to stop the vessel or heave her to in making a cast. The depth indicated by the tube depends only on the vertical distance descended and is independent of the inclination of the wire. Nor is it necessary to use the chemically prepared tube each time. If the speed of the ship be uniform, the reading of the counter when the tube is used will show the relation between the depth and the length of wire out, and the succeeding three or four casts could be estimated entirely by the counter. This apparatus has been used successfully in *H. M. S. Minotaur* when the ship was going ten knots, and it is reported that a sounding has been made with it from one of the *White Star Steamers* when the speed was sixteen knots.

The *Tuscarora* having demonstrated the feasibility of the wire method, the art of deep-sea sounding has been revolutionized. The days of rope soundings terminated last year with the cruise of the *Challenger*. With the exception of those made in that ship every deep sounding within the last three years has been made with wire. The inconsiderable labor necessary in making a cast, the short time required for the purpose, the accuracy of the result, are such that, henceforth, the bed of the ocean lies but at our hand. "International

\* Chromate of Silver.

† The writer has suggested another form of tube which does not require chemical preparation. A description of it may be found in "Nature," Jan. 17th, 1878.



coöperation alone is necessary in order that the principal features of the bottom of the sea may be mapped out with almost the same accuracy as that with which the geographer now depicts the land surface." In every step toward this wonderful result—wonderful, when we consider the few years in which it has been accomplished—those to whom we are united by ties of official brotherhood have largely contributed. It is to preserve the recollection of this fact that I present this imperfect record of their achievements.



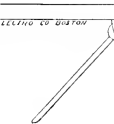




Plate I.

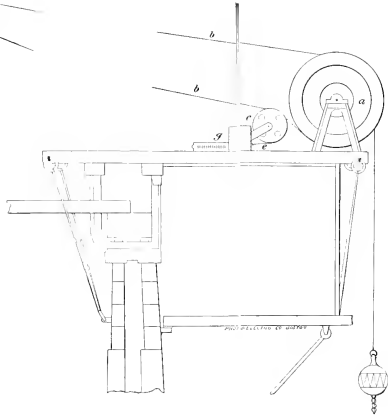
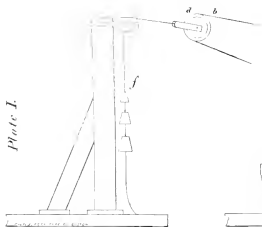


Fig. 2.

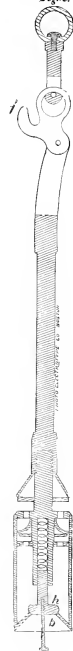


Fig. 1

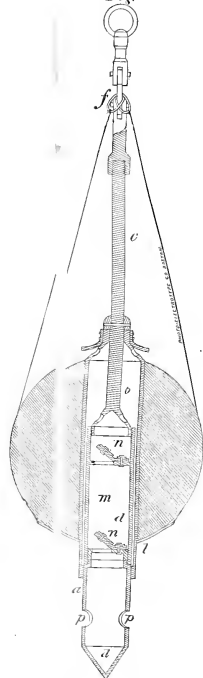


Plate II.

Fig. 3

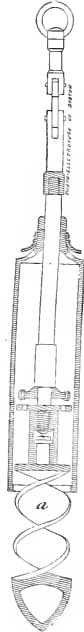
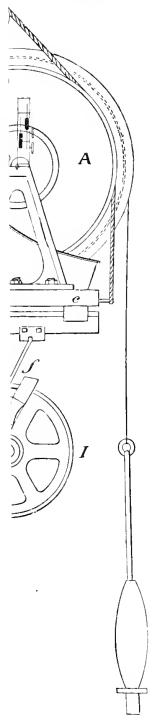




Plate III.



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Fig. 1.

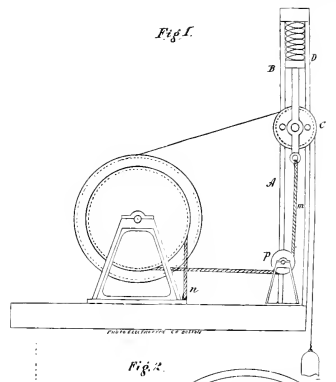


Fig. 2.

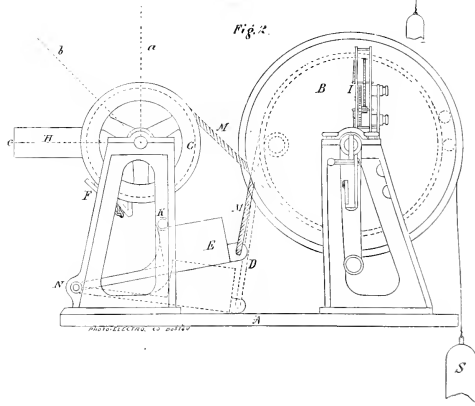
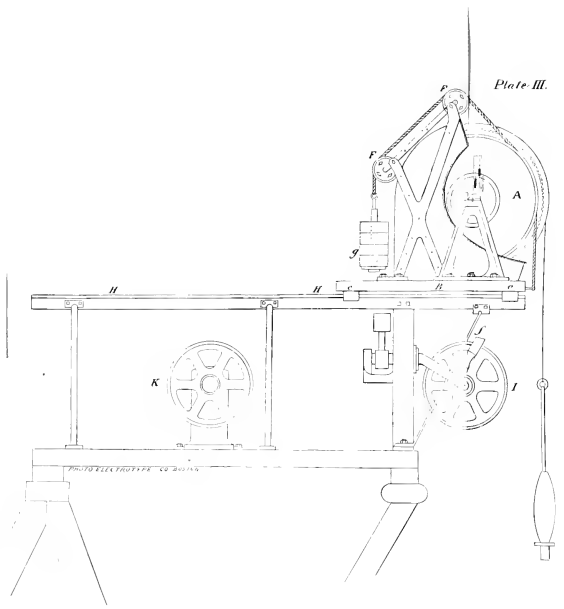


Plate III.





# THE RECORD

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## UNITED STATES NAVAL INSTITUTE.

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U. S. NAVAL ACADEMY, ANNAPOLIS,

JANUARY 17, 1878.

Commodore FOXHALL A. PARKER in the Chair.

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### THE NICARAGUA SURVEY.

BY LIEUTENANT J. W. MILLER, U. S. N.

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In the absence of the author, Master S. A. STAUNTON, U. S. Navy, read the following paper.

Not many months since a Commission, appointed by the President, was in session at Washington to determine the comparative merits of the various ship-canal routes across the Isthmus of Central America. As this Commission was composed of three officers of high rank in their several professions, whatever decision they may have reached may be considered exhaustive and final. The report of General Humphreys, Admiral Ammen, and Captain Patterson shows that the Nicaragua Line is feasible, and that, possessing certain great advantages over all its competitors, it is, in all probability, likely to become the site of the highway between the Atlantic and Pacific.

Since the adjournment of the Commission I have waited in vain for some abler hand than mine to lay before the Institute the results obtained by the survey of Nicaragua, and my only excuse in presenting this paper—written during the intervals of duty on board ship—is the desire of one who was connected with Commander Lull's expedition, to draw to your attention an enterprise which is in the future to become one of great importance to the Navy and to the country at large. By way of introduction, let me offer a short historical sketch of the various expeditions, both public and private, undertaken at Nicaragua.

The question of a passage to the Pacific, through the narrow Isthmian barrier is as old as the discovery of the continent itself, the very commission granted to Columbus surmising that the East Indies was the goal to be reached. In the great navigator's second and third voyages, we find him exploring the gulf of Paria, vainly imagining that he is about to discover the South Sea. In his wake follow a host of adventurers, seeking the "strait." Balboa, Ponce de Leon, Ogeja, Lotes, Pizarro, all—in connection with their other projects—sought to render their names famous by the discovery. Even as late as 1687, we find *Sieur de Lussan*, a French "Filibusterer" writing:—"This lake (Nicaragua) hems in three islands, that are not far distant the one from the other, and all of them very near the mouth thereof. Some few years since the *Hourqua* (specie vessel) of *Acapulco*, that went to the East Indies, on its return, entered in this lake through the bay, and we understood that some Spaniard had entered by the other end of it, through the river *Vastaqua* that discharges itself into a bay of New Spain and consequently the North Sea."

This account of a ship passing from ocean to ocean is undoubtedly overdrawn, though it is highly probable that the channel of the *San Juan* or *Vastaqua* was much deeper, prior to its partial destruction by the Spaniards during the last century.

*Dampier's Voyages* contain interesting accounts of Nicaragua; while *Humboldt*, in his "New Spain," after an elaborate description of several routes, states, that "communication with the Pacific ocean would be effectel by cutting a canal across the Isthmus, which separates the lake from the gulf of *Papagayo*."

The first regularly organized expedition to Nicaragua was probably undertaken in 1778, by two Spaniards named *Yzasi* and *Alexandre*. They were accompanied by two Englishmen, *Hodgson* and *Lee*, who published a description of their work on their return to England. This survey was supplemented by an examination of the territory west of Lake Nicaragua, conducted by a government engineer named *Manuel Galisteo*, in 1781.

In 1825, *De Witt Clinton* endeavored to arouse the interest of the United States to the importance of ship communication between the two oceans; though it was not till ten years later that President *Jackson* appointed an agent to examine the Isthmus, and then the objective point was *Darien* and not Nicaragua.

*Mr. Bailey*, a retired officer of the British Navy, was employed in 1838, by the government of Central America, to make a survey of this

canal route. His operations were confined to the territory between the Lake and the Pacific, and were consequently incomplete.

During the next few years several companies were formed in Europe, nominally for the colonization of the Isthmus, but actually as preliminary steps towards a future canal. But one of these companies commanded much attention, and that simply from the romantic interest attached to the man at its head. A political prisoner, confined in the fortress of Ham, and shut out from the hope of ever attaining the crown of France, conceived the idea of perpetuating in America the glory of a name already famous the world round. He entered into correspondence with Senor Castellon, the minister of the Central American government at the Court of Louis Philippe, reviewed with singular ability the various canal schemes, and offered, if released from confinement, to superintend in person the work at Nicaragua. In 1840 the princely prisoner was liberated, and, going to England, published—under the initials, “L. B.”—a pamphlet, setting forth all the arguments in favor of a canal, and adding the official proceedings by which the government of Nicaragua had vested in him full power to form a company in Europe. The canal was to be “Canale Napoleon de Nicaragua.” The late prisoner was Prince Louis Bonaparte.

The discovery of gold in California gave a fresh impetus to the question. As the new state increased in population, and San Francisco became a large city, the necessity of a highway between the Atlantic and Pacific was again urged. The voyage around Cape Horn was long and dangerous; the overland route, across the Plains, subject to attack from Indians; something must be done to avoid both; the settlers on the western coast needed the provisions of the eastern ports; the merchants of the old states, the gold of the new.

As the result of these arguments, “The Atlantic and Pacific Ship Canal Company” was formed, with Commodore Vanderbilt for its president. A. W. Childs, a prominent civil engineer, was sent to survey the lakes and rivers of Nicaragua. His party was in the field from August, 1850, to September, 1851, and returned to the United States with a very favorable report as to the feasibility of the project. Funds for its accomplishment were not, however, forthcoming and Childs carried his estimates and maps to England, where they were submitted to a commission of engineers, and afterwards to a committee of capitalists, who, though favoring the route, did not judge the plan sufficiently well developed to merit their support. The canal enterprise must have been considerably agitated about this time, for a convention was made between

Great Britain and the United States, in which Mr. Clayton on our part, and Sir Henry Lytton Bulwer on theirs, "define the principles which should apply to an inter-oceanic canal wherever and whenever constructed."

In 1855, Walker's filibustering expedition again drew the attention of the public to the State of Nicaragua; but the "gray-eyed man of destiny," succeeded only in making the inhabitants of the Isthmus look with mistrust upon any so called explorations or surveys.

Ten years later P. C. F. West was employed by the Central American Transit Company, and although his object was simply to devise means for the improvement of the San Juan, and the restoration of Greytown harbor, the maps which were made of that locality have been of value to the late expeditions, as they show the gradual changes taking place during the years that the harbor of San Juan del Norte has been closing.

The first regularly organized expedition sent to Nicaragua by the government, left the United States in the spring of 1872. We all remember who was at its head, and how Crossman and Force found a watery grave amid the surf and breakers at Greytown beach. The command then devolved upon Commander Hatfield. The dry season was half over before the work fairly began; but, by the energy of the officers, three lines on the western side of the lake were partially examined. With the month of July came the rainy weather, and the party returned to the United States to be completely fitted out for the ensuing winter.

On the 3d of December, 1872, the second expedition, consisting of eleven naval officers, four civilians and a force of about thirty men, sailed from Fortress Monroe in the "Kansas."

I would now ask your attention for a short time to the results obtained by Commander Lull and his officers, during the five months that the expedition was on the Isthmus.

The discussion of a Canal through Nicaragua naturally divides itself into three distinct parts; viz. The Lake; the Western Division; and the Eastern Division.

*The Lake.* It is a generally received idea that there is a range of mountains extending the entire length of the Isthmus, forming a complete barrier, through which it would be impossible to excavate or tunnel.

That the Cordilleras do certainly exist in one continuous chain is undoubtedly true, but at one point they sink to low elevations, be-

coming simply hills which skirt the Pacific shore. But as the mountains lose their altitude, the valleys to the eastward gain in depth, forming a basin into which the volcanoes of Costa Rica and Nicaragua pour the vast amount of waters which drain from their lofty sides.

This basin is known as the Lake of Nicaragua or Granada. It covers an area one hundred miles long by forty broad; is in places over one hundred fathoms deep; contains a channel, from its eastern to its western extremity, capable of floating the largest ships; is only one hundred feet above the ocean; and by reason of its magnitude, *is subject to none of those extreme changes of level so common in all small bodies of water situated in the Tropics.*

The distance of the lake from the Atlantic, in a straight line, is seventy miles, from the Pacific only ten; its outlet is the San Juan river, which flows from the S. E. extremity, and after many sinuosities reaches the Atlantic at a point one hundred and eighteen miles from the lake.

Here then, we have a reservoir capable of supplying a *uniform* and inexhaustible amount of water; the gauges of the San Juan showing a flow of over nine hundred million cubic feet per day; whereas the demand could never exceed a thirtieth of that quantity.

Over and above these advantages there is another of great importance. The lake divides the canal into two distinct sections; and, consequently eliminates any danger from a "block;" vessels being locked directly up to the lake where they can remain quietly at anchor, in fresh water, loading under the lee of the numerous islands, with the products of the country, repairing any damages with timber of the best quality, or provisioning for the coming ocean voyage.

The lake is then the great port, and in considering the question of harbors at either terminus it will be well to remember that they can be limited in size to the accommodation of the few ships which may daily arrive.\* This is especially true for the Pacific Division, for if the weather prove inclement, the out-going vessels can remain in the lake, and be locked down the sixteen miles whenever desirable.

*The Western Division.* The portion of the survey which it was anticipated would prove the most difficult of a practical engineering solution, was the narrow belt of land between lake Nicaragua and the Pacific. "Childs' route" was said to be the best, but on the arrival of the expedition every landholder in the Rivas Department whose

\* There are two snug anchorages near Brito, called San Juan del Sur and Nacascola.

property was adjacent to any seemingly low pass presented a claim for a tentative line. From the numerous applications the commanding officer selected the Ochomogo, the Gil-Gonzales, the Lajas, and the Virgen routes as the most likely to prove satisfactory.

As much had been written concerning the merits of the so called "Napoleonic route"—via lake Managua—the difference of level between that body of water and lake Nicaragua was also determined and the land contiguous to the former lake thoroughly examined; the results showing 22.5 feet between the water surfaces of the lakes, and a soil near Realejo so porous that an artificial lining would be required to retain the waters of any canal constructed in that vicinity. These disadvantages coupled with the liability of volcanic disturbances, and the lack of sufficient depth to the northern lake, showed the utter impracticability of Napoleon's scheme.

Of the Ochomogo, Gil-Gonzales, and Virgen surveys little need be said; the passes proved to be much loftier than had been anticipated, while the country leading up to them was far from favorable. They were all thoroughly surveyed, however, and only abandoned after numerous offsets had furnished a complete map of the adjoining land.

While the work had been progressing on the above mentioned lines, a party had also been in the field in the neighborhood of Rivas, examining the valley of the Lajas, and endeavoring to improve Childs' survey, by locating a route along a stream called the Rio-del-Medio. We will not follow the party through the vicissitudes of their camp-life in this region.

Let us suppose the last stake driven, the last station on the Pacific reached, and then stand at the summit of the Rio-del-Medio line at Jesus-Maria. Turning to the north-east, we see lying before us a gentle slope of nearly six miles, highly cultivated, dotted with haciendas, and checkered with a network of well made roads. To the right are the large indigo fields, with their substantial vats, constructed of the best lime—quantities of which are at hand ready for the canal-builder. To the left is the large town of Rivas, surrounded by its beautiful cacao plantations; while stretching to the northward for one hundred miles, and sweeping twelve leagues to the eastward, is the great lake with its cloud-capped, conical island, Ometopec, rising five thousand feet above the water horizon.

If we now turn to the westward, and follow the Medio line along a small ravine, we will find, at a distance of eight miles from the lake, a river flowing towards the east; this is the Lajas, which was surveyed



with great care. The summit level of its *bed* was found to be only forty-four feet above the lake, but the Medio line was preferred notwithstanding its additional excavation; the tortuous course of the former stream, and its narrow, deep channel presenting many dangers during the rainy season. Halting therefore at Las Serdas—instead of following the Lajas—we note that the two lines here become identical and descending through a densely wooded territory reach the Pacific at Brito, sixteen and thirty-three hundredths miles from the lake.

It would occupy too much time and space to go into all the details of the Western Division—details which will be found thoroughly amplified by Mr. Menocal in Commander Lull's Report. It has been seen that the section from the water shed, eastward, is a gentle slope, over well cultivated land, possessing means of transportation, as well as resources for subsisting the force that may be required for canal purposes. The height of the summit level is only one hundred and thirty four feet above the lake level; add to this twenty-six feet, the depth of the canal, and we have one hundred and sixty feet as the "cut" to be made through the Isthmus at Nicaragua. An excavation which certainly seems insignificant. This low summit level, being also so near the lake, leaves ample space for the development of the *ten* locks necessary to reach the Pacific, while the surface of the canal will, for the western slope, be on the average above the present profile—advantages to which it is sufficient only to allude. No large stream interferes materially with the canal, and the valleys are extended enough to give sufficient room for handling and depositing the material excavated.

Brito, the Pacific terminus of the canal, is a town and harbor only in name, the full force of the sea breaking upon a low sand beach, which terminates near the canal-exit in a tall cliff of indurated clay about two hundred and fifty feet high. At the foot of this cliff is a slight indentation of the coast where the Rio Grande empties. The land adjacent to this river is awash at low water for a distance inland of about half a mile. The intention is to dig out this loose sand, dredge the Rio Grande, and throw a break-water out from the base of the cliff to protect the harbor from the S. W. swell. All this will necessitate no little expense, the rise and fall of the tide, (nine feet), bringing an element into the problem, which greatly increases the estimates.

*The Eastern Division.* The work on the Eastern Division actually begins about six and a half miles from the fortress of San Carlos; the combined action of the tributary river Frio, and the drain of the San

Juan towards the south-east, having formed a bar which will have to be dredged to a depth of ten feet to form a channel of twenty-six. This bar has been gradually depositing for centuries, and is composed of a stratum of alluvial matter ten feet in thickness, underlying which is a bottom of hard clay. The outlay in this locality will however be trivial, the lake steamers even now being able to enter the San Juan, through the soft mud.

Here I would say a word as to the system proposed for this Division. As was before stated, the country for a large distance around lake Nicaragua is drained into that body of water, thus making the river San Juan, for the greater part of its course simply an outlet, free from the remarkable changes of level so observable in tropical regions. Dams can therefore be erected along the river without fear of demolition by the freshets of the rainy season. The valley is moreover enclosed by hills sufficiently high to prevent the stream from finding any other course, even if its surface were raised considerably above its present plane.

These facts have been utilized, and slack water navigation effected by a series of dams—four in number.

The first dam is placed at Castillo rapids, thirty seven miles from San Carlos, the water being raised eighteen feet, and becoming the summit level, or one hundred and seven feet above mean high tide. This elevation is also the extreme high water mark attained by the lake.

The two dams below Castillo, at Balas and Machuca rapids, could be of almost any desired height, as the river is here bordered with hills which at places attain considerable elevation; the water surface is to be raised 22.8 and 26.8 feet at each respectively.

The river, scarcely five hundred feet broad, runs for the next eighteen miles, through a narrow, tortuous valley and winds about the base of precipitous volcanic hills. The channel is from eighteen to ninety feet in depth—a canal ready in fact for the average ship. This region abounds with timber of the best quality, while a few miles back whole forests of the *hule*, or rubber tree are found.

At the foot of this section, called by the natives Agua Muerte, on account of its dead still waters, the last dam is placed, the water passing over the crest at an elevation of 23.8 feet above the present surface.

Around each of the dams there will be a short canal with a lock of 10.3 feet lift.

Below the Agua Muerte, the whole aspect of the country changes, the San Juan becoming broad and full of shoals and sand, brought down

by the river San Carlos from the interior of Costa Rica. The canal proper here begins, and, leaving the San Juan with all its silt and detritus, cuts straight across the lowland for Greytown harbor, reaching the ocean level at a distance of forty one miles from the last dam. There are seven locks between slack water navigation and the Atlantic, all of them located in rocky spurs which could not be avoided and were consequently turned to profitable account, the stone being suitable for foundations. The profile in this section was much better than had been expected; the mean excavation for the whole distance being less than two feet above the water-surface of the canal.

At a distance of seven and a half miles from Greytown the ground has a sharp fall of twenty feet, which brings it to the sea level, and the line to the borders of the first, or Silico, lagoon. Between this point and Greytown there is a system of lagoons, separated from one another by narrow marshes and connected by channels through which the tide ebbs and flows: These lagoons average from twelve to fourteen feet in depth, and have evidently been formed by the same causes which are now operating to close the outer harbor. The opening of a canal, deep enough for sea-going vessels, consequently here reduces itself to a question of dredging the alluvial matter and sand which form the bottom of these waters.

We now come to the last and most important feature of the survey.

*Greytown Harbor*, can it be restored? This problem is one of such magnitude, that a thorough discussion of the merits and demerits of the several plans proposed would lead these pages far beyond their proper limits; while modesty alone should make the young naval officer exceedingly chary of opposing the views of older and more experienced men. I will therefore confine myself to a few important points concerning the topography of the neighborhood.

It may be noticed that a small stream, called the San Juanillo, leaves the left bank of the San Juan about twenty six miles above Greytown. This small stream was undoubtedly, in time gone by, the main outlet; it flowed (as it does now during the midsummer freshets) into Silico lagoon, and in course of time pushed out, one beyond the other, the successive *harbors* mentioned above.

At last came an unusual amount of detritus from the San Carlos, which choked the San Juanillo exit, and diverted the whole mass of lake and river water over the low land to the southward. Then the lagoons closed\* and a new system began, only to end in our own day in

\* There is a tradition of an old Spanish vessel which was locked up in

the same results; thus, during the past ten years, Leaf's island, at the bifurcation of the lower San Juan and the Colorado, has been completely washed away, and, in 1873, ninety per cent. of the river flowed through the Colorado mouth, emptying into the ocean twenty miles below Greytown, where the lagoon process is again repeating itself.

The conclusion naturally is, that the San Juan, instead of serving to keep open the harbor of "San Juan-del-Norte," has, on the contrary, been the cause of its destruction; and the mouth of the earth-bearing river being now at a safe distance we have only to deal with the known amount of sand between the town and the Caribbean.

But is the coast current not adding to this amount? No, for we find the anchorage a mile outside to be clay and coral, while the specimens from the beach to the southward show that the light volcanic matter from the mouth of the Colorado is not set up the coast toward Greytown. To further prove that there is no motion of translation, and that the shifting of the bar is entirely local, the shores of the bay at Monkey point, thirty miles to the northward, are formed of a deposit which has evidently been long subject to the action of sea water.

Assuming then that the sand in the vicinity of Greytown harbor is a known quantity, neither increasing nor diminishing, the first step should be to endeavor to fix the inner portion, *above* water, by planting trees, which in a few years would render the whole of *Harbor Head* and *Point Arenas* solid and permanent.

The cost attending such an attempt would be slight, and the rapidity with which vegetation grows in the tropics would soon change the low mangrove bushes, which already cover the greater portion of the beach, into a large, deeply rooted forest.

It will be a more difficult matter to hold the sand now *under* water in place; for the N. W. current and easterly swell are continually setting the bar to the westward and towards the bight where the river channel formerly existed. To counteract this effect it is proposed to construct a break-water, to the eastward of what is known on the charts as *Point Arenas*.

Short jetties are to be thrown out at right angles to this break-water to receive any accumulation of sand and prevent it from drifting round the end and closing the channel beyond.

Whether this plan is feasible or not is a moot-point; as it is also an open question whether or not the action of the ocean would not ultimately fill the *Barco* lagoon, and never able to cross the bar on which Greytown is now built.

mately form a shoal still further to seaward, and off the end of the break-water. Such action would however, be necessarily slow, the jetties taking up the greater part of the sand composing the bar, and the water from the canal making a *clean* current, more or less effective against the encroachments of the sea.

Having thus followed the Nicaragua route from ocean to ocean, I will not dwell upon the financial view of trans-continental communication, nor enter into the commercial advantages to be derived from a ship channel through the isthmus; both of which were so thoroughly discussed in Lieut. Collins' very able paper on Darien and Atrato. The certain growth of our mercantile marine, and the necessity of avoiding the length and perils of Cape Horn navigation will ultimately decide that \$66,000,000 is a small price to pay for the incalculable advantages to be derived from the new route. Let us hope, therefore, that the "secret of the strait," so diligently sought by the bold navigators of the past centuries, may in this nineteenth be discovered at last by the energy and science of the American people.



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Passed-Assistant Engineer W. L. NICOLL in the Chair.

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LIFE SAVING AT SEA.

BY LIEUTENANT THEODORUS B. M. MASON, U. S. NAVY.

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MR. CHAIRMAN AND GENTLEMEN :

I would ask your attention this evening to a subject which may be literally of vital importance to some of us. It seems to me to be one that cannot be too much or too often discussed by sea-faring people. Plans suggested in hours of safety may be put in operation in moments of danger. I do not suppose that there is a man, who has ever been to sea, who has not formed some idea for self preservation; indeed many have written on the subject. My object has been to collect some of these ideas, especially those which seem the most simple and inexpensive, with the hope that in the discussion others may be proposed.

Happily for us there are some men in our country who are devoting much time, thought and energy, to this all important subject. In the foremost rank of these good workers stand the Hon. Sumner I. Kimball General Superintendent of the Life Saving Service, Mr. R. B. Forbes and Captains Merriman, Mc Gowan, and Ottinger of the Revenue Service. There are also two societies which have the matter in hand, the Humane Society of Massachusetts and the Life saving Benevolent Association of New York. In Europe much of the expense of the life saving service is covered by private subscription, with us but little.

Little I am sorry to say has ever been done by the Navy, even to preserve its own members. It seems to me, that next to overcoming

an enemy, the duty of a Naval officer is to protect his friends. A good general always plans his retreat. Why should not a good Naval officer arrange for withdrawing after an unsuccessful contest with the elements?

The Oneida and Huron furnish us with examples of the general ways in which vessels are lost, and, consequently, have to be abandoned and there is no doubt, that, a vessel once irretrievably lost, it is the duty of a commander to save his crew. The circumstances of the Oneida would have been similar if she had been burned, rammed, sunk by shot or torpedoed.

Let us examine these two cases, first seeing what was done to preserve life and then conjecturing what means, had they been at hand, might have been of service. I use the term "had they been at hand" because means must be provided beforehand and ought to be supplied in the outfit of every vessel.

The United States Steam Sloop Oneida (6) left the harbor of Yokohama, Japan, homeward bound, on the afternoon of the 24th of January, 1869. Her crew consisted of twenty-five officers and one hundred and fifty two men. At 7 o'clock that same evening she was run into in the Bay of Yedo by the English merchant steamer Bombay, and being cut into, on the quarter, to the water's edge, sank with twenty two officers and ninety five men, fifteen minutes afterwards. It is not in the province of this paper to discuss the whys and wherefores of this sad accident.

The Bombay, after the collision, continued on her way, her captain testifying that he supposed the Oneida all safe because he heard no sounds of alarm or signal guns.

The persons saved tell us that the officers and men were perfectly cool, that they fell in at their quarters and there remained until ordered into the rigging by the Captain; that one quarter boat was lowered, in which the surgeon and fifteen men got away, the boat being so much injured, in lowering, that she sank as she went alongside of the Idaho. The remaining survivors escaped in the 1st cutter which, fortunately, floated out of her cradle, as the ship went down. We are told that poor Adams after much delay in getting to the magazine succeeded in procuring three cartridges which were fired at least ten minutes after the accident. Capt. Williams' last recorded words were: "What can I do? They would not give me boats when I asked for them." The Oneida, like all vessels of her class, carried but few boats, which had they all been serviceable would have held but a part



of her crew. What boats she had were said to be unseaworthy, having been transferred from other ships on the station, and only two could be lowered directly from the davits and one of these was completely used up in the collision.

Let us now see what means might have been at hand, which would probably have saved most of her crew.

A man who can swim and float can support himself in the water for a long time without assistance, by judiciously husbanding his forces. The simplest means then for immediate preservation would have been swimming; especially in moderately smooth water and with the chance of meeting a floating spar or other part of the wreck. It is curious that such an important element seems to be entirely omitted from the routine drills of the navy and does not even find a place in the minute reports which are made of men's other qualifications.\* The intelligent management of the Naval Academy is obliterating this fault as far as the graduates are concerned and we may hope that some similar practice obtains on board our apprentice ships. Why should it not be found in the weekly routine of every ship in the service? Temperature permitting of course.

A person, even not a swimmer, who has confidence from practice can be sustained almost indefinitely by very little additional buoyancy. We have many different inventions which give such aid, but most of them require additional space, a coveted article in a crowded ship, and would generally be stowed where they could not be gotten at when really wanted. Every person on board has a bed of some kind, the man his hammock and mattress, the officer his mattress, these converted into life preservers are always on hand and take up no additional room.

Rear Admiral Ryder, R. N., first proposed the use of the hammock, in a short paper, published in volume XV of the Journal of the Royal United Service Institute, in which he says that at his request Com'dr. Cyprian Bridge, of the Caledonia, carried on some experiments and found; that, a rather new cotton hammock supported seven naked men for some minutes—four men for a considerable time—and believes that it could have continued to do so for an hour. Captain Arthur Wilms-

\* A boatman was once badgered by a student who informed him that because he could not read nor write at least half of his life was *wasted*. The boat soon after sinking the boatman asked the student if he could swim, the answer was in the negative. Then said he the whole of your life is *gone*.

hurst of the Valiant found that a hammock with a six pound shot attached to one end, a most trying test, sank in five minutes. The buoyancy of the hammock at first being 113.74 lbs. The same shot suspended from the middle of the hammock was sustained nine minutes. The ticking of the mattress was then oiled, and the hammock supported the weight two and a half hours. It can easily be imagined that a hammock capable of thus supporting a dead weight, would be of great use to a man.

By filling the mattress with cork shavings, which are very cheap, generally being thrown away, additional buoyancy may be obtained. A mattress six feet by four feet stuffed with this material weighed twenty pounds, its buoyancy was sufficient to support eighty pounds dead weight, indefinitely. The cost of the mattress was one half that of a hair one. Cocoa fibre has also been used with good results.

Cork mattresses 5 ft 6. × 1 ft 10 and three inches deep (hammock size) stuffed with granulated cork, weighing thirteen pounds and having a buoyancy of sixty pounds, are now issued to the Royal Navy.

Captain E. P. Wilson, R. N., in his account of the burning of the Bombay says that, had the idea occurred to them to use the hammocks, all hands might have been saved; as it was only those in the davit-boats were. It was impossible in this case to get the boom boats out on account of the burning of the tackles.

Admiral Ryder, in his pamphlet on "Life saving at sea by cork mattresses," tells us that the best way to use the hammock, for one person, is to secure the clews together, forming a ring, care being taken to have the lashing on the exterior in order to tauten it. A hammock secured in this way will support, not only the man in it, but, two other persons hanging on at the outside. If the precaution is taken to fit a piece of stuff for a seat, the person may even safely indulge in sleep. As with all life preservers a person must be satisfied in having his head and shoulders out of the water. Two hammocks are best secured together at the ends, the men placing themselves between them with one arm over each.

Mr. R. B. Forbes, in a letter to the Army and Navy Journal of January fifth, and in his pamphlet, "The Hammock as a life Preserver," tells us, that a cotton canvas hammock containing a mattress composed of cork shavings, sustained one hundred and sixty pounds of iron six minutes; ninety-six pounds ten minutes; sixty-two pounds one hour and five minutes, and thirty-two pounds indefinitely. The same hammock and bed put into a close woven cotton bag, subjected to a process of water

proofing, was sustained one hour and twelve minutes with one hundred and sixty pounds against six minutes as before stated; eight hours and a half with ninety-six pounds, against ten minutes, and with sixty-two pounds four hours against one hour and five minutes, it will be seen, thus, that, the hammock and mattress in the bag floats nearly four times longer than without it. A further test showed that a common hammock with the usual hair mattress, when put into a bag, floated twenty-four hours with one thirty-two pound shot. Twenty hammocks thus provided, lashed to spars, would float a two thousand pounds anchor and a hundred would float the largest anchor in the navy.

Further careful experiments showed that a cotton canvas bag, water proofed, containing a cork mattress, supported two thirty-two pound shot twenty-nine hours and forty minutes, and, with the common hair mattress, it remained above water ten hours and thirteen minutes with the same weight.

Mr. Forbes also makes some valuable suggestions in regard to the construction of rafts, using spars and hammocks.

Lieut. Commander F. W. Dickens, writing to the Army and Navy Journal, objects to Mr. Forbes' bag, as superfluous at all times except shipwreck and unserviceable if the hammocks should happen to be "down" at the moment of danger. He proposes instead a cork mattress with waterproof ticking and a waterproof clothes-bag, the officers being provided with similar bags for soiled linen receptacles.

From all the foregoing evidence it would seem that, in some form of the hammock, we have a serviceable life preserver. The cork mattress covered with a waterproof ticking, [this ticking to be furnished with straps so that it could be used separately from the hammock if necessary,] the hammock itself being also treated with a water-proofing mixture to add to its impenetrability and to preserve the bed clothes at exercise appears to me to be the best.

The objections that can be raised to the system are first, the hardness of the bed. Few I think would complain of this however if they fully realized the advantage to be derived in the time of danger; second the supplying of a convenient conveyance for deserters; as such it would really be doing double duty, ridding the service of bad men as well as preserving the good.

Had the hammocks of the Oneida been fitted as life preservers every man on board might have been saved and we should have had a useful realization of a witty caricature, in a late number of Punch, showing

a naval commander swimming off at the head of his officers and men, a sinking ship being shown in the background.

At sea, far from the land, it would be necessary to have boats, as provisions would then have to be provided for. It is evident that a ship cannot carry enough boats of the present style, to stow all hands, and then again the only boats, that can generally be used in an emergency are those that are all ready for lowering, time and the elements generally preventing elaborate proceedings. But when the additional misfortune of the boats provided being unseaworthy from long service or damage, or from the iniquitous system of taking the best boats of a homeward bound vessel to supply deficiencies on the station, a system sometimes rendered absolutely necessary by force of circumstances, befalls the luckless mariner, he is to be pitied. We should indeed look for improvement. Large bolsas and life rafts would seem to fill this void. But they are cumbersome and take time to fill or fit. The Rev. E. L. Berthon has invented a collapsing boat, a full description of which with illustrations will be found in volume XXI of the *Journal of the Royal United Service Institute*. This boat, consisting of a frame work of wood or iron and a skin of heavy canvass, is built of almost any size; stows in very small space; is light and easily handled. There need never be a lack of them, on foreign service, as they can be easily transported and stowed. A sailmaker can always rebuild them if necessary. They have been adopted in the English navy and transport service, especially for the troopships. An excellent lowering apparatus is provided which first expands and then lowers them.

If the present style of boat is to be depended upon they should at least be fitted partially as life-boats, roomy and perfectly seaworthy, not being built entirely for looks and speed, the latter quality being transferred to the ship. They should be fitted so as to be quickly and easily lowered, no lifting being necessary. An excellent lowering apparatus is proposed by Mr. G. G. Laurence of Dundee, a full description of which will be found in the *Engineer* for Dec. 14th 1877. The U. S. patent office could no doubt also provide some good patterns, of home invention; in fact there is now a first rate plan in operation on board some of the New York ferry boats.

And now in regard to the fact that the Bombay heard no sound of distress or signal gun. This was due in the first case to Naval discipline and was perfectly proper; but that a man-of-war should take ten minutes to make a recognized signal for assistance, when that assist-

ance was really needed, was not proper. Means of firing guns or rockets should always be at hand. That this is not the case we all know; powder is too much feared by its friends. We have all seen a lantern put out three decks away from a magazine which was to be opened. Powder in a tank on deck cannot possibly be more dangerous than a turpentine chest. As the cartridges might be drowned in a heavy sea or the primers might miss, it would be well to have special life saving and signal cartridges prepared, contained in metal cases, fitted with friction primers, a gun or mortar with an axial vent being provided for their use. The rockets should also be fitted with friction igniters.

Let us now turn to the sad story of the "Huron," so fresh in all our memories. It is hardly necessary to recount the events of that fearful night off Currituck. Many of us lost friends, noble fellows, who, if proper appliances had been at hand, might yet be with us.

Her crew should all have been swimmers and her hammocks life preservers. Her boats should all have been properly fitted. These precautions are enumerated, as they might, as a last resort, have saved life. As a general rule, however, none of them should be used. The records of our life-saving service show us that they are the most dangerous methods. The hawser with its life car or breeches buoy being generally the safest conveyance. In order to use these, however, it is first necessary to establish communication by means of a small line. This communication once established the crew are almost always saved.\* It is now the custom to send this line from the shore to the ship, but a slight study of the subject will show us that the contrary method is by far the easiest. From the shore the line sent through the air has to come against the wind, the accuracy and aim being thus greatly lessened; the ship is a much smaller target than the shore; the apparatus has sometimes to be conveyed miles under the most distressing circumstances whereas on the vessel it is always at hand one man being enough to do the shore work. The medium of the water, by means of current, wind and sea is entirely precluded from the shore, whereas from the ship it may be of the greatest service. It would therefore seem that every vessel, either in the name of humanity or by

\* The records of the Life-saving Service show a total of eight hundred and seventy one lives saved by its different contrivances in the fiscal year of 76-77. Thirty nine lives were lost on the coast, all whilst they were endeavoring to get ashore by boats or swimming with or without life preservers.

force of law, should carry some contrivance for conveying a small line on shore.

Many methods have been proposed, let us proceed to examine some of them.

Although the attempt is extremely uncertain and hazardous, a strong man and expert swimmer, as in the case of Ensign Lucien Young, might succeed by means of a life preserver, Merriman dress, spar or bolsa in carrying the line. Young would undoubtedly have succeeded had a proper line been provided. The danger to a swimmer is from the surf, a life preserver only adding to this danger as it keeps the man on top of the water and does not allow him to gain a footing. At any rate, lines, of at least two hundred fathoms in length, should be provided and kept on reels ready for such emergencies. These lines should be kept covered, so that they may be as light as possible when wanted for use.

Casks, spars and even boxes have sometimes been used with success, but the difficulty with them is, that they are kept back by the drag of line ; that once ashore they are drawn back by the undertow ; that the coast current, which generally exists, carries them in a diagonal direction, expending all the line before they can reach the shore. Mr. Kimball proposes a very simple apparatus which he describes as two planks shaped and placed like the runners of a sledge joined by battens at the top. These obviate the first objection, by advancing easily when aground but receding with difficulty. To add buoyancy a water cask or scuttle butt tightly closed is fastened to the forward part. At the after-end a reel, of new manilla line, is placed with its axle vertical, the bitter-end being made fast on board. The line unreels from the float, thus obviating the second difficulty. The third, he says, it will not surmount. I would propose the addition of a small sail which if the wind were on shore would probably remedy the difficulty. An inextinguishable light of some kind would also show the point of landing at night.

Commander Howell has suggested that in shoal water a howitzer carriage, fitted with a plank screen to add to the surface exposed to the advancing force of the waves, might be used.

A congreve or other rocket float such as proposed for torpedoes might also be successful.

The air is, however, the best medium of communication. Here, if our apparatus is good, we have everything in our favor.

Captain Nares R. N. proposes a kite made of canvass with a wooden

frame, a tripping line is fitted to dip it on getting over the land so that it will descend and be caught by those on shore, this might be made self attaching by adding a small grapnell to the tail. The mortar is advocated by our Life-saving Service on the score of cheapness and is being daily improved upon. The latest development, reported by Lieut. Lyle of the Army Ordnance, who is detailed to make experiments in this line, is a III inch M. L. R. weighing, with its bed, one hundred and ninety pounds. With this he has thrown a line six hundred and ninety-four and two thirds yards. Direction and force of the wind not stated. The line used is similar to that lately adopted, in the service, for signal halliards, being supplied in two sizes; the first, .22 inch in diameter, ninety threads; the second, .13 inch in diameter, twenty-seven threads. With the mortar it is necessary to have a pin board from which to pay off the line. A gun of this kind would answer for saluting and signalling aboard unarmed vessels. I think that the metallic cartridge and friction primer would add to its certainty in a case like the Huron's.

Mr. Forbes has just sent me an account of a mortar or firing tube, invented by a shoemaker of Weymouth, which would seem to have accomplished wonders. It consists of a pipe or tube of brass closed at the lower end, and fitted so as to be stuck up on the deck, on a block, or in the earth. Its weight is twenty nine and a half pounds. A charge of three ounces of powder is used. The projectile is a hollow tube three inches in diameter closed at one end, toward the charge: in this tube is coiled one hundred and fifty yards of small line the end of which is made fast to about three feet of a larger one strongly twisted: this latter passes out of the muzzle, over the fork, in the end of a rod, attached to the top of the gun, and is then secured to the end of a second small line of one hundred and fifty yards, which is coiled in a cylinder held in the hand of the operator. The line is treated with parafine. With this little apparatus a range of one thousand five hundred feet is said to have been obtained.

In an emergency, a gun, loaded with an empty shell, in the fuze hole of which a length of small chain should be toggled and a line fastened to the chain, might be used, the charge of course being greatly reduced. Or, again, a projectile might be extemporized by winding up the end of the chain into a ball of the required size, marling and covering it with canvas. For short distances the ramrod of a musket might be used.

Another favorite plan is the rocket. The English Hooper rocket,

very similar in construction to the original Boxer, has given excellent results. Its range is about four hundred and ten yards, weight about seventy pounds. This is being introduced for trial in our Life-saving Service.

The Germans have two kinds of rockets made at Spaudan. Of the first called the rescue rocket, there are two sizes one 3.15 inches the other 1.97 inches in diameter, weighing 41.87 pounds and 15.43 pounds, ranging five hundred and fifty, and three hundred and thirty yards. The second kind, called the anchor rocket, is fitted with a four armed anchor and can be used for hauling boats out through the surf or for attaching lines on uninhabited coasts.

The Russians have a rocket weighing twenty-eight pounds, with a range of five hundred and seventy yards.

In carrying on some experiments last spring, to find a method for conveying lines over a building, I found that, by attaching an untarred spun-yarn line to our common navy signal rocket and firing it at small angles, a range of over one hundred yards, running out three hundred yards of line, with remaining energy enough to carry quite a heavy pin board some distance, could be obtained. Even this might be of use.

The rocket would seem to have advantages over all the other methods; especially in the confusion of a wreck where a gun could not perhaps be trained or a mortar planted or steadied.

Lieut. Comd'r Dickens proposes a ball of unquenchable fire, which, when thrown in the water with the patch removed, lights up the surroundings for a great distance. This if used on board the Huron might have saved the valuable hours wasted, in waiting for day light, to find the shore.

Once the small line on shore a whip can be hauled in either direction by which the hawser is conveyed. Every ship could carry a breeches-buoy; if not, one could be easily extemporized with a hammock life preserver with a bag attached to stand in. The breeches-buoy is hauled along the hawser by means of the whip, the preserver being added to keep the passenger afloat in a very heavy sea.

Although we have deprecated the use of ships boats and individual efforts with life preservers there is one method which would seem to be feasible. The hammocks, being made buoyant, could be secured together, side by side, by attaching the clews to lines at either end; with a large number, two, or even three rows thus formed could be joined together. This raft being flexible would take the conforma-



tion of the surface and would not be open to the danger of pitching—a defect which exists with even the best life-boats.

Thus far we have only considered what could be done from the vessel. On shore much is done to assist ships in distress. In order to understand what, we must here make a brief retrospect. In 1791 the Humane Society of Massachusetts was incorporated for the purpose of rescuing ship-wrecked mariners. This society erected and equipped life saving stations and shelter huts on the coast of their own state, the expense being defrayed by private contributions. Many lives were saved by its volunteer crews. Even in this year we find seventy-six life saving stations and eight shelter huts are maintained by it. In 1848 the general government turned its attention to the subject and by small appropriations fitted out and maintained a number of stations. These stations were, however, wanting in many of the necessary features and were manned entirely by volunteers whose attendance could not always be counted on and who allowed the apparatus to deteriorate. The Life Saving Benevolent society of New York, incorporated March 29, 1849, like its sister in Massachusetts, established stations on the Long Island and Jersey coast, many of which are still in use. In 1872 the present very efficient and growing Life-saving Service was organized. The work done seems almost incomprehensible in view of the smallness of the appropriations. To Mr. Kimball, the General Superintendent, and his assistants, the greatest credit is due. We know little of the difficulties which they have had to surmount. Results are the best means by which to measure the value of an institution. Wherever the proper development has been afforded, by legislative action, the success has been wonderful. The coast of North Carolina is the weakest point now, and Mr. Kimball is using every endeavor to get money to render it as humanly secure as the rest of our shore line. Those who have the work in hand, are fully competent to make the needed improvements, if only they have the means given them. They want assistance and it would seem particularly appropriate that we of the navy should do what we can for them by word or deed.

The coast from Maine to Florida is divided into seven districts. Each district is in charge of a superintendent and the large ones have, besides, an assistant. It is the duty of this superintendent to be always on the go inspecting and drilling his crews.

This duty seems to be creditably performed. There are besides these superintendents several general inspectors, who are as a rule taken from the Revenue marine.

The districts are as follows:—

No. 1, Maine and New Hampshire, six Life-saving Stations.

No. 2, Massachusetts, fourteen Life-saving Stations.

No. 3, Rhode Island and Long Island, thirty-six Life-saving Stations.

No. 4, New Jersey, forty Life-saving Stations.

No. 5, Delaware, Maryland, and Virginia, to Cape Charles, eight Life-saving Stations.

No. 6, Virginia, from Cape Henry and North Carolina, ten Life-saving Stations.

No. 7, Florida, eight houses of refuge.

The eighth, ninth and tenth districts are on the great lakes, and the eleventh is the coast of California and Oregon, furnished with eleven life boat stations.

In the second district besides the government stations are those of the Humane Society.

There are three classes of stations.

First, Life-saving Stations:—Situated in localities remote from settlements, furnished with every possible appliance for rescuing the shipwrecked, and ministering to the immediate necessities and comforts of those saved. They also furnish quarters for the keepers and crews. On account of the limited means at the disposal of the management, the stations are manned only during the winter months. That this is unwise, although necessary, the Huron disaster showed. The crews now consist of six surf men besides the keeper.

Second, Life boat Stations:—located near settlements where volunteer crews can easily be summoned. These are furnished with boats and such other appliances as the nature of their situation calls for. The stations of the 11th district are of this nature.

Third, Houses of Refuge:—Situated in desolate localities, where the general state of the coast does not call for the use of the appliances furnished to the other classes of stations. These are intended to afford shelter to those who may come ashore. They are provisioned and supplied with medicines, blankets, beds, &c. Small boats are placed in them with which to reach points of safety or passing vessels. A keeper, with his family, resides in them.

Some of the stations are connected with the Weather Signal Service, and are used as warning posts for passing vessels: this feature should be extended to all of them, and if the International code flags were added to the outfits, vessels could communicate with any part of the world from many points on the coast. A shore line of telegraph

should connect the stations with each other, this line being besides fitted with alarm boxes on the poles, would serve for the patrols to send in signals of distress from wherever they might be.

The small surf-boat is used at almost all the stations. Our coast is so sandy and rugged that it is impossible to transport life-boats weighing generally four or five thousand pounds. The surf men are also familiar with this style of boat and seem to place more reliance in it than in any other. The smallness of the crews renders even this very difficult of transportation to any distance. Where they can be hired, horses are used, but where they are most wanted they cannot be obtained. It is recommended that four horses be kept at the stations on the most exposed and desolate parts of the coast. The patrols could ride two of these horses, the other two being always in reserve to bring out the apparatus.

The men, as we have before stated, are employed for only a part of the year. This necessitates the breaking in of new crews every season. The pay is small and the work most arduous, which prevents men from reshipping. It is now proposed to regularly enlist the men; employing them in the off months in drilling, making a coast road, building stations, repairing apparatus, putting up telegraphs and patrolling the coast, in case of a possible accident, or to prevent smuggling. The crew as it now stands is too small. Two men are always on patrol; in case of an alarm one or both of these will be absent. The beats at present, in some localities, are longer than can possibly be watched by one man, often reaching a length of eight miles. Then again no leeway is left for the sick list or unavoidable absence. By a regular system of enlistment good crews could be obtained from districts where plenty of men are to be found, and transferred to those where the material is poor.

The appliances furnished at a complete station are:—

A surf-boat fully equipped, boat carriage, mortar and appliances, pin board with line, sand tarpaulin and pegs, whip and hawser. Sand anchor, tackle and crutch.

Signal flags, lanterns and coston lights.

Beach light.

Life car, life raft and breeches buoy, medicines, tools, provisions, blankets and beds, also

A hand cart, in which those of the above named articles, except the boat, that are required at the scene of action, are conveyed.

The boat is used when advisable ; chief reliance however is placed in the line.

The method of proceeding is as follows :—three hundred fathoms of line are coiled on a pin board, the different layers running clear of each other and paying off of the pins. This board is placed to windward of the mortar, and the end of the line is attached, either by means of a spiral spring, or directly, to the projectile. The latter method has proved the most certain ; care is taken to wet the end of the line to prevent its burning. The projectile is elongated in shape, the line coming to the outer end which protrudes from the muzzle. On starting, the projectile first turns over so as to bring the line to the rear. The mortar is trained so as to point between the masts of the vessel. Should the first shot miss, the line is run in and coiled on the tarpaulin, which is pinned down to the ground with tent pegs.

The line, having reached the vessel, is hauled upon by those on board, the whip block having been attached to the shore end. Attached to the block, is a board or bottle with directions in English, French and German for making it fast. The block is made fast as high above the deck as possible, by means of its tail. The next operation is the hauling out of the hawser ; done by those on shore, who have first taken the precaution to join the two ends of the whip. The hawser is made fast to the mast above the tail block. As soon as “all fast” is signalled, from the vessel, the shore end is hauled hand taut. The sand anchor, two pieces of heavy plank crossed and fitted with an eye bolt at the intersection, is planted in a trench. The crutch is then set up ; the hawser being taken over its crotch. The tackle is clapped on to the hawser, and hooked to the sand anchor. If the vessel is rolling, it is necessary to tend the tackle, if not it is set taut and belayed. The life-car, which is like a small life boat with a cover, is then suspended to the hawser, hauled out to the wreck by means of the whip, the bight of which is made fast to a traveller ; when loaded it is hauled ashore again by the other part of the whip.

The car is necessary when there are landsmen, women, children or invalids to be conveyed ; for seamen the breeches buoy is used. This is a large cork life preserver with a pair of canvas breeches attached, the man sitting in it. This buoy, may be used on the whip alone, if necessary.

We can easily see, how, especially in the case of a man-of-war, much of this operation might to advantage, be reversed.

The rescued persons once ashore are taken to the station and cared

for. One necessary article is omitted in the supply list, that is clothing of a rough, but warm character. Many of the saved come on shore naked or nearly so. Would it not be a good thing for us to direct our charities toward supplying this want?

And now gentlemen, as I know you would like to have a look at the practical working of the system, let me invite you to put on your warmest clothing, your oil skins, and your sea boots, and come with me this evening, to the lonely coast of North Carolina, not quite so lonely as it was on the night the Huron was lost. The patrol man of the nearest station, which is eight miles off, is now there. But see, he is looking to seaward. He thought just now that he saw the gleam of a light. He was right. Almost blinded by the salt spray from the sea mixed with sand from the beach, he is able to make out a vessel's lights and to add to his certainty, there goes her gun. She is heading right in for the breakers and will ground in a few seconds. The patrol burns his coston light to show them that they are seen. More he cannot do until he summons assistance. He starts for the station and after weary hours of toiling, which can only be appreciated by those who have tried such a journey, on our coast in a winter's storm, he reaches his destination. The alarm is given, and in a few minutes the crew start with their apparatus. Six men, all told, one being far away to the westward on patrol, and cannot be recalled, and one of this small number is already exhausted by his previous endeavors, dragging a hand cart far heavier than our heaviest howitzer to which we allot, under favorable circumstances, at least sixteen men. After tugging through sand and floundering in mud, sometimes entirely halted by the storm, at all times straining every muscle, they reach the scene of disaster. There they find that hours before, the vessel has gone to pieces, and all that they can do, is, to save a few corpses from the surf. Could human beings have done more with the means at hand? And when we know that these men get for such work a sum of \$ 1.33 a day, for five months in the year, can we say that they have not fully earned it. Yet with all this, to-morrow the opinion will go forth, from the pens of a hundred well clothed and comfortably lodged gentlemen who value their writings at the sum of a penny a line, that the U. S. Life-saving Service is a fraud, the organization is bad, the officers are insufficient, the crews are poor, and the patrolmen negligent in the performance of their duties. Now should these same gentlemen devote their vast energies to assisting the Service, instead of belittling it in the popular opinion, how much could be gained. The lesson would be

taken to heart ; public sentiment would come to the aid of the organization ; appropriations would be increased and every thing done to make such another accident impossible. With such aid to carry out the plans already matured, we should have another story. The patrolman two, or at most three miles from his station would have dismounted from his horse, going to the nearest telegraph pole, he would have sent in the alarm ; burnt his light ; and watched for the line to come ashore ; he would then have attached the line to his horse and with his aid have hauled in the whip. In the meantime, the crew with the apparatus drawn by two good horses, would have arrived by an excellent coast road made by the men in summer. The hawser would then be sent out, or one might be hauled ashore from the ship if it could be gotten at on board. The car then attached and hauled out, the horses being used to assist ; it would then come ashore, and when opened who knows but what young Simkins, son of Congressman Simkins, and Mr. Hardcash, the great banker and beloved friend of Senator Smith, might not be found comfortably ensconced therein. What a comforting thing it would be, to Messrs. Smith and Simkins to think that they had both voted for the increased appropriation, and a bill for the further perfecting of the United States Life-saving Service. Who knows but we ourselves or our companions may some day need the life car ? Let us this evening decide that whatever we can do to help on this good work, we will do. Let a question of rank or precedence arise, and it finds plenty of friends and opponents. This subject may be of far more importance to some of us in the future.

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Commander A. T. MAHAN in the Chair.

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A BRIEF ACCOUNT OF THE PROGRESS OF THE ART  
OF NAVIGATION.

BY LIEUTENANT COMMANDER ALLAN D. BROWN, U. S. N.

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Navigation is defined by one of the old writers upon this subject to be "the art of conducting a vessel from one port to another in the safest, speediest and most accurate manner, as wind and tide shall serve." This definition is somewhat open to the objection that it brings in the practice of the kindred art of seamanship, with which indeed the practice of navigation is most closely allied. The modern lexicographer defines it as "the art of conducting a vessel from one port to another." Inasmuch as this definition seems to be open to the same objection as the earlier one, I would suggest the following, as defining more clearly the part which navigation properly takes in passing by sea from port to port. "Navigation is the art of determining the position of a vessel upon the ocean at any given time, and obtaining the direction to be pursued from such position to reach any given point."

With the purpose of recounting briefly the various steps in the progress of this art, (from the days when creeping timidly along the coast, the navigators of the past rarely ventured out of sight of land, to the present time when no ocean remains untraversed by the keel of the adventurous mariner, save the waters of the so called Palæocrystic sea, the barriers of which let us hope the genius and daring of the Ameri-

can navigator will yet triumphantly surmount,) I propose to consider the subjects of

- First, the CHART ;
- Second, the COMPASS ;
- Third, other INSTRUMENTS ;
- Fourth, the RECKONING.

#### THE CHART.

The first map of which we have any record was constructed by Anaximander of Miletus, about 610 B. C. ; in the state of geographical knowledge existing at that date, this map could have been but rude and imperfect, yet it served its purpose until improved by Eratosthenes, three and a half centuries later. On this map were placed parallels and meridians, not as we place them, at certain fixed intervals, but simply through places whose relative position had been as well determined as possible at that time. There was, therefore, no prime meridian, and the differences of longitude only were given, and (naturally) in the great majority of cases incorrectly. Strabo, writing about the beginning of the Christian era, in reviewing the work of Eratosthenes, seems to have no fault to find with the methods upon which the maps of the latter were constructed ; but he confines himself to the correction of the positions assigned to several well known points. In this connection he makes the following assertion ; “ if the extent of the Atlantic ocean were not an obstacle, we might pass by sea from Iberia to India,” which is remarkable as antedating the ideas of Columbus more than fourteen hundred years. Eratosthenes admitted the rotundity of the earth, but made his chart as if it were a plane, asserting that beyond the then known regions the world was uninhabitable. Later (A. D. 150) Ptolemy constructed a map in a more elaborate manner, placing parallels and meridians at equal intervals of five or ten degrees, and causing the meridians to converge in their approach to the regions remote from the equator ; there seems to have been no fixed method by which this was done ; it shows however, that some dim ideas of the correct principles of cartography were prevalent, even at that early day. For Ptolemy says, “ that the degrees of longitude should bear in some measure that proportion to the degrees of latitude, which the magnitude of the respective parallels bears to a great circle of the sphere.” These maps sufficed for the use of the navigator, so long as his voyages were confined to coasting ; but were of but little use to him after the invention of the Mariner’s Compass enabled him to pursue his way across the water remote from land ; accordingly soon after the begin-



ning of the impetus given to the progress of maritime discovery, by the aid of that useful instrument, we find that the sea chart came into use.

This chart was the projection of a spherical zone upon a cylinder whose axis was parallel to the axis of the earth, and whose elements intersected the sphere in the middle latitude of the zone under consideration. Upon this chart the parallels and meridians were at right angles: the length of a degree of latitude was assumed to be the same in all latitudes, and was taken on the chart, as sixty minutes of five thousand feet each: the length of a degree of longitude was computed from the formula  $L' = L \times \cos$  middle latitude, thus carrying out Ptolemy's principle before referred to. The middle parallel was thus developed in its true length in minutes, but all the others were inaccurate, and the true relation of the parallels and meridians being shown only at the middle latitude, the courses laid down upon the chart were very inaccurate.

The introduction of this chart is ascribed to Prince Henry the Navigator, (A. D. 1400), to whose patronage the navigators of that age were greatly indebted, and to whom Portugal owed the leading position which she then took among the maritime nations. It is evident that this chart must have been, (except for a few degrees on either side of the equator) in the highest degree inaccurate, and but slightly to be depended upon, as being only better than nothing. It was not until one hundred and fifty years later that any marked improvement was made. Yet, during this century and a half, the progress of maritime discovery had been most great: the new world had been brought to light by Columbus; the Cape of Good Hope had been doubled by Vasco de Gama; the earth had been circumnavigated to the westward by Magellan; and the adventurous navigators of every nation had pushed their vessels far beyond the expectations of the most sanguine, thus enlarging the commerce of their respective countries, and preparing a favorable reception for the improvement in the chart introduced by GERARD MERCATOR in 1556. Mercator's original chart, though a most decided advance, was yet full of grave errors; inasmuch as his table of meridional parts was very far from accurate, and consequently his degrees of latitude were not properly expanded.

Although so especially designed for the use of navigators, Mercator's improvement met with great opposition among the very class who were to receive most benefit from it. Some saying, "that by augmentation of the degrees of latitude toward the poles, it is much

more fit to behold for such as study in cosmography, by reading authors upon land, than to be used in navigation at sea."

Some forty years later, just at the close of the sixteenth century, EDWARD WRIGHT of Caius College, Cambridge, published a work entitled, "Certain errors in Navigation detected and corrected." In the preface to this work he says, "By occasion of the first map of Mercator, I first thought of correcting so many errors, by increasing the distance of the parallels from the equinoctial towards the poles, in such sort, that at every point of latitude in the chart, a small part of the meridian might have the same proportion almost to the like part of the parallel, that it hath in the globe. But the way how this should be done, I learned neither of Mercator nor of any man else." It would seem to be then, an indubitable fact that to Wright is due the credit of constructing a chart after the proper method. In the body of his work he shows that "the length of a minute on the proper meridian must be to the length of a minute on the enlarged meridian as the radius to the secant of the latitude." Upon this theory he constructed his table of meridional parts, supposing the earth to be a sphere. At a later day, when it was determined that the figure of the earth was that of an oblate spheroid, new tables were constructed in consonance with that fact, and these are the ones now in use for the construction of the ordinary sea chart. Other methods of developing the surface of the spheroid upon a plane have been used, each of which has its particular advantages; but for a chart which is to comprise a large extent of the earth's surface, nothing has been devised superior to WRIGHT'S; its disadvantage of the distortion of the surface in high latitudes being far outweighed by its chief merit that the loxodromic curve is represented upon it by a straight line. For surveying purposes, and for a comparatively small area, the ordinary polyconic of the U. S. Coast survey is unquestionably the best; but for large areas and for the general use of the Navigator, WRIGHT'S must be conceded the precedence.

#### THE MARINER'S COMPASS.

It is entirely unknown to whom is to be attributed the invention of this instrument, so indispensable to the mariner and without which it hardly seems possible that mankind could have reached their present state of civilization. Various have been the speculations upon the matter, with equally various results. The attractive power of the loadstone or magnet was well known centuries before the Christian era: but when the knowledge of its directive power was attained is entirely uncertain

The Chinese claim to have been acquainted with it twenty-five hundred years B. C., and to have used the compass on land since that date: no mention is made in their chronicles of its application to purposes of navigation, until about four hundred years after the birth of Christ; it being stated that at that date "ships were directed to the south by the needle." It is perhaps doubtful if these claims can be substantiated, and we must look to a later day for more authentic information. A writer of the year 1242 states that "the captains who navigate the Syrian seas use a needle to point out the North and South when the stars are obscured;" this was accomplished by placing a needle, immediately after being touched with the loadstone, upon a float of wood in a basin of water.

A manuscript of a date later by a quarter of a century (1269), gives an accurate account of a compass, with an alidade attachment for obtaining the bearing of any heavenly body: in this instrument the needle was not suspended freely, but was inserted in a vertical axis, so that its motion must have been very sluggish indeed. The author of this manuscript was also cognizant of the variation of the Compass, for he says; "Take notice that the magnet, as well as the needle which has been touched by it, does not point exactly to the poles, but that part which looks toward the North declines a little toward the East; the exact quantity of this declination, I have found to be five degrees." If the date assigned to this manuscript be not incorrect, it would seem strange that all knowledge of such an important item as the variation should have been entirely lost two centuries later; for the discovery of the variation is generally ascribed to COLUMBUS, who noticed it in his first trans-atlantic voyage in 1492; it was again discovered independently by SEBASTIAN CABOT in 1497; if we admit the authenticity of the above mentioned manuscript, these were only re-discoveries of that which had been known two hundred years before.

It is probably true that the land compass was known to Europeans at the beginning of the 14th century, but it was not, so far as can be ascertained, applied to nautical uses before that time. In 1362 FLAVIO DE AMALFI made what was probably the first step toward this application; he invented the attachment of the compass card or fly to the needle; and hence he is generally considered as entitled to the honor of being the inventor of the *Mariner's* compass. His compass card was however divided into but eight points; the present sub-division into thirty-two points being of more modern origin.

The dip of the needle was discovered by Robert Norman, an Englishman, in 1576. About 1600, the first extended series of observations upon the variation was undertaken, by direction of Prince Maurice of Nassau, Lord High Admiral of the United Provinces; he ordered all seamen under his jurisdiction to be particularly careful to observe the variation, and on their return from their voyages, to report the results obtained to the Admiralty, in order that they might be collated, compared and published for the benefit of all mariners. As late as 1622, the change of the variation at any place was entirely unsuspected, it being supposed to be a constant quantity; but in that year Gunter found that since the latest observations of Norman a change of five degrees had taken place; this discovery was not then made public, but the observations were recorded for future reference. Thirteen years afterward (in 1635), Gunter's successor renewed the observations and found the change still going on; the results obtained by both observers were then published to the world. Various theories have from time to time been advanced as to the cause of the polarity of the needle and of the annual change of the variation, to enter into any description of which is foreign to the purpose of this paper; Professor Airy, however, sums up the results in the statement that "we must express our opinion that the general cause of the earth's magnetism still remains one of the mysteries of cosmical physics." As we shall afterwards see, it was for a long time hoped that through the variation of the compass might be solved the difficult problem of the finding of the longitude at sea: but it was found to be an inadequate means to this end, and was finally reluctantly abandoned.

The deviation of the compass on board ship seems to have been noticed by Dampier in 1680, and again a century later (in 1769) by Cook; but it was not until the beginning of the present century that Captain Flinders, R. N. called the particular attention of seamen, "to the influence upon the compass of the ferruginous matters on board ship." The later history of the deviation and of the methods of obtaining it, are so familiar to the members of the Institute that it is unnecessary to do anything more than merely mention the fact of their existence.

The needle, as we have seen, was first floated upon wood in water; the next improvement consisted in suspending it by means of a silken thread; and the method of balancing it upon a fine point was soon after adopted. As first used with the card, the latter was poised upon the point of the spindle, and the needle had an elliptical opening

in its centre to admit of this. The next improvement was in the use of a straight needle; and latterly we have the form which is familiar in the shape of the Admiralty compass, with its four compound needles placed parallel to each other, thirty degrees apart.

The present method of suspending the compass bowl in gimbals was invented about 1608, by the Rev. William Barlow, an Englishman. The great oscillation of the ordinary card when running in a heavy sea with a free wind, caused Ingenhous, an Englishman, to propose (in 1799) the filling of the compass bowl with some sort of liquid.

Various improvements have been made from time to time in the construction of various parts of the instrument, until at the present time the high state of perfection to which the liquid compass, as furnished to the Navy by Ritchie, has been brought, would seem to leave no room for further improvement.

Sir William Thomson has devised a compass which is remarkable for the lightness of its construction and the small size of its needles. A central boss of aluminum is connected by means of silk cords with a ring of the same material which forms the outer circumference of the instrument: four needles about 4 inches long and about the size of ordinary knitting needles, are placed on each side the centre, being secured to the cords; by reason of this the weight of the compass is greatly lessened, and the time of its vibration greatly increased, so that it is remarkably steady in a seaway. While very good results have been obtained from this instrument, it would seem that the delicacy of its construction would be an objection to its common use.

## INSTRUMENTS.

The next division of the subject leads us to consider the various instruments that have been used at different periods for the purpose of determining the altitude of a heavenly body. These in the order of time are the astrolabe; the sea ring; the cross (or fore) staff; the nocturlabe; the quadrant of Davis, or, as it was sometimes called, the back staff; the single reflecting quadrant of Coles; and lastly, the double reflecting quadrant of Hadley, upon the optical principle of which are constructed also the sextant and the octant.

A description of the astrolabe, cross staff and nocturlabe was given in a paper which I had the honor to read before the Institute several months ago; figures of them [figs. 1, 2 & 3] are given herewith, which sufficiently explain themselves. The sea ring (fig. 4) was considered to be an improvement upon the astrolabe: as generally made it was of

brass, about nine inches in diameter, an inch wide, and from one-sixteenth to one-eighth of an inch in thickness: it was, like the astrolabe, suspended from the thumb of the observer by means of a swivel ring, and was turned to the sun in such manner as to cause its rays to pass through an aperture in the manner shown in the figure; the spot of light upon the inner surface of the graduated arc indicated the altitude; the method employed in the graduation of the instrument is sufficiently pointed out in the figure. It is obvious that both the ring and astrolabe were open to very serious objections as affording only very inaccurate methods of attaining the object sought. The cross staff was therefore a great improvement; having been introduced about 1550. The next advance was made in the quadrant (fig. 5) invented by Captain JOHN DAVIS, an Englishman, about 1590. The instrument was made of wood: the smaller arc was called the sixty arc, from the fact that it contained that number of degrees; the larger arc was called the thirty arc, for a similar reason. The sixty arc was graduated to degrees from  $0^{\circ}$  to  $60^{\circ}$ , from the upper part of the arc towards the lower end; the thirty arc was graduated to five minutes from  $0^{\circ}$  to  $30^{\circ}$  in the opposite direction, the sum of the figures at the two central extremities amounting to ninety degrees. In using the instrument, the horizon vane at the extremity of the long radius, and sight vane upon the thirty arc were shipped in place as shown by the figure; the shade vane being placed upon the sixty arc so that its upper edge read to a number of degrees less by fifteen or twenty than the estimated zenith distance. The vanes having been thus placed, the observer, turning his back to the sun and looking through the sight vane, caused the upper edge of the shadow cast by the shade vane to lie upon the upper edge of the slit in the horizon vane, through which the horizon would be visible if the sight vane were placed correctly; if this were not the case, the sight vane was moved up or down the limb as necessary, until the horizon and the shadow were in coincidence. The altitude was obviously the angle at the horizon vane formed by the lines drawn from the other vanes; but as the obtaining of this would involve two subtractions and one addition, the zenith distance was obtained directly by adding the reading shown by the shade vane to that shown by the sight vane. The specimen of this instrument which is exhibited, was once the property of Captain JOHN PAUL JONES. Sometimes a vernier was added to the sight vane making the least count of the instrument thirty seconds. It is evident that this quadrant could not be used for observing altitudes of a body whose rays were

not sufficiently strong to cast a shadow ; and in this respect it was inferior to the fore staff. Flamsteed improved it by causing a lens to be placed in the shade vane, throwing a spot of light on the horizon vane.

*Elton's* improvement upon this instrument consisted in placing a spirit level upon the radius, thus allowing the horizon vane to be dispensed with ; it is obvious that this so-called improvement was of but doubtful utility for the purposes of the navigator.

*Gunter's* quadrant was also made of wood, consisting of a sector of a circle whose angle was ninety degrees ; upon its face, as a primitive plane (in addition to the graduated limb) were projected stereographically, the equinoctial, the ecliptic, the tropic and various other circles of the sphere. It was not designed to be any improvement over *Davis'* instrument for taking altitudes, but was intended chiefly for the graphic solution of various problems in nautical astronomy.

*Coles'* reflecting quadrant (fig. 6) was also constructed of wood, having a movable arm with vernier attached : at the centre of the instrument was a silvered mirror which reflected the rays of the sun through a hole in the sight vane which was situated upon the prolongation of the radius bar beyond the limb. This instrument does not seem to have been much used. Fig. 7 is an illustration of *Newton's* quadrant, the first double reflecting instrument.

The greatest improvement, however, was that made by *Hadley*, in 1742, in his double reflecting quadrant. As originally designed, this quadrant had two horizon glasses, being intended for both fore and back observations. The sextant was designed originally for the measurement of lunar distances, and consequently the back horizon glass was unnecessary. In this form it has come down to us, and is now used, as is so well known, for taking altitudes also, the quadrant, with its distinguishing mark of two horizon glasses, having long since been discarded. Various attempts have been made to improve the sextant by placing upon it a spirit level or an artificial horizon, but none of them have been successful for use afloat. A proposition has also been made to place an artificial horizon on gimbals for use at sea, but this also has met with failure.\* Some means of determining the zenith distance of a celestial body, when the horizon is obscured, would be gladly welcomed by the navigator. *Laurent's* night octant, in which the shade glasses are replaced by a plano-cylindrical lens causing the image of the star to

\* A *Sea top* in which the instrument was made to rotate rapidly, with the intention of preserving its perpendicularity, and thus giving a correct artificial horizon, was invented about a hundred years ago.

appear reflected as a band of light, has met with great approval for the purpose for which it is intended. A cruder form of a night instrument, in which the instrument is kept horizontal by means of a spirit level, has been devised, but it has not proved at all satisfactory in use.

#### OTHER DEVICES.

As early as the middle of the sixteenth century Mercator's invention of the celestial globe furnished the mariner with an easy method for the solution of the various spherical triangles involved in different cases of nautical astronomy. Since that day, many devices having the same end in view, have been produced. I refer here however to but three: the first (which is shown) was devised by a graduate of the Naval Academy: it involves no new principles and (being constructed of wood) is valuable chiefly as an exhibition of industry and skill with the jack-knife. A similar instrument to be constructed of brass, has also been devised by another graduate: these gentlemen have evidently been independent inventors. A third instrument called the *Nautrigon* has been constructed upon precisely the same principles as the other two; these principles are identical with those upon which Mercator based his invention; and he in his turn but made an adaptation of the armillary sphere of Ptolemy, who seems to have been the original inventor of the device which has turned up in the different shapes to which I have referred. These and kindred mechanical devices, however, can never supply the place of that practical and theoretical knowledge of which every student of navigation should endeavor to possess himself.

#### THE RECKONING.

We come next to a consideration of the various means employed for the purpose of keeping an account of the vessel's progress and of determining her position. It is not within the scope of this paper to *discuss* the various methods now in use for the determination of the coordinates of the ship's place upon the surface of the earth; but it is my desire briefly to call attention to the difficulties with which the navigator of the past was weighted, and to the gradual overcoming of them in successive years.

History is unable to point out the beginning of the practice of this art, for from the earliest times of which we have any record, passages by sea have been made. So long as the directive power of the magnet remained unknown, the ancient navigators had no means of guiding their vessels over the waters; and were consequently obliged to remain



enar the land, regulating their direction by means of the sun and stars, chiefly however by the latter. In the words of Dryden,

“ Rude as their ships was navigation then,  
 No useful compass or meridian known :  
 Coasting, they kept the land within their ken,  
 And knew no North, but when the pole star shone.”

Under such conditions, but little scope was afforded for anything more than guessing as to the position of the vessel: and yet it would seem to be a well authenticated fact that the bold Phœnician mariners, coasted not only throughout the extent of the Mediterranean, but extended their voyages along the western coasts of Europe and Africa; and it is not entirely beyond belief that the Cape of Good Hope was doubled by these adventurers of 600 B. C.

It was not until the adaptation of the magnet in the shape of the Mariner's compass, that there was furnished a means of keeping any sort of reckoning, when out of sight of land. As, under the guidance of the needle, it was found possible to venture into open water, some means of determining his relative position was demanded by the mariner. As the true form of the earth was considered, the motions of the heavenly bodies studied and the path of the sun approximately mapped out, the problem of the determination of the latitude had been solved on shore long before it was desired for use at sea. And the sea astrolabe for the observation of the meridian altitude of the sun or of the altitude of the pole star, was but a modification of the instrument used on shore for the same purpose. And here let us notice the important part which the science of astronomy performs in laying the theories upon which the practice of the art of navigation is founded. Without the profound investigations of those well versed in this most exact of the mixed sciences, the navigator would even now be at a loss to find his way from port to port.

The latitude then has been always easily determined approximately, by the two methods alluded to: the method by the sun was not accurate, by reason of the imperfection of the solar tables as well as by want of precise means of observing the altitude: that by the pole star was still less accurate, for the amount to be added to or subtracted from the observed altitude, on account of the star's position relative to the celestial pole, was determined only by the very rough method of obtaining the compass bearing of the *pointers* of the Great Bear or the *guards* of the Little Bear: a table being constructed, by entering which with this bearing as an argument could be ascertained the cor-

rection to be applied. As voyages were extended into south latitude and new stars discovered about the south pole, the meridian altitude of the star in the foot of the southern cross was taken; it being known that it was thirty degrees from the pole. This method of meridian altitudes is still the chief reliance of the navigator, and the precision of his results is due to the increased accuracy of his means for determining the declination of the body observed, to the greater nicety of his instruments and to the knowledge of the proper corrections to be applied to the observed, to get the true, altitude.

In the middle of the sixteenth century, the reckoning was kept as follows: as soon as possible after leaving port the latitude was determined, the course steered in the meanwhile having been noted; should the course not have been constant the mariner was directed to estimate as nearly as practicable, the mean of all his courses steered; with this course and the difference of latitude, the distance and departure were obtained from a table which showed "for an alteration of one degree in the latitude, how many leagues had been run on each rhumb, and the departure from the meridian" of the point left. Knowing these quantities the place of the ship was plotted upon the chart; as at this time the plane chart was in use, the difference of longitude and departure were considered to be the same. About this time *Mercator* invented the terrestrial globe and by means of a table which showed the length of a degree of longitude on a given parallel of latitude, the departure could be turned into difference of longitude and the ship's place plotted upon the globe; but of course with results far from the truth, as the determination of the departure was itself liable to most grave errors.

With the advent of *WRIGHT's* chart, came the application of this principle to the plotting of the position. If the distance were great, the departure was taken as in the middle latitude, it being very evident that it would be incorrect to use either of the extreme parallels for this purpose. At the same time that *WRIGHT* constructed his chart, he stated that the position of the ship could be found by calculation, but inasmuch as the courses were liable to great error he thought it advisable to make no change. *Handson*, in 1614, published solutions of what is known to us as *Mercator's* sailing. The longitude being so uncertain, the usual practice was to run into the latitude of the port sought, and thence sail East or West: hence the term parallel sailing. But inasmuch as there was no change of latitude upon this course, there was no method of finding the change of longitude, be-

cause there were no means of determining the distance sailed, save its estimation by the navigator, the log at this time not having as yet come into use. Although mention of this indispensable instrument is made as early as 1577, yet it seems not to have come into common use for more than thirty years subsequent thereto.\* At this time the length of the knot was generally taken at forty two feet, and a thirty seconds glass used, on the theory that the length of a sea mile was but five thousand feet. WRIGHT called attention to the fact that altitudes observed at sea should be corrected for the dip of the horizon, to determine which it was necessary to know the magnitude of the earth, and he seems to have been the first to construct tables of the dip, although he considered his results to be but approximate; and as his conclusions agreed with the generally received length of a nautical mile, his attention was not drawn to the log line. NORWOOD, in 1635, measured an arc of the meridian, and determined the length of a minute of the great circle to be six thousand one hundred and twenty feet; he thereupon proposed to change the length of the knot upon the log line to fifty feet, to correspond to the thirty seconds glass. So wedded to their custom were the mariners of that day, that (instead of making the change recommended by Norwood), they altered the length of the glass to twenty eight seconds, leaving the knot five feet short of its proper length, a practice which obtained until a recent date.

The Traverse Table, so useful to the mariner in his daily work, seems to have been first published about 1625, by ADDISON, an Englishman. NORWOOD was the first to call attention (in 1637), to the application of the Variation to the Compass Course; and he at the same time proposed a method for ascertaining the existence of a current.

The application of the Refraction to the observed altitude was not made until nearly the middle of the seventeenth century: that of the Parallax, at a later date, when the distance of the sun and moon became approximately known.

The problem of the longitude early engaged the attention and study of mathematicians; and observations of lunar eclipses seem to have first suggested themselves. WERNER of Nuremberg (in 1514), was the first person who proposed the method of lunar distances: the method in brief, was to find the longitude of the moon, by her distance from the sun or other star; from the difference between the true longitude as computed from the tables of the moon's motion and her longitude

\* The principle involved in the construction of Massey's Patent Log was first enunciated by Phillips, about 1650.

as found by observation, in connection with her hourly motion, could be obtained the difference of longitude between the place of observation, and that for the meridian of which the tables were calculated.

About 1530, GEMMA FRISIUS proposed the method by time keepers now actually in use; but he did not consider this applicable to sea use on account of the liability of the time pieces to rust. In 1581, Coignet proposed a method to be used in parallel sailing, whereby the distance sailed could be determined by means of the difference of time turned into difference of longitude; this being obtained by keeping a twenty four hour sand glass running from noon at the port of departure, and the number of hours that the sand ran out before or after noon, at the place of arrival gave the difference of time sought. Of course this method was very crude, but it was a great advance beyond any other that had ever been proposed, and it could have been used for determining the difference of time between any two places.

At the beginning of the seventeenth century, PHILIP III of Spain offered a reward of one thousand crowns for a correct solution of the problem; and soon afterward the States General of Holland offered a reward of one hundred thousand florins. Notwithstanding the stimulus offered by these rewards, no new theories were proposed, but some improvements were made in the lunar tables, which though not sufficient to gain the prizes, were yet a step in advance of those formerly in use.

About 1650, BOND announced that "having found the true theory of the variation of the compass," he could thereby determine what the variation ought to be in any given longitude; and hence with the obtaining of the variation by any of the usual methods, the longitude would at once be known. As a proof that he had discovered the true theory, he foretold that the variation at London (being then easterly), would in 1657, be zero; and would afterward change to westerly; which prediction proved true. But unfortunately it was found that Bond's hypothesis was not correct, and that no good results could be obtained. Accordingly HALLEY undertook the subject, and after discussing a large number of observations, he formed a theory as to the location of the four magnetic poles, and published (in 1700), a chart with the lines of equal variation upon it, and he hoped that this would greatly assist the mariner in finding his longitude. Some twenty years after, a dip chart was published with the same end in view, but neither of these methods could be successful, as can be readily seen from the various directions of the isogonic and isoclinic lines in reference to the meridians and parallels.

In 1675 the Royal observatory at Greenwich was founded; and FLAMSTEED appointed to its charge as the first Astronomer Royal. He was particularly enjoined "to apply himself with the utmost care and diligence to the rectifying the tables of the motions of the heavens and the places of the fixed stars, in order to find out the so much desired longitude at sea, for perfecting the art of navigation." Flamsteed said "that after two thousand years we find the best tables erring sometimes twelve minutes or more in the moon's apparent place, which would cause an error of half an hour or seven and one half degrees of longitude, by comparing her place in the heavens with that given in the tables."

Eclipses of Jupiter's satellites were also recommended; and in 1693 Cassini published, under the patronage of Louis XIV, tables for facilitating the use of these phenomena; this method, however, has never been found useful at sea.

In 1714, the English parliament constituted a Board of Longitude and offered a reward of twenty thousand pounds sterling for any method by which the longitude could be determined at sea within thirty miles; fifteen thousand pounds sterling, if it could be determined within forty miles, and ten thousand pounds sterling, if the method were sufficiently accurate to obtain it within one degree. In 1716, a reward of one hundred thousand livres was offered by the Duke of Orleans. The stimulus of these magnificent offers, and the improved means of correcting the lunar tables owing to the profound investigations of Newton, urged many to compete for the prize.\* In 1755 *Mayer's* tables gave the place of the moon to within one minute; and his widow received three thousand pounds

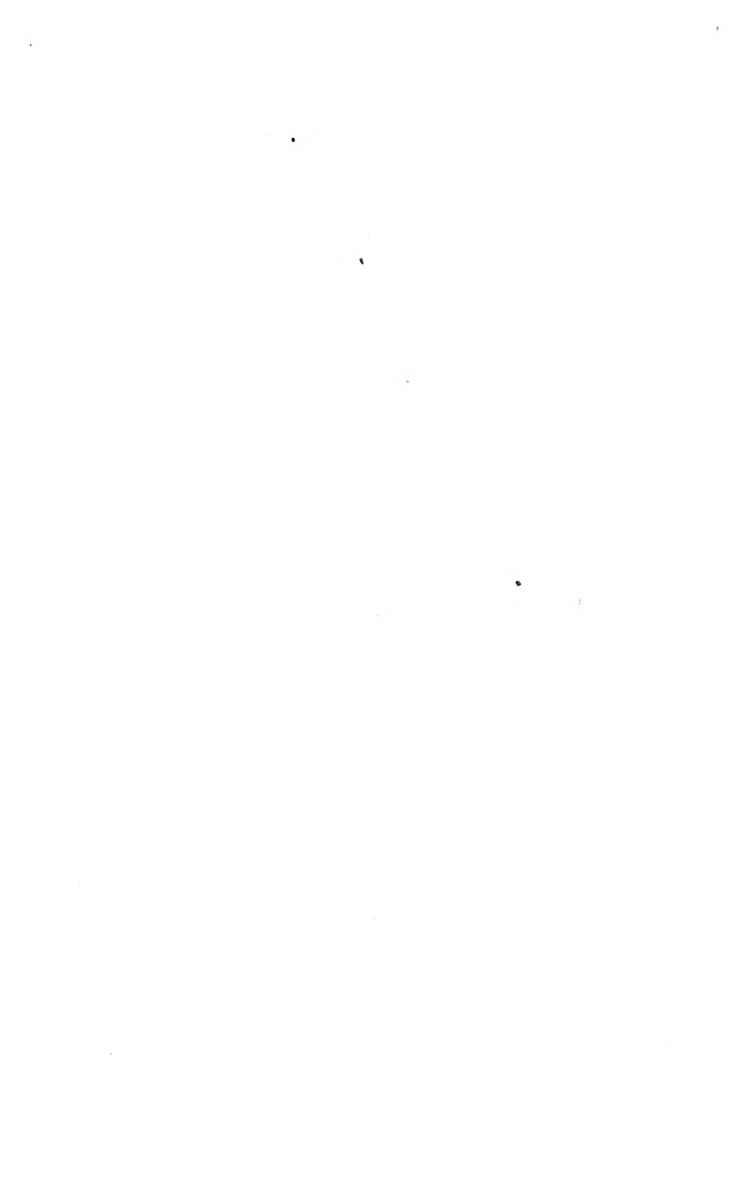
\* As showing the necessity which existed for greater accuracy in finding the longitude the following instance is cited. In Commodore Anson's voyage around the world in 1740-44, while beating to the westward around Cape Horn, the squadron was by reckoning (after making, as was supposed, sufficient allowance for an easterly current) in latitude  $54^{\circ} 30' S.$ , longitude  $87^{\circ} 30' W.$  Seeing himself well clear of the cape the Commodore was standing to the Northward with a favoring breeze, when suddenly, about two o'clock in the morning, land was seen directly ahead and but a few miles distant; the squadron was at once hove to until daylight, when it was found that they were off Cape Noir; whose latitude was the same as that in which their reckoning placed them, but whose longitude was  $78^{\circ} 45' W.$ ; nearly nine degrees (or *three hundred miles*) east of their estimated position! With such difficulties were the navigators of but little more than a century since obliged to contend.

sterling as a reward therefor. These tables were immediately printed ; and in 1766 was published the first issue of the British Nautical Almanac containing not only these tables but the directions for using them, and for interpolating, by means of proportional logarithms ; these were devised by MASKELYNE, who was then Astronomer Royal.

In a voyage to St. Helena, Maskelyne tested these tables and found his longitude by observation to be within a degree of the truth ; while that by the dead reckoning was many degrees out ; in a subsequent voyage to Barbadoes, he was by his observations within thirty minutes of his true position on making the land, and on his return was but sixteen minutes out in making the Isle of Wight. On this last voyage he also invented the method of ascertaining the index error of the quadrant by measuring the sun's diameter on and off the arc. These results led many others to endeavor to improve the methods for the reduction of the apparent to the true distance and the finding of lunar distances has remained, until a comparatively recent period, the chief reliance of the navigator. Other lunar methods have been proposed ; among which may be mentioned that by the meridian altitude of the moon ; but, inasmuch as this requires an exact measurement of the altitude and a correct knowledge of the latitude, it can hardly be said to be of any use at sea. While the method by means of lunar distances is still taught, yet its chief use is that of giving us a check upon the chronometer ; which brings us to consider the modern method. As already noticed, Gemma Frisius gave us the theory,—but it remained for later generations to construct a time-piece which should fulfill the conditions required. In 1662, a pendulum clock was tried at sea, the clock being weighted and suspended near the centre of motion of the ship ; the attempt was fairly successful. About this time the balance spring was applied to the clock, rendering a pendulum unnecessary, but no more trials of this method seem to have been made during the succeeding half century. The reward offered by the Board of Longitude, however, inspired the watch-makers to attempts at such improvements in their instruments as might gain the coveted prize. In 1736, HARRISON made the first trial of his chronometer with a very fair measure of success ; for this he received a portion of the reward from the Board, with an intimation of their desire for a further prosecution of his design.

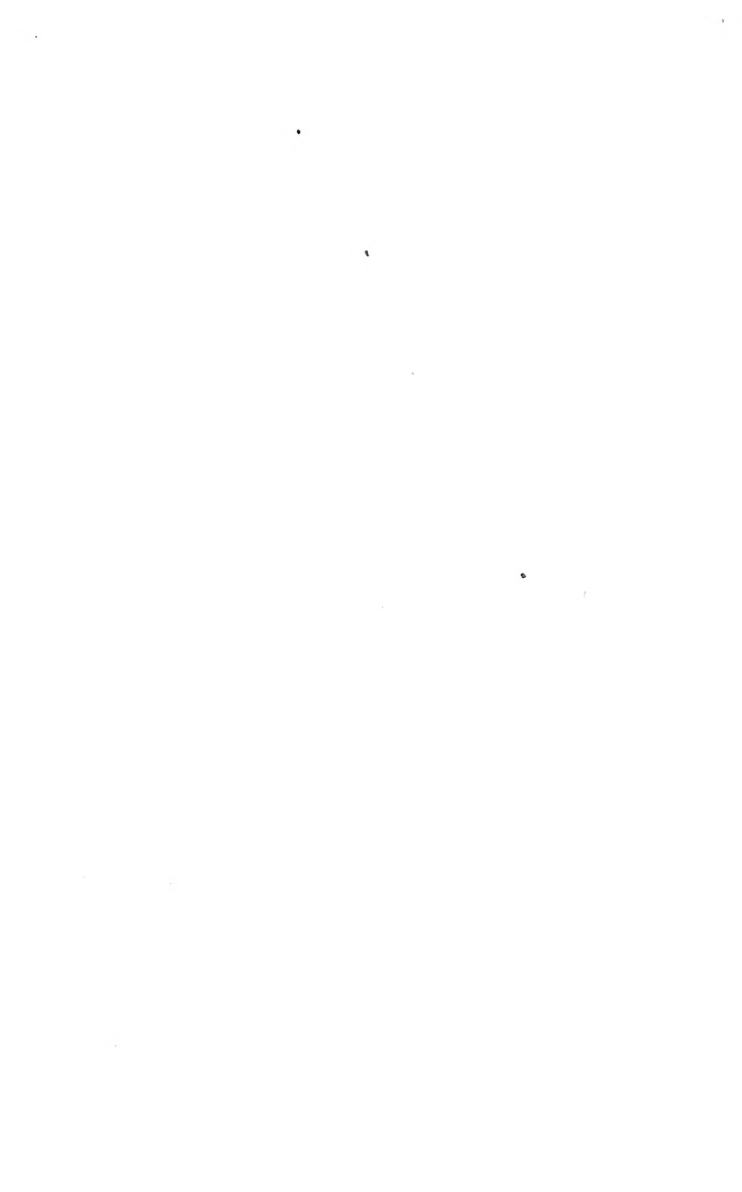
Three years later, he produced a second, which gave better results than its predecessor ; ten years later, a third was produced, and after twenty-five years of labor he was able ( in 1761 ) to offer an instrument

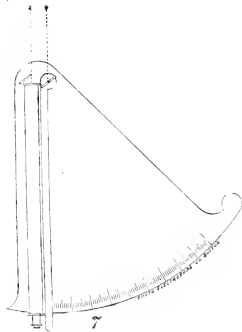
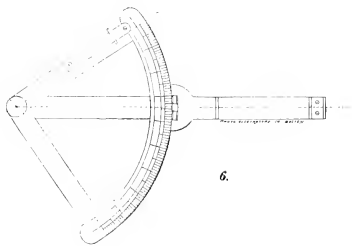
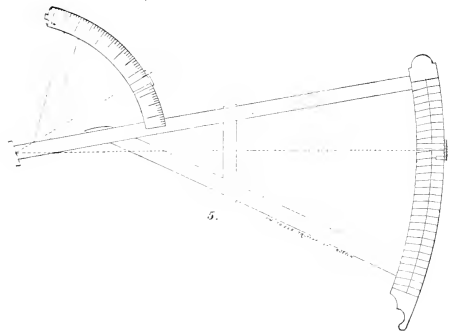
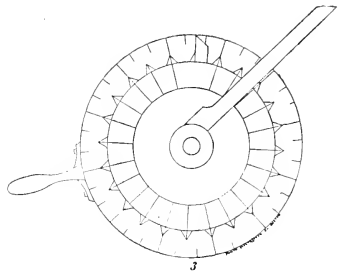
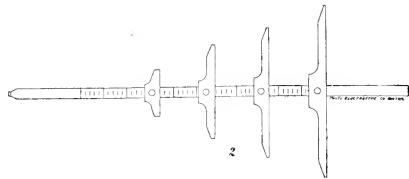
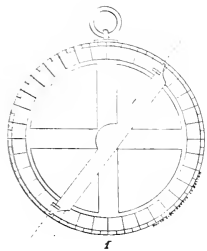
which he claimed would answer the desired purpose. In this year Harrison made a voyage to Jamaica; the longitude of Port Royal, by his chronometer, differed from that deduced from a transit of Mercury by only one minute of arc. On his return the chronometer was found to be about two minutes slow; for these results Harrison was awarded five thousand pounds sterling. In 1764, Harrison again made a voyage to the West Indies, having, in the meantime, made some improvements in his chronometer; before sailing, he deposited with the Admiralty a statement as to his expectations of the rate of the chronometer at different temperatures, and also of its probable mean rate. On his return the chronometer was found to be less than one minute out on its mean rate, and but fifteen seconds out when account was taken of the temperatures to which it had been subjected. The instrument and the working drawings, with a statement of the principles involved in its construction, being delivered to the Board, a further reward of ten thousand pounds sterling was paid, the remainder being promised when it was found that an instrument constructed by some other person from his drawings should be equally successful. The one so made was used by Cook in his voyage of circumnavigation in 1772-74; and the report of its performance was such as to cause the remainder of the reward to be paid to Harrison; he also received gratuities from the East India Company and others; so that for his efforts of forty years, he received about twenty-five thousand pounds sterling; by no means an inadequate reward, if we consider the immense benefit conferred upon the mariner by his invention. During the last century the watchmaker's art has made great progress and the best chronometers furnished at the present day are far more reliable for the determination of the longitude than any lunar observations can possibly be; and yet it is by no means wise to trust them entirely; the careful navigator finds that here, as in all other parts of his practice, "eternal vigilance is the price of safety."













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APRIL 11, 1878.

Commander WILLIAM T. SAMPSON in the Chair.

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THE BAROMETER IN HIGH SOUTHERN LATITUDES.

By Commander NORMAN H. FARQUHAR, U. S. NAVY.

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In submitting the following, I am aware that I may be assailed with the remark that a rule cannot be laid down from observations during so limited a period, or only at one season; in which I fully agree. Still as a glimpse of the sun, when running for your port, is better than no observation at all, so I trust that my experience may be, at least, a ray of light.

The subject of the Barometer off Cape Horn has been one of fruitful inquiry and discussion, some asserting its reliability and others the reverse; one theory after another broached, only to be controverted. One party laying down rules from its operations on the adjacent shores and islands, others again after beating, and being tossed about for many days, till almost in despair, deny the assertions of the former.

Some, like our great Maury, (to appreciate whom one needs to make this long passage from San Francisco around Cape Horn), theorizing from the disjointed statements of others and their abstract logs, say "More light is required."

Captains King and Fitzroy of the Royal Navy, who spent several seasons, at different times, surveying, (and whose charts are everlasting monuments to their intelligence and indefatigability) do not agree.

Captain King says, "With respect to the utility of the barometer, as an indicator of the weather that is experienced off Cape Horn, I do not think it can be considered so unfailing a guide as it is in the lower or middle latitudes."

"Captain Fitzroy, however, has a better opinion of the indications

shown by this valuable instrument ; “ My opinion is, that although the rise or fall at times precedes the change, yet it more frequently accompanies it.” *Narrative of the Voyages of the Adventure and Beagle, Vol. I., p. 465.*

And that fine weather may occur when the barometer is very low, as above stated, the following extract from the same work will demonstrate ; “ April 2nd, 1830, (near Cape Horn) the glass had been falling so much, and was then so extremely low, that I thought it prudent to prepare for the worst, and struck topmasts.

Notwithstanding the unusual fall of the barometer and sympiesometer, and their still continuing to sink, this day was as fine, and seemed likely to continue so, as any day I had ever seen, therefore we took advantage of it.

3rd and 4th.—Still very fine weather, although the barometer and sympiesometer were lower than I had yet seen them in this country.

5th and 6th.—Two more fine days, with a very low glass, shook my faith in the certainty of the barometer and sympiesometer.

During those days the wind had been light from N. N. W. and twice before I had known these instruments to be similarly affected during exactly similar wind and weather.

The mercury in the barometer had now fallen to 28.94, and the oil in the sympiesometer to 28.52; the thermometer ranging from 40° to 48° Fahrenheit.

10th.—Still fine, steady weather, notwithstanding the unusually low fall of the barometer.

12th.—The glasses had at last been rising; and during the past night and this day the wind was very strong, with much rain.

The wind shifted from the northern quarter into the southern, drawing round to the S. E., which, of course, would make the mercury rise higher after being so very low, though the weather might prove extremely bad.” *Ibid. pp. 426—429. South Atlantic Memoir, page 8.*

Captain Mayne, Royal Navy, who spent some time also in these latitudes a few years ago, in command of the Nassau, says ; “ The backing of the wind from S. W. to N. W. is always accompanied by a falling barometer, or its ceasing to rise, as it does during the whole time it blows from S. W.

The change of wind, however, usually accompanies the change in the barometer, and the mercury merely ceasing to rise may indicate the S. W. wind subsiding.

If the wind backs from N. to N. E. the same dirty weather may be

expected that is mentioned as usual when it draws round to the E. from the Southward, and generally the seaman may be prepared for bad weather when the wind backs, even though the barometer does not fall.

Northerly winds are often preceded by low flying clouds, with a thickly overcast sky, in which the upper clouds appear at a great height.

The sun shows dimly through them with a reddish appearance, and with its edges so indistinct that it is impossible to take an altitude, often for hours, before a gale comes on.

Sometimes, but very rarely, with the wind light between N. N. E. and N. N. W. a few days fine weather may occur.

Each day of this must be gratefully received as it comes, for it cannot be predicted, and occurs sometimes with a high and at times with a low barometer.

Easterly winds are certainly more common, and the strait is on the whole less windy in winter (June, July, and August,) than in summer; but when against this possible advantage is placed the cold, with the long nights and short days, this season is not likely to be preferred by the mariner in a vessel bound westward.

Though beyond the limits of this chapter, it may be well to mention that ships getting as far as Cape Froward with a S. W. wind will generally find it N. W. on rounding the cape, as the wind follows the direction of the channel.

Captain King, after remaining nearly a year in Port Famine, and a considerable time in the eastern part of Magellan Strait, came to the conclusion that the barometer could not be considered so unfailing a guide as in the lower and middle latitudes, and that, although the rise and fall do sometimes precede the change, yet they more frequently accompany it.

After two seasons careful observation, the writer coincides in this opinion, as far as the actual strait itself is concerned." *Pages 99 and 100 of Gen. Ex. Atlantic Ocean.*

"As a rule, the wind will be found stronger from the S. W. and the squalls heavier from the N. W., and no certain warning is given of this shift.

Sometimes the Barometer precedes it, but more generally accompanies it." *Page 99.*

"It has already been said, when speaking of this shift of wind from the N. W. to S. W., that the barometer invariably rises with it, and the only rule which we can give as at all settled is, that a rising bar-

ometer precedes or accompanies a shift of wind from N. W. or W. to S. W., and that generally, if the mercury falls while it is blowing from S. W. the wind will back to N. W. again; but in both these cases, nine times out of ten, the two events will occur simultaneously." *Page 101. General Examination Atlantic Ocean.*

"My object in writing," says the late Rear Admiral, [then Captain] Bailey, of the United States Ship *St. Mary's*, "is to call your attention to the barometrical indications south of Staten Land and Terra del Fuego, and to the regularity and certainty with which the mercury falls with a northerly wind and rises with a southerly.

At this season—the summer—an easterly wind is rare, and, if it occurs, is of short duration. We found none.

The north or northwest winds are usually accompanied by cloudy, rainy, or misty weather; soon after it sets in, the mercury begins to fall, and continues to sink as long as the wind has nothing in it, when there is usually an interval of calm or light, variable winds, lasting two or three hours; after which it veers to the southward or southwestward, squally, precipitating the mists in the form of hail and sleet, and exposing (at the S. W.) clouds of the cumulus character.

At this point the mercury begins to rise, and continues ascending as long as the wind has southing in it.

A low barometer (say 28.50) will thus react with a southerly wind, and a high barometer (say 29.90) with a northerly.

This has been my experience, after three passages around Cape Horn, in which my attention has been directed to this phenomenon.

And so fully convinced am I of the truth of my experience, that I would advise ships (after passing the Straits of Le Maire, which is free from all danger, saving thereby at least one degree of westing), having a northerly wind and a falling barometer, to stand on a wind to the southward, confident of the wind's direction, so long as the mercury tends to fall.

If it reaches a minimum somewhat below twenty nine inches, and a calm ensues, equally to be certain of a "southwester," and to be in a position, if possible, to profit by it."

Rear Admiral Hoff, (then Captain) commanding *John Adams*, encloses a report of his navigator, Commander, (then Lieut.) E. P. McCrea, which says: "Regarding the Barometer, it never failed us while west of Cape Horn, and told us faithfully the approach and abatement of all the gales; off the Falkland Islands it was not so correct, though we had no gales, but drizzling, rainy weather and easterly winds."



"I have never known the barometer to range so low, and know not what to make of it."—*B. Buxton, ship Union.*

"A most extraordinary fluctuation in the barometer, from 30.03 inches to 29.3 inches, the weather and appearance giving no indication of storm or rain."—*Robert Mc Cerran, ship Defiance.*

"The barometer continues to fall, although the wind is southwest.

I have always seen it rise with the wind from that quarter."—*W. B. Daniels, ship Seaman.*

"The barometer ranges the highest with the wind W. S. W., and lowest from the northward. It either accompanied or followed the change, never preceded it." *John Gillan, barque Delegate.*

"I do not see that it (the barometer) is a guide to be depended upon. Certainly my experience this passage would show its fall followed by delightful weather."—*R. F. Coffin, ship Senator.*

"I have Maury's Sailing Directions, and I find that almost all the captains who have furnished him with abstracts have had something to say about their barometers when in the vicinity of Cape Horn; and as there is a good deal of disagreement, I thought I would add my opinion to theirs, while every circumstance is fresh in my memory.

In the first place, I have two barometers, one belongs to the ship, the other to myself. Mine I have had six years, and used almost constantly for that time and have become in that time pretty well acquainted with its workings; for that reason I have used my own barometer altogether in this log, though it differs materially from the ship's. In fine weather, when my barometer was at 30.00, the ship's stood 30.25; in heavy weather when mine stood 28.50, the ship's stood 28.40 or 28.35; at 29 inches they were both alike.

Now, as to the use of a barometer off Cape Horn, so far as I can judge, they work as well and are of much use there as anywhere; though I think it requires considerable study to understand the workings of the mercury in such high latitudes.

I think my barometer stood in 58° south latitude three-quarters of an inch lower than it would in the same amount of wind or storm off Cape Hatteras.

I notice some of the captains say the barometer always falls in a northerly wind, and it does not blow hard from that quarter.

I noticed this myself; but my barometer always stayed down, and most always continued to fall till the wind came to the southwestward and blew heavily, then it would begin to rise.

My barometer and also the ship's, I have known to be down to 28.50

inches, several times for twenty-four and sometimes for over thirty hours before the blow came on; but it always came, and as soon as it came and got fairly to blowing, the barometer started up.

Every hard westerly blow I have had about Cape Horn, I have had a low mercury before it came on."—*William Fales, ship Star.*

"June 11, 9 A. M. barometer falling; land in sight about Cape Pinas; noon, quite thick and dark; barometer 29.35; lower than I have noticed it before; no change in the weather except the fog.

Thus far I have made no remarks upon the barometer. If I should dare to hazard an opinion, would say that, with the wind at N. E. and E., north of the equator, it ranges highest; and with southerly winds south of it, and particularly south of Capricorn, lowest; or, at least, that southerly winds may be expected when low, and westerly and northwesterly when quite high; though we have had our highest wind (even a terrific gale for a few hours) after the barometer had fallen to 29.40 some two hours and stopped. I think it was rising at the time; wind from about west, perhaps a little northerly and inclining southward.

Running along the land; wind veering north; saw what looked like snow on the mountain tops; at 10 p. m. up with Cape Diego in sight; at the end of the day in the straits; weather getting fair; wind strong at N. W."—*O. G. Lane, ship Victory.*

"Sept. 2. Lat.  $56^{\circ}$  S., long.  $65^{\circ}$  W.

At 9 P. M. light wind from S. W., wore ship.

At 10 P. M. calm, squall gathering from S. S. W.; in royals and clewed up everything except topsail and foresail; but before we got through, it struck us, and I was glad that I was so well prepared for it.

It blew very hard for three hours; close reefed fore and mizzen topsails, and double reefed main topsail and mainsail. Latter part, heavy gales and hail; ship under the same sail. We seem to be pursued by contrary winds.

(I see in your book of directions that some of the captains state that they do not consider the barometer as a guide in high southern latitudes; but I differ from them although I may not have had as much experience as some of them, having been thirteen years at sea, of which time I have been captain six years.)

I think if the glass falls three or four tenths in a few hours, it is almost positive that it will be succeeded by a gale or very heavy gust which will last several hours, although the simple fact that the barometer falls does not, as a natural consequence, predict wind; it only

shows that there is a commotion in the atmosphere in your vicinity which may be succeeded by wind or rain, but I think more likely by the former." *John Zeega, Queen of Clippers.*

On the other hand, other opinions are adverse; I quote a few more pro and con:

"The barometer remains low all the time; it appears to be of no use here."—*D. C. Landis, ship F. W. Brune.*

"Barometer useless."—*W. L. Phinney, ship Kentucky.*

"The mercury here appears to be very lively; will rise and fall from 30.10 to 29.16 rapidly; but it is to be observed that this variation is not attended with the same degree of increase and decrease of wind that we experience elsewhere. Consider the barometer here of very little use."—*T. Dahlgren, barque Byron.*

"Barometer rising; but find it no guide whatever."—*S. M. Hudgins, barque Hugh Birkhead.*

"Barometer unsteady: squalls the same, without any apparent effect on the barometer. I do not trust to it."—*Charles A. Ranlett, ship Surprise.*

"The mercury fell this day 1.42 inches, and no wind to speak of."—*W. E. Putnam, ship Empress of the Seas.*

"I watch the barometer closely; but do not think it is to be depended on here as in the North Atlantic Ocean.—*Samuel Harding, ship Robert Harding.*

"My barometer has been almost useless since I was in the latitude of the Rio de la Plata. The heaviest gales I had, it ranged from 29.15 to 29.40, and it has been as low as 28.35 with a whole sail breeze. It has, however, invariably fallen for a northerly wind and risen for a southerly one. It has ranged during the last six weeks from 28.35 to 30."—*Oliver H. Sanders, ship B. Howard.*

*Captain Hull.* says, "My barometer tells the weather here to a charm."

*Captain Littlefield* says: "Never, in one instance, has my barometer deceived me," and *Captain Scott* remarks; "Thus far, I think the barometer has been an infallible guide as to the weather." *pp. 447-449 Maury's Sailing Directions.*

June 2, Latitude 47° 46' S., long. 47° 46' E.

Barometer, 29.10; air, 31°; water, 35°.

Winds, N. and E. N. E.

Commences with light air, and variable, with heavy snow squalls; midnight, weather and wind the same.

6 A. M., calms, and heavy dark clouds coming up from N. N. W.

Barometer falling very fast.

Noon, light breeze springs up from the north.

Barometer still falling; there must be a heavy gale close upon us from the sudden fall of the mercury.

June 3, Lat.  $48^{\circ} 19'$  S. long.  $52^{\circ} 35'$  E.

Barometer, 28.40; air,  $32^{\circ}$ ; water,  $37^{\circ}$ .

Winds; E. N. E. to W.

First part light breeze.

Barometer still falling; midnight, observed the fluctuation of barometer about  $\frac{1}{2}$  inch in the tube, the wind coming in gusts, with a howling noise. Sea tumbling about in all directions.

8 A. M., fine, pleasant weather; noon, the same.

Barometer rising slowly.

June 4, Lat.  $48^{\circ} 13'$  S., Long.  $58^{\circ} 00'$  E.

Barometer, 28.60; air,  $31^{\circ}$ ; water,  $34^{\circ}$ . Winds, W.

Begins with moderate breeze, and variable from W. N. W. to W. S. W.

Weather getting a little settled.

Barometer rising; midnight, squalls and snow showers; noon, wind and weather the same.

June 12, Lat.  $46^{\circ} 18'$  S., long.  $89^{\circ} 31'$  E.

Barometer, 29.05; air,  $42^{\circ}$ ; water,  $42^{\circ}$ . Winds, S. S. E. to S. W.

Commences with light breezes with sleet; wind variable from S. W. to N.

At 1 P. M., wind S. E.; tacked to N. E.

Midnight, clear and wind hauling southerly.

I have always experienced as soon as the wind (along here) gets into N., that it hauls round easterly into S. W., and blows from that quarter; when the gale has reached its height, it then begins to veer northerly by west, and the barometer begins to rise fast, until the wind gets into the north; it then stands whilst the wind retraces its westerly course round into S. E., and then blows again; latterly falls calm, and the wind again springs up from N. W.

Noon, light breezes and wind westing.

June 18, Lat.  $42^{\circ} 47'$  S., long.  $115^{\circ} 54'$  E.

Barometer, 29.20; air,  $40^{\circ}$ ; water  $48^{\circ}$ . Winds, W. to S. W.

First part, breeze freshening; at 6 P. M., wind S. W. and freshening; at 8. 30 P. M., in all starboard stunsails, ship going 21 knots, with main skysail set; midnight, fresh gale and fine clear night; 8 A.

M., wind and weather same ; noon, less wind, attended with snow squall.

June 19, Lat.  $42^{\circ} 42'$  S., long.  $118^{\circ} 00'$  E.

Barometer, 29.40 ; air,  $48^{\circ}$  ; water,  $51^{\circ}$ . Winds, W. to S. W.

Commences with fresh gales and sleet squalls.

Midnight, wind strong, and hauling to northward ; at 4 A. M., wind N. N. E. ; tacked to the N. ; 8 A. M., wind S. W. ; with drizzling rain ; noon, fresh breeze, and fine, clear weather.

June 22, Lat.  $41^{\circ} 40'$  S., Long.  $134^{\circ} 58'$  E.

Barometer, 29.30 ; air,  $50^{\circ}$  ; water,  $51^{\circ}$ . Winds ; N. W. to W. Commences with strong breezes and squally ; at 5 P. M. ship was struck with a most terrific squall, which lasted in full strength only about three minutes.

The ship broached to, blew away all head sails, fore topsail, fore top-gallant sail, main topmast and middle staysails, mainsail and main top gallant sail, mizzen lower and mizzen topmast staysails ; carried away main top gallant mast, and main yard.

I never before experienced such a terrific gust of wind. The barometer gave no indication, whatever, of the approach of the squall.

Midnight, moderate breezes and fine clear weather, with frequent flashes of lightning ; 8 A. M., fine and clear ; noon, wind hauling to N. W., with light rain at intervals. *Abstract log of the ship "James Baines," (Charles McDonnell, Commander,) from Liverpool to Melbourne ; 23 days out, pp. 644, 5 and 6, Maury.*

Again Maury, *pages 583 and 584, says ;*

"The barometer, especially in high southern latitudes, is very puzzling, particularly to those navigators who have been cruising mostly in the North Atlantic.

There are many rules, in truth almost as many rules as there are generalizers, for telling by the mercury how the wind and weather are to be off Cape Horn, and how they are to be in the long stretch for easting both on the outward and homeward route from and to Australia.

I am free to confess that I have never yet been able to discover the actual relation between barometric pressure and the weather off Cape Horn and in those high southern latitudes ; nor have I been able to give any rule by which the mariner might certainly fortell the approaching storm in those seas."

*Captain George W. Brown, of the "Kitty Simpson," who is a very close observer and clever navigator, in his abstract log, says :*

July 3rd, 1857, Latitude  $48^{\circ} 09' S.$ , Longitude  $87^{\circ} 54' E.$  Barometer, 28.86. Wind, North West.

First part, moderate breezes, thick and rainy; middle, light winds, with foul looking weather, and squalls with rain.

5 A. M., wind suddenly from S. W., with squalls and rain.

9 A. M., hard squalls; reefed the main topsail and took in the jib; ends wind on the increase; passed much kelp; numerous Petrels and other birds about.

I fully expected a gale from the N. or N. E., with such a low glass. (28.70 in.)

I find by experience a low barometer does not but rarely indicate them, unless it falls during the time it is blowing from these quarters.

In this, as in the South Atlantic and Pacific oceans, a low glass with baffling winds and unsettled weather (I mean in the high latitudes) is almost a sure precursor of a S. W. gale, hauling suddenly to that quarter a few hours after the column has fallen to 28.70, or perhaps a tenth or two lower; and also if the barometer falls with a northerly gale and continues to fall after the gale ceases, or remains steady at 29.00, or less, then look out for a sudden shift from S. or S. W., after which the silver will rise fast or not, according to the force of wind.

In the heaviest gales from W. or N. W., the glass seldom falls below 29.30, (that is my own experience.)

I may here remark that a low barometer does not always indicate wind from any particular quarter, for on the 13th and 14th of June, with the glass at 29 inches on the average, I had south and easterly winds, with various kinds of weather, calms, &c.; but such cases I think, but seldom transpire: indeed I am at a loss to know what influenced the mercury to act so contrary to the general rule, for a high glass is always experienced with S. E. winds.

July 7, Latitude,  $46^{\circ} 39' S.$ , Longitude,  $103^{\circ} 28' E.$

Barometer, 28.80. Winds; west.

First part, calm and cloudy; middle part, fresh breezes, and thick, rainy weather; latter, light breezes, with cloudy weather and rain till 7 A. M.

Saw plenty of kelp, some of which I caught; it appeared to have been in the water a long time, being covered with barnacles.

Numerous albatross and other sea fowl about. I was much surprised to see a large black land bird, something like a gannet, hovering overhead for more than an hour, seeing there is no land that is known

hundreds of miles from us; yet it is my opinion there are islands in this vicinity.

The color of the water, the peculiar weather, the various birds, the abundance of kelp, and the indescribable feeling of the air, denote it.

The barometer fell to 28.60 with a southerly wind again, which lasted but a few hours, when it hauled to west, the glass rising a couple of tenths, the wind gradually increasing.

Now what is the meaning of the mercury being so low with southerly winds and calms?

This is the second time it has shown me that the silver does not fall always for wind, nor in fact any particular kind of weather, except, indeed, it be for S. E. wind, which I have always found the barometer to rise for heretofore."

The barometer is an instrument by means of which the pressure of the air at a particular place may be measured.

If there were no tides nor winds, and if the sea and the air were perfectly calm in the whole region between the two places, then the actual pressure of the air at the level of the sea must be the same in these two places; for the surface of the sea is everywhere perpendicular to the force of gravity.

If therefore the pressure on its surface were different in two places, water would flow from the place of greater pressure to the place of less pressure till equilibrium ensued.

Hence, if in calm weather the barometer is found to stand at a different height in two different places at the level of the sea, the reason must be that gravity is more intense at the place where the barometer is low.

The intensity of gravitation varies at different places, being less at the equator than at the poles, and less at the top of a mountain than at the level of the sea. (*Maxwell Theory of Heat.*)

Now a barometer is also effected by the density of the atmosphere or by its rarefaction.

In other words, storms are propagated by rarefaction of the air and the outside air rushing in to restore the equilibrium; when this rarefaction is sudden, hurricanes are the result.

Heat produces this rarefaction, and we all know how a warm winter's day is followed by a storm.

These two causes, in my opinion, explain all.

In the first place we admit that gravity is more intense at the poles than at the equator; hence a lower barometer.

Secondly.—The theory of the Trade winds, supposes the air at the equator to be heated, consequently expanded, hence lighter and therefore brings a low barometer, the cold air rushes in to take its place; now this air from the equator flows towards the poles charged with vapor and finally replaces the trade winds; forming the westerly winds.

*Ansted's Physical Geography, pages, 236 and 256, says:* "The main cause of the frequent oscillation of the barometer, and also of the permanent difference that exists in the mean barometric pressure at different parts of the earth's surface, is that the whole body of the atmosphere is made up partly of air and partly of vapor; and as vapor, volume for volume, is lighter than dry air and takes its place, the evaporation due to changes of temperature sensibly alters the pressure.

The dry-air atmosphere is thus the heaviest, and corresponds to a high pressure.

The vapor-atmosphere is the lightest, and when it takes the place of the other the barometer shows it by falling.

This is quite independent of any alteration of the height of the column of air, such as is produced by the action of the sun and moon, or by the difference of level at different stations.

To understand fully the important influence of vapor in lowering the pressure of the air, it must be remembered that three-fourths of the atmosphere is compressed within the five miles nearest the earth, and that dry air is no less than forty per cent heavier than the same volume of vapor, at the same temperature.

Thus, the pressure of a dry-air atmosphere being equal to that of 30 inches of mercury, that of a vapor atmosphere replacing it would only be  $21\frac{1}{2}$  inches.

But, if a part of the vapor-atmosphere be condensed into water, heat is given off by the change in condition, and the vapor that remains, absorbing this extra heat, becomes lighter, so that the height of the whole atmospheric column being the same, the column of mercury in the barometer (representing the pressure of the atmospheric column) must sink still lower.

Thus, when there is constant precipitation there must be a low barometer.

We have already remarked, that the barometer stands at a higher point in the calm latitudes between the tropics and temperate zones than elsewhere.

It has also been observed, that in the Antarctic regions the mean



height of the column of mercury is less than 29 inches at the sea level, whereas in the Arctic regions it is nearly an inch higher.

This accumulation of pressure in the northern hemisphere is due to the excess of land in that part of the world ; for while in the southern hemisphere the winds passing almost entirely over the sea are loaded with vapor, the winds reach the Polar seas over vast tracts of dry land, and are thus comparatively dry

The vapor-atmosphere thus occupying so large a part of the whole air in the Antarctic district, is also frequently condensed into rain or snow, and in this operation large quantities of heat are set free.

Such heat warms and rarefies the air, and thus lowers the barometer still more, in a manner explained in a previous page. (237.)

For a similar reason the barometer is low under the equator.

The Trade winds pressing as it were into this belt. and being always loaded with vapor, the air is permanently moist.

But the heat at the surface is very great, and the heated, moist air, rises rapidly into cooler regions where it is condensed into rain.

In this condensation a large quantity of heat is set free, so that the vapor that remains in the air is still more expanded, and the whole column of air is rendered light. As the expanded air rises it flows off towards the poles.

The atmosphere at the equator is thus probably higher than elsewhere, although it exerts a lower pressure."

Coming from the Equator or High Barometer, being becalmed several days in the vicinity of Cape Horn, and having the winds while in that neighborhood from every quarter, and in all kinds of weather have all combined to give me more experience than usual to one coming from the Pacific to the Atlantic.

Add to which a very short crew, a desire to make a good passage it may be imagined that a careful study was made of the barometer.

The westerly winds were first encountered, as the result of a gale experienced from the Nd.

I quote from my Remark Book: December 3rd, Latitude 33° S. Long. 128° W. Wind Nd. and Ed. Barometer 30. 30. Wind increasing and hauling to Nd. and Wd. Barometer falling, rainy, dirty weather

At 7.15 A. M. December 4th, Latitude 38° S. Long., 127° W. barometer fell to 29.70 going down .20 inches in two hours ; for a short time wind lulled, then came out in a furious squall from S. S. W.

Fortunately we were prepared for this change, having reduced sail.

The barometer having reached this height remained so for some days when it rose slowly the wind back to the Nd. by the West; after there remaining stationary for some time, it again fell, the wind coming out once more S. W., this last stand was again retained for some time until a rise accompanied a northerly wind, which finally backed to East.

Barometer then stationary it fell calm for some hours; then wind westward barometer falling at S. W., reached a level; again it rose after a day or so, and continued rising, the wind backing by way of West to North then E. N. E. and S. E.; finally barometer reaching 29.40 the wind came out fresh and squally from S. W., soon blowing a gale, which sent the "Portsmouth" flying past Cape Horn.

My conclusions on the subject of the barometer off Cape Horn or in High Southern Latitudes, may be summed up as follows.

Admit that naturally a low barometer exists there, and assume it.

When the barometer is above its mean, good weather; when it falls to reach this mean, also good weather; when steady at high barometer, moderate winds; steady low barometer, fresh winds.

Wind S. W. first rise; wind back to Nd.

Should it continue to rise, it will go to Ed, and finally South by way of East, S. S. E. its highest then a fall; S. W. again and dirty weather.

Should however the wind reach N. W. from S. W., and the barometer fall, the wind will come out S. W. again.

S. E. to S. S. W. winds brought dirty, thick weather, hail, rain and fogs.

N. W. weather was rainy and squally.

Easterly weather very pleasant, as also S. W., after it had blown for some hours and cleared off.

I failed to find any premonition of the weather from observations of the Thermometer; its changes always accompanied the changes in wind and never preceded them.

The lowest point reached was 35° Fah.

I subjoin a table of the mean heights of the Barometer as given on an Ice Chart furnished by the Hydrographic Office.

AT 32° FAHRENHEIT.

Lat. 30° } 30.08	Lat. 50° } 29.48.
" 35° } 29.98	" 55° } 29.27
Lat. 35° } 29.98	" 60° } 29.13
" 40° } 29.90	" 65° } 29.03
" 40° } 29.90	" 70° }
" 45° } 29.75	
" 45° } 29.75	
" 50° }	

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Commander A. T. MAHAN, U. S. N., in the Chair.

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### ON A PROPOSED TYPE OF CRUISER FOR THE UNITED STATES NAVY.

By LIEUTENANT J. C. SOLEY, U. S. N.

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For many years, we have, perforce, remained comparatively idle, without making any improvement in our Navy, content that it should be so because the art of building ships of war was making such rapid strides that it was out of the question for us, with our small appropriations, to keep pace with European nations, and because we felt that it was just as well for us to save our money and to remain quiet observers, while a jealous watch was kept upon all improvements, and an intelligent body of officers was studying every step taken in advance, so that, when the time came for us to build, we might be warned by the mistakes of other nations and profit by their successes. Once we were pioneers in ship-building, now we are out of the race altogether; but it seems that our legislators are waking up to a realization of the forlorn condition of the *materiel* of the navy, and that a more generous spirit is likely to predominate in their councils; and a proposition has been made to vote a certain sum yearly to be expended in laying down new ships. This, then, seems to be eminently the time for naval officers to say what ships they want, what speed they are to have, what batteries they are to carry, in short what work they are to be able to do.

Before going into the question of the future type for our own service we must consider the vessels we are to encounter. The following table

embraces the latest vessels of the rapid cruiser type which have been built for foreign navies :

CRUISERS OF THE RAPID TYPE.

NAMES.	Displacement in tons.	Length betw'n perpendiculars	Beam.	GUNS.	
				Main Deck.	Upper Deck.
BRITISH NAVY.					
Inconstant,	5,782	333	50	10 12½-ton 2 64-pdrs.	6 6½-ton 2 18-ton
Shah,	6,040	334	52	16 6½-ton 14 4½-ton 2 64-pdrs.	6 64-pdrs.
Raleigh,	5,200	289	49		2 12½-ton 4 64-pdrs.
Boadicea,	4,027	280	45	16	
Bacchante,	3,932	280	45	16	
Euryalus,	3,932	280	45	16	
Rover,	3,494	280	43		18
Volve,	3,078	270	42		18
Active,	3,078	270	42		10
FRENCH NAVY,					
Duquesne,	5,436	326	50	20 4½-ton	7 7-ton
Tourville,	5,436	326	50	20 4½-ton	7 7-ton
ITALIAN NAVY,					
Cristoforo Colombo,	2,500	250	36	4 4½-ton	1 4½-ton
RUSSIAN NAVY.					
Duke of Edinburgh,	4,500	286	48	Armor Belt.	4 9-ton 2 7-ton
General Admiral,	4,500	286	48		
Peresvett,	3,840				
Assletia,	2,980				
Sveteana,	3,090				

Great Britain, with her large mercantile marine, first of all nations, recognizes the necessity for protecting her commerce, and her first object is to build vessels powerful enough to perform that duty, not vessels to prey upon an enemy's merchant ships and run away from his war vessels. A distinguished writer in a London magazine not long ago enunciated the principle which has governed the English authorities in laying down ships. "England is bound always to maintain an unarmored fleet more powerful than that of the United States and not to allow individual unarmored ships in her navy to be surpassed in speed or power by vessels of the American Navy."

Our naval history has been a glorious one; our flag has never been dishonored on the sea, but, though few in numbers, our ships have always held their own, and done noble service against a powerful enemy; but our successes in 1812 were due to the fact that our fathers, with wise forethought, built their individual ships so as to be stronger than those with which they would have to cope; where the English had 38 gun

frigates, we had 44 gun frigates; where they had 32 pdr. carronades we had 44 pdrs.; where they had long 18's we had long 24's. So it must be in the future, if we are to enforce obedience to our laws on our coasts and in our own harbors, or if we are to fight with honor to ourselves and our country. We are peculiarly situated; our harbors are easily protected from an enemy; hostile squadrons will not be able to cruise on our coasts, and there will be no fleet actions; there will be, as in 1812, engagements between individual ships at sea, and we must have vessels to carry our flag on every sea able to meet any unarmored cruiser and perhaps engage with success an armored vessel.

If we look upon the vessels of our Navy as "commerce destroyers," we make a grievous mistake. Some vessels there must be whose mission is to "sink, burn and destroy," but that duty may be performed by swift, small vessels, armed with one or two heavy guns, in which every consideration is sacrificed to speed, but let the main duty of the Navy be that of "commerce protector," a duty nobler in every sense of the word and one that more exactly fulfills the ideal of every true hearted sailor. The vessels to perform this duty must be superior to the Raleigh, the Boadicea, the Rover,\* or the Duquesne in speed, in guns, and in their ability to keep the sea. No one quality should be subordinated to another; but the vessel of the future should be large enough and strong enough to carry a powerful engine, it should be a ram of sufficient strength to do its work without serious injury to itself, it should have a battery of heavy guns, delivering an all round fire, it should have coal capacity to steam at least three weeks at 9 knots, and sufficient sail power to cruise under sail alone.

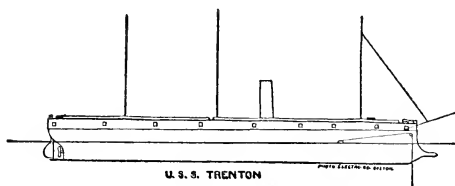
Having considered the subject from two points of view, viz.—what other nations have and what we need, there remains one more point to be noticed, and that is what we have. The following table gives all the vessels available as cruisers:

NAME.	DISPLACEMENT.	GUNS.
Trenton	3800	11
Hartford	3900	18
Richmond	2700	14
Pensacola	3000	22
Powhatan	3980	17

\* NOTE.—I have purposely left the Inconstant and the Shah out of consideration, as they are admitted by the British authorities to be too costly to maintain and too unwieldy to handle.

NAME.	DISPLACEMENT.	GUNS.
Alaska	2400	12
Plymouth	2400	12
Monongahela	2100	11
Ossipee	1900	8
Swatara	1900	8
Marion	1900	8
Vandalia	2080	8

To these might be added the four steam frigates. It is needless for me to go into detail with regard to these vessels as their qualities are only too well known. Suffice it to say that most of them are so slow as to be of very little service in time of war, while their batteries, which are numerically large are principally composed of nine inch smooth bore guns which are not guns which would give us the victory in any naval action. Of all these vessels only two are worthy of mention. The others are old, out of repair, or as I have said, carry insignificant batteries. The two to which I refer are the Trenton and the Monongahela. The Monongahela has two 8-inch rifles and a large coal capacity. The Trenton is the least known of any of our ships as it is the last one fitted out. This ship, in general terms may be said to fulfill the purposes for which it was designed, as it can steam 12 knots and perhaps more; it carries a battery of eleven 8-inch rifles; it has a powerful ram and great handiness for turning, and is the only cruiser in the navy which has an all round fire. But with these good qualities there are many defects to which I propose to call attention, and at the same time to offer suggestions for their correction which occur to me from my observations on board of foreign men-of-war. These suggestions are offered, not in a spirit of carping criticism but to elicit discussion and, perhaps, to insure improvements in the next vessel built.



The Trenton is a frigate-built vessel, 253 feet long between perpen-

diculars, 48 feet beam, and 21 feet draught, with a ram projecting about 15 feet from the perpendicular, made of solid wood bolted to the stem and deadwood, and covered with a casing of bronze which is bolted through and through the stem. The shape is peculiar and lacking in strength and if it were injured in ramming, the injury would be fatal to the ship. The swau-breast shape with modifications is generally conceded to be the best and less liable to be broken off. Such a shape might be fitted to the Trenton and better supported so that a sudden wrench would not break it off.

There are, as usual, two hawse holes on each side for the cables, the inner one being very near the stem and not quite 8 feet from the water line. The hawse pipes are below the main deck and the cables come in on the upper part of the berth deck instead of on the main deck as is customary. In consequence of the nearness of the hawse holes to the stem and of the peculiar shape of the ram, the bill of the anchor frequently hooks in the ram in heaving up the anchor and incidentally there is added trouble in mooring and unmooring and clearing hawse. The cables lead from the hawse holes near the ceiling to the steam capstan which is on the deck itself, consequently the cable comes in at a right angle or less, and, although the capstan is a powerful one, it often becomes necessary to assist it with a deck tackle, particularly in heavy heaving, while there is always an undue strain on the cable from its coming at such a sharp angle; when the anchor is let go the tendency of the cable is to fly up off the bitts, at the same time violently striking the deck overhead. The berth deck is of course very dirty and it is more difficult to clean than a gun deck; while, small as it is, the little remaining space is taken up with cables, bitts, manger, &c. In addition to all these, there is still another and more serious defect. The hawse holes are so low, coming in as they do, on the berth deck, that they are always a source of leakage while steaming head to sea, and they would be a *source of absolute danger in getting underway on a lee shore*. Even in getting underway in the harbor of Ville-franche, in a moderate sea the berth deck was flooded with water.

These defects might be remedied by moving the hawse holes farther from the stem, continuing their pipes to the gun deck, and leading the cables to bitts near the foremast and then over rollers to the steam capstan. There are three water-tight compartments forward of the fire room but they hardly deserve the name, as the bulk-head of the forward one only comes up to the orlop deck, which is some six feet below the water line, and the others only to the berth deck. There are no means of

pumping them out separately but there are valves leading from one to the other and there is a pump for the after one. It is evident that the division of a ship into compartments has not, as yet, received much attention from our constructors, but it is hardly necessary to describe the arrangements usually made, as they are to be found in so many books. One thing is vitally necessary, which we lack very much, namely, powerful pumps that can be worked by hand to clear each compartment, and, if need be, to serve in case of fire; while the bulk-heads should come up to the gun deck.

The bowsprit is intended to be rigged in, in clearing for action and it was the original intention to have it come straight in on the gun deck, the iron stanchions, supporting the spar deck, being triced up to make room for it, but the spar deck was so overloaded with fore-castle guns that the iron stanchions could not support it and had to be replaced by permanent wooden ones. In consequence of this change a plan had to be devised for making the bowsprit diverge from the direct line and go off in a diagonal direction to starboard. This is an arrangement of doubtful utility because if there is any strain on the head gear it will be difficult to give it the new direction. As it required a long time at the Navy Yard, with all the dock appliances, to get it in place, it is probable that it will not be moved. If it became necessary to get rid of it in order to use the ram in action, the simplest and most expeditious course would be to saw it off outside the gammoning; at the same time, one cannot but be struck by the incongruity of an arrangement for rigging in the bowsprit with the lower and topmast stays rove through bee blocks. In connection with the bowsprit I suggest that a top gallant fore-castle could be built and a much shorter bowsprit, without any other head booms, be fitted to rig in and out on top of it, the fore and foretopmast stays being set up at the knighthead.

An important consideration in connection with the health and comfort of the crew is the location of the heads. These are built on the forward part of the gun deck and may be said to have no ventilation whatever; they are a constant source of annoyance, particularly at sea when the forward ports have to be closed; and the discomfort which they cause to the men who are berthed in that part of the ship can be better imagined than described. They should be moved to the spar deck forward of the fore rigging and discharged through iron shoots bolted outside the ship. They should be roofed over, with air ports in the side and slats all round so that a current of air would always be maintained. Large tanks should be built overhead in which



soluble disinfectants could be put and there would always be a good head of water for flushing the troughs, at the same time doing away with any disagreeable odors.

The sick bays are placed one on each side of the berth-deck forward of the coal bunkers and are about 30 feet long and 8 feet wide, extending as far forward as the bitts, which leaves a space of 50 feet from bay to manger in which to stow mess chests and bags for 450 men and to berth a portion of the crew. There is no ventilation for either sick bay except through the air ports and there is a water closet in the end of each one. The remedy which I propose in this case is to put the hospital on the gun deck forward of the battery on one side, taking one or two ports.

The ship is particularly defective in ventilation. The iron ventilators which are generally placed in fire rooms have been placed in this ship but perhaps as much because of their utility for hoisting ashes as for any other reason. There are two pipes from the shaft alley to the outside of the ship at the stern, with branches to the ward room pantry, but, as they were arranged, the current was generally into the ward-room from the alley, particularly with a following wind. These were removed. There are no other ventilators except the windsails which serve to carry fresh air below, but there are no artificial means for creating a return up current for the foul air of the bilges; but the deck strakes on the gun and berth decks were scored on top as far as the timbers so that between every timber there was an up current of mephitic air, discharging into officers' quarters, hospitals, gun and berth decks. At the same time that part of the bilge under the after magazine was entirely enclosed so that it could not be cleared without cutting holes in the bulk heads; where this was done it was found that a large quantity of decaying animal and vegetable matter had collected here, which caused a most unhealthy smell, and, in consequence of those arrangements, officers and men, sick and well, were obliged to eat and sleep in a vitiated atmosphere. These openings have been nearly all closed.

While on the subject of health and comfort I wish to say a few words about our system of feeding and messing the crew. There is no need for me to describe it; every one who hears me is familiar with it, and with the degrading and at the same time injurious effects which it has on the men. Long since abandoned in every Navy but our own it has fastened itself on our service by the force of habit, and no one in authority does anything to eradicate it, while it might be

done at very little trouble or expense by supplying tables and benches. Every one acknowledges that if we want a good class of men we must do something to raise the standard instead of lowering it, and yet we adhere to one custom at least which, more than almost any other, is brutalizing to the men and discreditable to the officers.

The life-saving apparatus is lamentably defective. There is a life buoy on each quarter but they were put on when the cabin ports were closed; when they are open, the buoys cannot be dropped until the laniards are cast off below, or cut. There are no rubber life rafts, and the only chance a man who fell overboard would have would be to swim until a boat picked him up.

The boats of the ship will carry in smooth water, crowded to their utmost capacity, about 400 men, with water and bread at short rations for two days, leaving 70 men on board. The station bill of the ship provides for building a raft in case of emergency, to carry the other 70 men, but there is only one wooden balsa to serve as a foundation for a raft, and any one who has had experience in building a raft from resources on board ship can judge how long it will take to build one to float 70 men; but if an accident happens to the ship in a seaway not so many men by 80 can get into the boats, so there will be 150 men unprovided for, who would inevitably be lost. These defects are easily remedied. A change in the position of the life buoys, a supply of life rafts, and a reduction in the number of the crew in times of peace, and an increase in the number and size of the boats;—all of these are easily effected, and imperatively needed.

Another very important point presents itself in connection with the fact that this vessel is intended for ramming. The side of a ram vessel should be perfectly smooth; no projection should be allowed which can be caught by another vessel in passing, but here we have an almost immovable bowsprit, three channels on each side, catheads and all the boat davits, even the guns should be mounted so that the muzzles will scarcely project beyond the ports.

The steam steering engine is located on the main deck in the battery, a most objectionable position. It can be worked either on the spar deck or on the gun deck, but there is no compass on the gun deck, and no conveniences for working it there. The holes for the wheel ropes are the same as those for the hand-wheel on the quarter-deck so that one set must be unrove before the others can be used. The hand-wheel is of the ordinary kind but not sufficiently powerful for four men to control the rudder, particularly in a seaway. Both arrangements might be

made more efficient if the steam wheel were moved to the spar deck near the fore-mast, covered over and worked by a wheel on the bridge above, with an independent set of wheel ropes, and the quarter-deck wheel made more powerful and fitted with a strap brake.

In connection with the battery, I shall only refer to the location of the guns. There are four 8 inch rifles on each side of the main deck, two on the spar-deck forward of the foremast and one abaft the mizzen mast, and it is with these last that we have most to do. The guns with their carriages weigh nearly twelve tons so we have twenty-four tons at one end and twelve at the other which are not waterborne and must strain the ship. At the same time the complication of tracks and pivots rendered necessary by an adhesion to the old system of maneuvering guns has defeated its own object and there is a loss instead of a gain in handiness and rapidity of fire. These guns are manned by twenty-five men each and they are totally exposed to the fire of sharpshooters so that soon after beginning an engagement they would probably be hors du combat. The top-gallant fore castle suggested would obviate one difficulty in screening the men, and the removal of one gun and mounting the other on a turn table with a muzzle pivoting carriage would obviate another. The two remaining guns could be mounted on the quarter-deck with muzzle pivoting carriages also, and arranged to fire in three directions by means of indented ports.

I have gone thus much into details, some of them disagreeable ones, because it is in the details that the ship is defective, and because this is the only new ship in the service in which any modern appliances have been placed; but the manner of using them shows a want of study of those appliances, and a neglect of some of the most important principles of efficiency and health and comfort which should govern the internal arrangements of a man-of-war.

Having considered what we have and what we want I now pass to the explanation of the designs for the proposed cruiser.

## DETAILS.

### DIMENSIONS.

Length at water line,	275 feet
Beam,	52 "
Mean draught,	21 "
Height of main truck from water line,	150 "
Displacement,	4,900 tons.
Coal capacity,	720 tons.

RIG.—Full brig—lower, top-sail and top-gallant yards.

BATTERY.

Spar-deck. Five 8 inch rifles.  
 Four 20 pdr. B. L. R. on depression carriages.  
 One 3 in. B. L. R. } on poop.  
 One gatling, }  
 Two 12 pdr. S. B. howitzers on forecastle.  
 One gatling—top.

Main-deck. Ten 8 inch (or 9 inch) M. L. R.

BOATS. One steam launch. Three pulling launches.

Four 12 oared cutters. Two 10 oared cutters.

One whale-boat—One gig. One dingy.

COMPLEMENT. 500 men.

CONSTRUCTION.

TYPE. Unarmored, iron, sheathed with wood.

Ram, projecting 6 feet.

MATERIALS. Iron for frames and beams; steel for plating.

SYSTEM. Longitudinal. The ship to be divided by bulkheads into compartments; between the bulkheads, transverse girders. Flat plate keel, of same breadth as garboard strakes with internal vertical keel of mild steel: the vertical keel is composed of a continuous plate running over the girders riveted to intercostal pieces between the girders, and these in turn, riveted to the flat keel plate by angle irons, also intercostal. The longitudinals are iron stringers, one along the center of every plate of the skin. The main longitudinals are continuous from stem to stern and made like the vertical keel. They are carried as high as the gun deck: at the bow they meet and form breast-hooks, which are plated across as far as the ram bulkhead. The alternate longitudinals extend from the stuffing box bulkhead to the ram bulkhead and are only carried as high as the berth deck: they are intercostal to the bulkheads to which they are riveted by angle irons. The berth deck is of iron, continuous, carried by the bulkheads and by longitudinals under it. The transverse girders and the intercostal pieces of the longitudinals have holes cut for water courses. The ram is made by bolting heavy forged plates to the longitudinals and breast-hooks. Very heavy forgings will not be required for the bow by this system of construction as the strength of the ram is in the structure of the bow which takes up the force of the blow and transmits it by the longitudinals and berth deck throughout the ship. Thus each portion of the ship is made to do its work in ramming and the whole ship becomes the ram and not that

part only which is forward of the ram compartment. The plating is covered with two courses of plank sheathed with zinc.

**COMPARTMENTS.** The first compartment extends from the stem to the first bulkhead and is called the ram compartment. The bulkhead extends athwart-ship from side to side and from the keel to the gun deck. It is water-tight and can be entered only from the berth deck by a door which must always be kept closed. The plating of the breast hooks and of the berth deck has man holes cut so as to permit communication throughout the compartment. There is no pump in this compartment, but there is a sluice valve near the keel, by which, if necessary, water may be allowed to run into the next compartment and can then be pumped out. All the bulkheads are alike except No. 6 which only extends as high as the berth deck. The second compartment is between 1 and 2 bulkheads, and includes a shell room, store room, cable tier, a small orlop for stores, and the capstan engine on the berth deck. It is entered by a hatch on the gun deck and by a door in the bulkhead on the berth deck. An iron floor is laid on the vertical keel extending to either side, and no bulkhead in the compartment comes below this floor, thus leaving an open space for cleaning and ventilation. A man hole is cut in this floor on either side of the vertical keel to permit entrance to the inner bottom: holes for water courses are cut in the intercostal pieces of the vertical keel. The third compartment is between 2 and 3 bulkheads and includes a magazine, two shell rooms, an orlop with general store room, bread room, sail room and marine store room. The floors in all the compartments are laid as already described. The foremast is in this compartment and has three holes cut in it which ventilate the inner bottom, the orlop and the berth deck. The fourth compartment includes the hold and coal bunker. There is a side bunker on the berth deck from which the main bunker on the berth deck is filled from a coaling port in the ship's side, the inner plates of the berth deck within the bunker being omitted. The fifth compartment includes the engines and boilers, and side bunkers. The side bunkers are made of the shape shown in the drawing of the transverse section with a coaling port for each bunker. On the berth deck running along the bulkheads of the side bunkers are rows of shelves for rigging, tackles, blocks &c. which have generally been kept in the hold. The sixth compartment includes magazines and shell rooms, an orlop with store rooms, tiller room, steerage and warrant officers quarters on the berth deck. Aft No. 6 bulkhead is a small compartment which contains the stuffing box for the shaft.

**SPARS AND RIGGING.** The bowsprit is a single spar stepped on the top gallant forecastle, and is rigged in entirely in clearing for action. The top mast and lower stays set up on the top gallant forecastle. The lower masts are hollow, of steel, with diaphragms. There are no channels and the lower rigging sets up to dead eyes above the hammock netting, the chain plates being bolted to the side and coming up through the netting. The top gallant rigging is to be of hemp instead of wire.

**PUMPS.** The main steam bilge pumps are connected with a large pipe underneath the floor running fore and aft, near the vertical keel communicating with all the compartments except Nos. 1 and 7. This pipe has holes in each compartment which can be closed by sliding a curved plate over them. In addition to the steam pumps, there is a rotary pump in each compartment to be worked by hand which can be used for freeing the ship or as force pumps in case of fire.

Ventilation is obtained by means of pipes carried up between the girders from holds and berth deck fitted with cowls on the upper deck.

Stanchions are to be placed under every beam for half the length: under alternate beams before and abaft that length to be secured at head and heel to act both as strut and tie, and to be made hollow with solid heads and heels. Voice tubes and electric bells are to be placed in each compartment communicating with the bridge.

*The steering engine* is on the berth deck in the engine compartment. The rods and chains connecting the engine with the tiller run directly fore and aft on rollers on the deck to a leader near the tiller, then to the tiller block, back through the leader and they then join the tiller ropes from the quarter deck wheel. By means of a clamp either one can be made the standing part so that in case of an accident to one apparatus, the other can be worked immediately. If both are injured the relieving tackles from the spare tiller on the gun deck can be taken to the second drum on the spar deck wheel.

The steering engine can be worked from the bridge, the gun deck or the berth deck, so that there are five different places from which the ship can be steered with very little loss of time in changing from one to another.

*The capstan engine* can be understood from the figure. The ordinary capstan is placed on the gun deck and the spindle continued to the berth deck where it is connected with a two cylinder oscillating engine by means of an endless chain and cog wheels. The capstan can be disconnected from the engine and worked by means of bars.

*Gun deck.* Forward on the gun deck are the hospital, galley, cook's wash room and closets. A battery of ten guns, and abaft the battery a bulkhead, beyond this bulkhead are the offices and quarters of the wardroom officers. The ports for the guns are whole shutters which are hinged at the top with a small hole in the middle for the rammer or sponge handle when working with closed ports. Forward of and abaft the battery the ports are much nearer together and one foot square. There are mess tables and benches triced up between the guns for every mess.

*SPAR DECK.* There is a top gallant forecastle under which is an 8 inch rifle on a turn table and the heads for the crew. On the top of the forecastle two 12 pdr. S. B. howitzers for use against torpedo boats. The cat heads are made of metal and hinged so that the anchor being secured on the forecastle they can be swung against the side in clearing for action. Two 8 inch rifles are placed in indented ports to fire ahead or abeam: two 20 pdr. B. L. rifles on depression carriages are mounted in the waist on either side for saluting and for firing down along side: two 8 inch rifles in indented ports for firing astern or abeam, a poop containing the commanding officer's quarters, and on the poop a gatling and a 3 inch B. L. rifle. A iron gutterway sunk in the deck connecting beams and stringers to the framing runs fore and aft on either side. This serves to carry water off the deck and also as a longitudinal stringer adding a great deal to the strength of the upper works. The smoke stack is made elliptical for the sake of the additional room which is gained for working the guns and stowing the boats. The boats are stowed in nests on the deck, the steam launch on one side, a launch and two cutters on the other. The boat davits are of the shape shown in the figure, and in clearing for action the boats are to be swung in over the deck, thus preventing them from injury in firing and leaving a smooth side for ramming.

I have already stated the requirements of a type of vessel which the circumstances of our navy demand; to recapitulate, they are that the vessel should be large enough and strong enough to carry a powerful engine, that it should be a powerful ram, that it should have an all round fire of heavy guns, with large coal capacity and sufficient sail power for cruising under sail alone. The designs which I have submitted will, I believe, meet all these requirements. A vessel such as I have described would probably cost \$1,250,000 but with a yearly appropriation of \$3,000,000 four of these vessels could be laid down in the first year; in the second year those might be pushed to completion

and two others laid down and so on. It would probably take two years at least to complete one, and in the mean time, by this progressive method new inventions might be developed and improvements made in each successive one and even this much work would stimulate ship building and iron production throughout the country.



U. S. NAVAL INSTITUTE,

ANNAPOLIS, Md., JUNE 13, 1878.

Commander A. T. MAHAN, U. S. N., Vice President, in the Chair.

The following rules were adopted :

**RULE I.** That a prize to consist of one hundred dollars in money and a gold medal of the value of fifty dollars be offered annually for an essay on a given subject, under the rules herein stated. The money value of the medal may be given to the successful Competitor, if he so elect.

1. Competition for the Annual prize to be open to all persons who are eligible for membership.

2. Each Competitor is to send his essay in a sealed envelope to the Secretary, on or before the 1st of January in each year ; the name of the writer shall not be given in this envelope, but instead thereof a motto. This motto with the writer's name to be sent to the Secretary in a separate sealed envelope, which is not to be opened until after the decision of the Judges.

3. The Judges are to be three gentlemen of eminent professional attainments, to be selected by the Executive Committee.

4. The successful Essay is to be published in the Proceedings of the Institute, and the Essays of other Competitors to be published also, at the discretion of the Executive Committee, with the consent of the writers.

5. The successful Competitor shall be made a Life Member of the Institute.

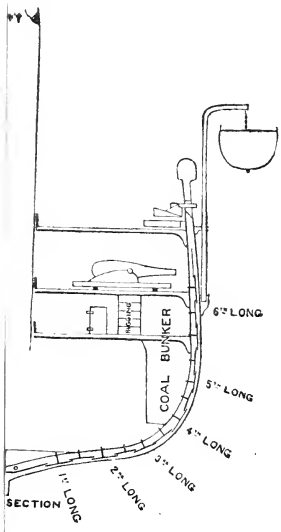
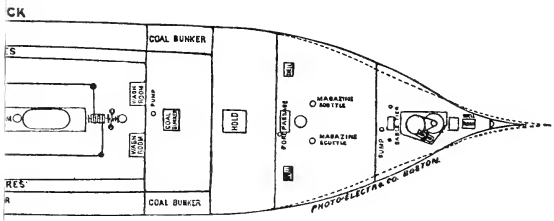
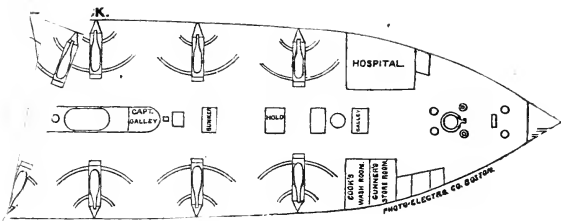
**RULE II.** The subject of the first Prize Essay is to be

“NAVAL EDUCATION.

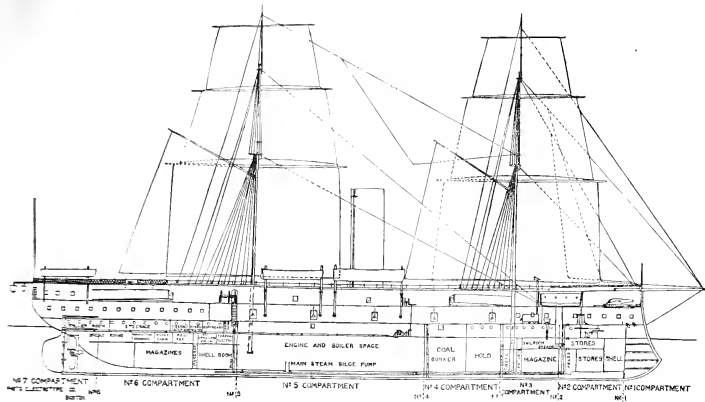
I. OFFICERS.—II. MEN,”

and the Essay is to be limited to 48 printed pages of the Proceedings of the Institute.

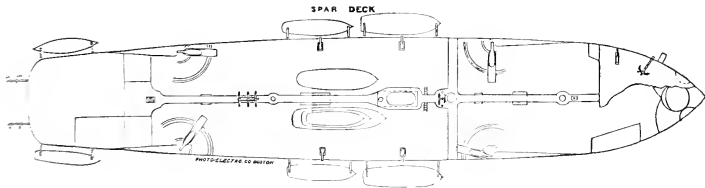






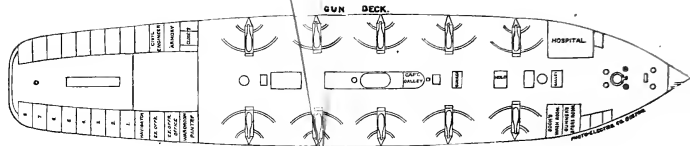


N°7 COMPARTMENT  
N°6 COMPARTMENT  
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N°3 COMPARTMENT  
N°2 COMPARTMENT  
N°1 COMPARTMENT



SPAR DECK

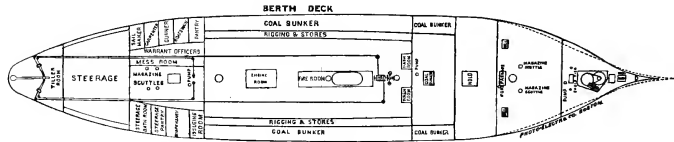
PHOTOLECTRIC CO. BOSTON



GUN DECK

HOSPITAL

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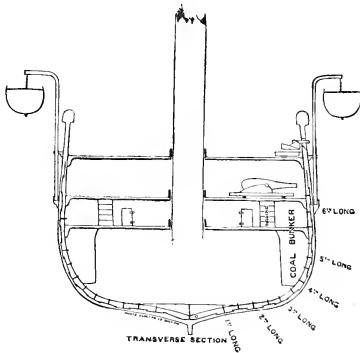
BERTH DECK

COAL BUNKER

COAL BUNKER

HOSPITAL

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TRANSVERSE SECTION

8' LONG

5' LONG

4' LONG

3' LONG

2' LONG

1' LONG

COAL BUNKER















