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17 May 1897 – 10 Jan. 1898.

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THE

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOLUME X.

BOSTON:
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
1897.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY held its first meeting on April 8, 1862. By the act of incorporation, which was accepted at this meeting, the SOCIETY OF ARTS was created as a part of the Institute coördinate with the School of Industrial Science.

The objects of the Society are to awaken and maintain an active interest in the sciences and their practical applications, and to aid generally in their advancement in connection with the arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May.

The Society discontinued the publication of the *Abstracts of Proceedings* in 1891, and since then has published its proceedings and the principal papers read at its meetings in the *Technology Quarterly.* The present volume contains the proceedings from October, 1896, to May, 1897, inclusive.

The *Quarterly* contains, also, the results of scientific investigations carried on at the Institute, and other papers of interest to its graduates and friends.

Neither the Massachusetts Institute of Technology nor the SOCIETY OF ARTS assumes any responsibility for the opinions or statements in the papers.

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ROBERT P. BIGELOW.

Executive Committee.

GEORGE W. BLODGETT, *Chairman.*
EDMUND H. HEWINS.
DESMOND FITZGERALD.
FRANK W. HODGDON.
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Board of Publication.

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DWIGHT PORTER.
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OBJECTS OF THE SOCIETY.

THE objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement and development in connection with arts, agriculture, manufactures, and commerce.

The Society invites all who have any valuable knowledge of this kind which they are willing to contribute to attend its meetings and become members. Persons having valuable inventions or discoveries which they wish to explain will find a suitable occasion in the Society meetings, subject to regulations hereafter provided; and while the Society will never indorse, by vote or diploma or other official recognition, any invention, discovery, theory, or machine, it will give every facility to those who wish to discuss the principles and intentions of their own machines or inventions, and will endeavor at its meetings, or through properly constituted committees, to show how far any communications made to it are likely to prove of real service to the community.

SECTION I. — ADMINISTRATION.

The immediate management and control of the affairs of the Society of Arts shall be exercised by an Executive Committee, consisting of the President of the Institute and the Secretary of the Society (who shall be members *ex officiis*), and five other members, who shall be elected by the Society of Arts at each annual meeting, to continue in office until other persons have been chosen in their place.

SECT. II. — DUTIES OF THE EXECUTIVE COMMITTEE.

The Executive Committee shall elect its chairman, prescribe his duties, and, with the concurrence of the Treasurer of the Institute, fix his compensation when the interests of the Society require that he should be paid for his services; they may invite any person to preside at any ordinary meeting who is well versed in the subjects to be discussed; they shall appoint the days and times of meeting, when not fixed by the Society, and determine the subjects to be considered at the meetings and the mode of conducting the discussions; they may, with the concurrence of the President of the Institute, make such arrangements for reporting and publishing the proceedings of the Society as they may deem best suited to advance its interests; they may receive moneys in behalf of the Society in aid of its objects, by subscription, donation, or bequest; they shall make a report of their doings to the Society at its annual meeting and at such other times as a report may be called for by a majority of the members present at any meeting; they shall also make a report of their doings to the President of the Institute prior to the annual meeting, and at such other times as the Corporation may require it. Three members shall constitute a quorum for the transaction of business.

SECT. III. — DUTIES OF THE PRESIDENT AND SECRETARY.

1. It shall be the duty of the President of the Institute to preside at the annual and the special meetings of the Society, and also at its ordinary meetings when the Executive Committee does not invite a special chairman to preside.

2. It shall be the duty of the Secretary of the Society to give notice of and attend all meetings of the Society and of the Executive Committee; to keep a record of the business and orders of each meeting, and read the same at the next meeting; to keep a list of the members of the Society, and notify them of their election and of their appointment on committees; and generally to devote his best efforts, under the direction of the Executive Committee, to forwarding the business and advancing the interests of the Society. He shall also record the names of the Executive Committee attending each meeting.

SECT. IV. — FUNDS OF THE SOCIETY.

All the fees and assessments of members, and all moneys received by subscription, donation, or otherwise, in aid of the Society, shall be paid into the treasury of the Corporation, to be held and used for the objects of the Society under the direction of the Executive Committee, and shall be subject to the order of its Chairman, countersigned by the President of the Corporation.

SECT. V. — MEETINGS OF THE SOCIETY.

1. The annual meeting of the Society shall be held at the Institute on the second Thursday in May. The ordinary meetings shall be held semi-monthly, or whenever deemed expedient by the Society or by the Executive Committee, excepting in the months of June, July, August, and September.

2. If from any cause the annual meeting shall not have been duly notified or held as above required, the same shall be notified and held at such time as the Executive Committee may direct.

3. A special meeting of the Society may at any time be called by the Secretary on a written request of ten members. Twelve members of the Society shall constitute a quorum for the transaction of business.

SECT. VI. — MEMBERS AND THEIR ELECTION.

1. Members of the Society of Arts shall be of three kinds — Associate, Corresponding, and Honorary Members.

2. Candidates for Associate Membership shall be recommended by not less than two members, whose signatures shall be affixed to a written or printed form to that effect. Each nomination shall be referred to the Executive Committee, and when reported favorably upon by them, and read by the Secretary, may be acted upon at the same meeting; the election shall be conducted by ballot, and affirmative votes to the number of three fourths of the votes cast shall be necessary for an election.

3. Corresponding and Honorary Members may be elected in the same way, on nomination by the Executive Committee.

4. Associate Members shall pay an admission fee of three dollars before being entitled to the privileges of membership, and an annual assessment of three dollars on the first of October of each year, this sum to include subscription to the *Technology Quarterly and Proceedings of the Society of Arts.*

An Associate Member who shall have paid at any one time the sum of fifty dollars, or annual assessments for twenty years, shall become a member for life, and be thereafter exempted from annual assessments.

A member neglecting to pay his annual assessment for six months after being notified that the same is due shall be regarded as having withdrawn his membership, unless otherwise decided by the Executive Committee, which shall be authorized, for cause shown, to remit the assessments for any one year; and which shall moreover be empowered to exempt particular members from assessments whenever their claims and the interests of the Society make it proper to do so.

SECT. VII. — ELECTION OF THE EXECUTIVE COMMITTEE AND OF THE SECRETARY.

1. At an ordinary meeting of the Society, preceding the annual meeting, a nominating committee of *five* shall be chosen, whose duty it shall be to nominate candidates for the Executive Committee, to post a list of the names selected in the office of the Secretary, and to furnish printed copies thereof to the members at or before the time of election.

2. At a meeting at which an election is to take place the presiding officer shall appoint a committee to collect and count the votes and report the names and the number of votes for each candidate, whereupon he shall announce the same to the meeting.

3. A majority of the votes cast shall be necessary to an election.

4. In the first organization under these By-Laws, the Executive Committee may be elected at an ordinary or special meeting.

5. Vacancies in the committee occurring during the year may be filled by the Society at an ordinary meeting.

6. The Secretary shall be elected by the Society, on nomination by the Executive Committee, at each annual meeting of the Society, or, in case of a vacancy during the session, at such other time as the Executive Committee may appoint; and he shall be reëligible in the same way at the pleasure of the Society.

7. The compensation of the Secretary shall be fixed from year to year by the Executive Committee with the concurrence of the Treasurer of the Institute.

SECT. VIII. — COMMITTEES OF ARTS.

1. The Members of the Society of Arts may be enrolled in divisions, under the following heads, according to the taste or preference of

the individual; each division to constitute a committee upon the subjects to which it appertains:

(1) On Mineral Materials, Mining, and the Manufacture of Iron, Copper, and other Metals.

(2) On Organic Materials — their culture and preparation.

(3) On Tools and Implements.

(4) On Machinery and Motive Powers.

(5) On Textile Manufactures.

(6) On Manufactures of Wood, Leather, Paper, India Rubber, and Gutta Percha.

(7) On Pottery, Glass, Jewelry, and works in the Precious Metals.

(8) On Chemical Products and Processes.

(9) On Household Economy; including Warming, Illumination, Water-Supply, Drainage, Ventilation, and the Preparation and Preservation of Food.

(10) On Engineering, Architecture, and Ship-building.

(11) On Commerce, Marine Navigation, and Inland Transportation.

(12) On Agriculture and Rural Affairs.

(13) On the Graphic and Fine Arts.

(14) On Ordnance, Firearms, and Military Equipments.

(15) On Physical Apparatus.

2. Any member may belong to more than one of the above-named Committees of Arts, but shall not at the same time be eligible as chairman in more than one.

3. It shall be competent for each Committee of Arts, of ten or more members entitled to vote, to organize; to elect annually in October, or whenever a vacancy shall occur, a chairman; to appoint its own meetings; and to frame its own By-Laws, provided the same do not conflict with the regulations of the Society of Arts.

SECT. IX. — AMENDMENT AND REPEAL.

1. These By-Laws may be amended or repealed, or other provisions added, by a vote of three fourths of the members present at any regular meeting of the Society; provided that such changes shall have been recommended and approved in accordance with the By-Laws of the Corporation (see extract from By-Laws of Corporation as

printed below) and presented in writing at a preceding meeting of the Society.

2. These By-Laws shall take effect immediately after their approval by the Corporation and adoption by the Society, and all previous By-Laws are hereby repealed.

As amended December 9, 1897.

EXTRACT FROM THE BY-LAWS OF THE CORPORATION.

SECT. VI. — There shall be a Committee on the Society of Arts consisting of five members, appointed at the annual meeting of the Corporation, to hold office for one year, who shall have the general charge and supervision of the organization and proceedings of the Society, subject to the approval of the Corporation. It shall be their duty, in connection with a committee chosen by the Society, to frame By-Laws for the government of the Society, which shall take effect when adopted by the Society and approved by the Corporation.

February, 1894.

LIST OF MEMBERS.

DECEMBER, 1897.

Members are requested to inform the Secretary of any change of address.

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Addicks, J. Edward . . . . Wilmington, Del.
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TECHNOLOGY QUARTERLY

AND PROCEEDINGS OF THE SOCIETY OF ARTS

CONTENTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,

BOSTON.

Entered as second-class mail matter at the Boston Post Office.

Results of Tests Made in the Engineering Laboratories of the Massachusetts Institute of Technology.

Published in the Technology Quarterly.

I. APPLIED MECHANICS. In July Number, 1894.

Steel tension. Wrought iron tension. Cast iron tension. Compressive tests, wrought iron. Compressive tests, cast iron. Iron wire tests. Copper wire tests. Tests on torsion machine. Rope tests. Spruce beams. Yellow pine beams. Kiln-dried western white pine. Hemlock. White oak beams. Time tests.

II. STEAM AND HYDRAULICS. In April Number, 1895.

Ejector tests. Pulsometer tests. Duplex pump. Flow of steam. Horizontal belt machine. Wheeler condenser. Mack injector. Boiler tests. 72-hour boiler test. 128-hour boiler test. 56-hour boiler test on a battery of two 208 H. P. Babcock & Wilcox boilers. 128-hour boiler test on No. 3 boiler. 54-hour boiler test. 88-hour boiler test. 60-hour boiler test on a battery of two 208 H. P. Babcock & Wilcox boilers. Tests on a No. 6 Douglas hydraulic ram.

III. APPLIED MECHANICS, STEAM AND HYDRAULICS. In October Number, 1895.

Column tests. Compression of spruce columns. Wooden columns. Column test, yellow pine. Oak bolsters. Maple bolsters. Spruce columns with yellow pine bolsters. Aluminum tension. Steel tension. Wrought iron tension. Iron wire. Copper wire. Rope tests. Tests on torsion machine. White oak beams. Maple beams. Hemlock beams. Spruce beams. Flow of steam tests. Tests on Davis plunger pump. Pulsometer tests. Tests on Douglas hydraulic ram. Hancock inspirator, No. 4 C. Tests on the horizontal belt machine.

IV. STEAM TEST. In June and September Number, 1896.

Description and computation of a 24-hour duty test on the twenty million gallon Leavitt pumping engine at Chestnut Hill, by EDWARD F. MILLER, S.B.

V. APPLIED MECHANICS. In June and September Number, 1896.

Tests on bolted joints. Tension tests, boiler plate. Tests on bolted joints, Boston Bridge Works. Wrought iron pipe columns. Transverse strength of spruce beams. Norway pine beams. Sand tests, compression. Sand tests, tension. Neat cement, compression. Neat cement, tension. Compression of timber across the grain. Tension tests. Tension tests of wire. Torsion tests. Torsion tests on wire. Bessemer steel. Refined iron bar. Swedish iron. Composition. Brass. Rope tests.

VI. STEAM AND HYDRAULICS. In December Number, 1896.

Description and results of a 50-hour test made May 7, 8, 9, 1896, at the West End Street Railway's power station, near Sullivan Square, Charlestown, Mass. Boiler tests. Pulsometer tests. Flow of steam. Tests on Davis pump. Test on belt machine, using a 4″ leather belt. Tests on a triple expansion engine, 9″–16″–24″ x 30″ run as a compound. Hancock inspirator. Tests on a Pelton water wheel. Test on a No. 6 Douglas hydraulic ram. Tests on a compound Marsh pump, 10″, 16″, and 9½″ x 16″ stroke.

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TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. X. MARCH, 1897. No. 1.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FIFTH YEAR, 1896–97.

THURSDAY, October 8, 1896.

THE 488th regular meeting of the SOCIETY OF ARTS was held this day at the Institute at 8 P.M., the President in the chair.

The record of the previous meeting was read and approved.

Messrs. Louis F. Cutter, of Winchester, R. R. Taylor, of Tuskegee, Alabama, Frank M. James, of Haverhill, Horace J. Howe, of Medford, Charles H. Chase, of Medford, and Frank Vogel, of the Institute, were duly elected Associate Members of the Society.

The following papers were presented by title:

"Hydrolysis of Ferric Chloride," by H. M. Goodwin.

"An Improvement in the Sedgwick-Rafter Method for the Microscopical Examination of Drinking Water," by D. D. Jackson.

"Experience with the Sedgwick-Rafter Method at the Biological Laboratory of the Boston Water Works," by G. C. Whipple.

"Instruction in Theoretical Chemistry," by A. A. Noyes.

"Origin of Pegmatite," by W. O. Crosby and M. L. Fuller.

"Determination of Reducing Sugars in Terms of Cupric Oxide," by George Defren.

"The Viscosity of Mercury Vapor," by H. M. Goodwin and A. A. Noyes.

Before introducing the speakers of the evening, the President made a few remarks calling attention to the recently issued double number of the TECHNOLOGY QUARTERLY and to the excellence of the work of the Institute as reflected in its pages, especial mention being made of the *Results of Tests Made in the Engineering Laboratory* and of the *Review of American Chemical Research.*

Professor William T. Sedgwick then read a paper on "The Milk-Supply Problem." The value of milk as food was first spoken of, and then the process by which a large city is supplied was described in detail. The difficulties in the way of cleanliness and the danger of infection were pointed out. The mixing of milk by the dealers was declared to be the worst feature of the system in Boston, owing to the greatly increased chance for the spread of infection. Pasteurizing was suggested as a partial solution of the problem of pure milk supply of large cities.

Mr. Samuel C. Prescott then read a paper, of which he is joint author with Mr. W. Lyman Underwood, on "An Investigation of the Causes of Spoiling in Certain Kinds of Canned Foods." The authors found eight species of bacteria in spoiled cans of lobster and clams. It was found by experiment that the old method of heating in the water bath was not sufficient to insure sterilization of cans inoculated with these bacteria, but heating in retorts with steam under fifteen pounds pressure, giving a temperature of 250° F., was always successful. Specimens of several of the species were exhibited, together with both good and spoiled cans of clams and lobster.

The President thanked the speakers for their very interesting papers, and the Society adjourned.

THURSDAY, October 22, 1896.

The 489th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

There being no further business, the President introduced Professor E. B. Homer, of the Institute, who read a paper on "A Bicycle Tour Through Surrey, Normandy, and Touraine." The paper was an account of the excursion made by the Summer School of Architecture of 1896. The students under the direction of Professor Homer, traveled on bicycles through the countries named and made sketches and photographs of the many interesting works of architecture upon their route. The lecture was illustrated by over a hundred views made from photographs taken by members of the party. The paper is published in full in the present number of the TECHNOLOGY QUARTERLY.

The Chair thanked Professor Homer for his very interesting paper, and the Society adjourned.

THURSDAY, November 12, 1896.

The 490th meeting of the SOCIETY OF ARTS was held this day at the Institute, President Walker in the chair.

The record of the previous meeting was read and approved.

Messrs. Louis J. Schiller, of Boston, and J. P. B. Fiske, of Auburndale, were duly elected Associate Members of the Society.

The Society then proceeded to the consideration of the paper of the evening "On the Scientific work of Last Summer's Expedition to Umanak Fiord, West Greenland," by Professor A. E. Burton and Assistant Professor G. H. Barton.

Professor Burton spoke of the general plan of the expedition. He described the apparatus used in making the pendulum and magnetic observations, and the stations in which they were set up, such stations being established at several points on the coasts of Labrador and Greenland.[1] The motion of the ice in the Karajak Glacier was studied. A thermaphone made especially for the expedition by Mr. A. M. Ritchie was used for the determination of the temperature of deep crevasses, and proved to be very serviceable. A trip on the inland ice was described, and the speaker closed with a comparison of the natives of Greenland with those of Labrador.

Professor Barton spoke briefly of the geological work of the expedition. No evidence of present waning of the ice sheet could be found. The crevassing of the glaciers extends far back into the inland ice. This, with the vertical edges of the ice cap, makes the approach to the inland ice very difficult. Ample evidence was obtained that the ice sheet had extended at some former period much farther than at

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[1] See this volume, pp. 56-132.

present in Greenland, and evidences of glacial action were observed also in Labrador.

At the close of Professor Barton's remarks the President thanked the speakers, and the Society adjourned.

WEDNESDAY, November 18, 1896.

A special joint meeting of the SOCIETY OF ARTS, with the Boston Society of Civil Engineers was held this day in Chipman Hall, Tremont Temple, with Professor Swain, President of the Society of Civil Engineers, in the chair.

There being no business, the President introduced Mr. E. L. Corthell, of New York, who read a paper on "The Tampico Harbor Works, Mexico, with some remarks upon the Mouth of the Mississippi River."

Mr. Corthell began by referring to a paper that he had read ten years ago before the SOCIETY OF ARTS, and he reaffirmed his opinion that the Edes Tehuantepec ship railway is practicable. He then spoke of the importance of Tampico as a seaport, and of the hindrance to its development caused by the dangerous bars at the entrance to its harbor. In this connection he described the country through which the railroad had been built from the Mexican Central Railroad to Tampico, and paid a high tribute to the daring and skill of the engineers who constructed it. Turning to his own work at Tampico, Mr. Corthell described the harbor works, and the method of their construction. The works consist of two jetties, 1,000 feet apart, running parallel for a mile and one third into the Gulf of Mexico, one from each side of the mouth of the Rio Panuco. The first operation in the construction of the jetties was to build a double track railroad trestle along the line of each jetty. From these trestles the mattresses composing the jetties were sunk. The mattresses were peculiar. They were built while suspended under the trestle, above the reach of the waves. They were 60 feet long, 84 feet wide, and about 7 feet thick. First a strong frame was constructed, then the brush was added, and then when all was firmly bound together, the mattress was lowered to the surface of the water, and quickly sunk by stones dumped from cars upon the trestle. The slopes of the jetties were steeper inshore, and more gradual further out. The effect of the jetties was seen very soon in the deepening of the channel, and the disappearance of the dangerous bar. In closing, Mr. Corthell spoke of the beneficial effects of the Mississippi jetties, and of the danger which now threatens those works from their being out of repair. The paper was illustrated with many beautiful lantern views.

At the close of the paper Professor Swain thanked the speaker in the name of the two societies, and the meeting was adjourned.

THURSDAY, December 10, 1896.

The 492d meeting of the SOCIETY OF ARTS was held this day at the Institute, Mr. Blodgett in the chair.

The records of the last two meetings were read and approved.

The Secretary read a letter from the Pasteur Monument Committee of the United States, asking the coöperation of the SOCIETY OF ARTS in its efforts to obtain subscriptions for the erection of a monument to Pasteur in Paris.

The chair then introduced Mr. Henry C. Mercer, Curator of the Museum of American and Prehistoric Archæology in the University of Pennsylvania, who read a paper on "Cave Hunting in Yucatan." The speaker began by showing how caves furnish the key to the state of culture of prehistoric people, and then spoke of the country and present inhabitants of Yucatan, and of the remains of former civilization there. The caves of Yucatan differ from those formerly inhabited by man in Europe and North America, in that they open from the top. They probably would not have been inhabited if it were not that they often contained the only supply of water. Excavations in over twenty caves led to uniform results. The stratum forming the floor of the cave is about a foot thick, and was found to contain fragments of charcoal, pottery, and bones of recent animals. The red earth under this contained some remains of animals, but excavations through to the solid rock beneath showed no trace of the presence of man. The prehistoric culture of Yucatan was not developed there, but came from abroad. At the close of the paper Mr. Mercer showed a large number of views of caves in Europe, the United States, and Yucatan.

The President thanked the lecturer for his very interesting paper, and the Society adjourned.

ROBERT P. BIGELOW, *Secretary.*

THE APSE OF ST. SAUVEUR, CAEN.
From photograph by Mieusement.

THE SUMMER SCHOOL OF ARCHITECTURE FOR 1896 IN SOUTHERN ENGLAND, NORMANDY, AND TOURAINE.

BY ELEAZER B. HOMER, S.B.

Read October 22, 1896.

As the great steamer Cestrian backed slowly from the East Boston pier the Technology yell awoke the echoes among the wharves and elevators, and for a time rivalled the deep voice calling for right of way into the harbor channel. The first section of the M. I. T. Summer School of Architecture had at last started on its way across the Atlantic, and its one thousand miles of bicycle travel in Europe. A new departure for American schools was being attempted, and excellent results were expected from the proposed combination of study and healthful exercise. But only in the method of moving the party of students from town to town, was the attempt a new one.

The making of short excursions to interesting buildings and towns, has long been considered an essential part of an architectural student's education. Years ago, when books were few and methods of photographic reproduction unheard of, technical knowledge could only be acquired through personal visits to existing buildings, and through laborious efforts, with pencil or brush, in transferring upon paper the student's impressions of the masterpieces of architecture.

To-day the necessity for travel and close observation does not seem, at first sight, as imperative as in times gone by; for the foreign masterpieces are now brought within the reach of every one, through our public and technical libraries and the modern processes of illustration. The careful examination of books and photographs alone, however, gives only a limited idea of the true appearance of a building, for the more or less correct representation upon paper necessarily fails to express the real values of scale, broad surfaces, and detail, values that can only be understood by inspection of the buildings themselves.

The Summer School of Architecture was accordingly established at the Institute, in order that its work might supplement the regular winter courses. This out-of-door study has proved to be of the great-

GROUP AT HAMPTON COURT.

Enlarged from photograph by E. B. H.

Members of the M. I. T. Summer School of Architecture, 1896.

1. F. Nevin.
2. F. M. Mann, Instructor.
3. F. L. Harlowe.
4. R. L. Fuller.
5. M. F. Ewen.
6. A. H. Spahr.
7. A. D. Spiess.
8. C. K. B. Nevin.
9. D. D. Cassidy.
10. E. S. VanGorder.
11. W. D. Bradley.
12. H. Cummings, Jr.
13. H. D. Rawson.
14. A. W. Jackson.
15. F. B. Heathman.
16. J. H. Willis.
17. F. H. Keisker.
18. E S. Dodge.

Not included in photograph.
Prof. E. B. Homer.
O. C. Hering.
F. N. LeBaron.
W. C. Potter.

est value, for, aside from the spirit of good fellowship that always adds so much to the pleasure of the traveler, one learns to appreciate architecture as it exists in solid form, and soon gains a clear idea of the relative proportions and importance of the works visited.

In past years the summer work has been confined to the study of buildings and details of the Colonial architecture of our New England States. We possess much that is original and beautiful in the simple dwellings of our old seaport towns, and as these buildings are rapidly disappearing we have made an attempt to preserve at least a small part of the best material by means of measured drawings, sketches, and photographs. But such study, although of great benefit, has heretofore been mainly limited to wooden buildings of comparatively small size, and does not give the broad knowledge of style that all students of architecture should possess. The history of Architecture includes the buildings of America, as the application of older forms to the new conditions of a new country. As such, our American work cannot be perfectly understood until one has become at least partially familiar with European architecture.

An important step, therefore, was taken last spring when it was decided to change the scene of our summer's work from New England to a limited section of France, and to supplement the winter's indoor studies by an excursion among the interesting buildings of the south of England, of Normandy, and Touraine.

Our party included twenty students from the third and fourth year classes, in charge of two instructors. The journey was made on bicycles, partially on account of the expense of railway travel, but principally in order to afford an opportunity for intimate acquaintance with local architecture. By this means a little over 950 miles were covered during our fifty days on land, and much was seen that is not revealed to those who travel by rail alone.

The route was arranged to include the principal towns of Normandy and Touraine, two of the most interesting architectural sections of France, while a short excursion in England was planned in order to give a comparative view of the architecture of the two countries. Detailed maps, covering the proposed route, were imported early in May, and the selection of the roads from town to town, with the plotting of the route upon the English Government Ordnance maps and the thirty-nine sheets of the Carte de la France, consumed quite a little time in the way of preparation. These maps were taken with us, and through their assistance the selected route was followed with very little difficulty or need for variation.

We were unusually fortunate in having only a few days of bad weather, so that engagements made with hotels were kept without a break throughout the entire trip. Good hotel accommodations for a party of twenty-two can be obtained in few towns without due warning of from two to ten days, but the advance letters sent to all hotels from America, and the telegrams despatched a few days before our arrival, not only secured as comfortable quarters as could be had, but also insured much lower rates than the regular charges for transient guests. It was not possible, however, to obtain room for the entire party on one steamer, so the first section sailed from Boston June 3, on the Leyland freighter Cestrian, and the second section, June 6, on the Gallia, of the Cunard line.

Both parties traveled by rail to London, where the actual wheeling tour began, and Liverpool, Chester, Shrewsbury, and Oxford were visited on the way. Every one visits Chester, and the city is so accustomed to receiving Americans that its buildings have a prosperous and ready-for-visitors air that suggested the intentionally picturesque appearance of the World's Fair Plaisance. It being Sunday, we seemed to meet all the young people of the town during our morning walk around the walls, but in the afternoon the beautiful choral service in the old cathedral gave us an entirely different impression of the modern life of the town.

Shrewsbury, also, possesses much of its old-time half-timber architecture, which does not offend by the presence of too much fresh paint, and therefore seems older and more attractive than the more ambitious buildings of Chester. The hill on which the old town is built is surrounded on three sides by the picturesque Severn, and along its shores the great rows of lime trees form promenades that far excel those of the famous English gardens at Rambouillet, or any others that I have seen of similar character. We were comfortably housed at The George, and after our evening tramp through the old part of the town, were well satisfied that our quarters were quite superior to those offered by either the String of Horses Inn or The Headless Woman, although these houses displayed signs of far greater antiquity.

At Oxford, all the students were particularly charmed by the quiet dignity of the college buildings, but, much to our regret, our short stay only gave us a glimpse of the outward side of English college life.

Meanwhile, our American bicycles had been journeying by steamer directly to London, where, after five days of interesting but tiresome sightseeing, the wheels were unpacked and put together. Bundles of wearing apparel and drawing and photographic materials were then securely strapped on, and all was ready for the start. The morning of the 19th saw the party on board one of the Thames steamers en route for Putney. This proved to be a good way of leaving the city, as the busy London streets were avoided, and we began riding in comparatively open country.

On this first day, lunch was obtained at Kingston on Thames, and Hampton Court Palace was visited. After looking through the great palace, its extensive picture galleries and gardens, sketches were made of interesting doorways, chimneys, and bits of brick detail. It was found that permission to sketch should have been obtained from the Board of Public Works in London, but the courteous superintendent of the palace gave permission for outside sketching, also accompanying the party to the old Cardinal Wolsey kitchen, and the famous tennis court, pointing out many interesting things that we should not otherwise have seen.

Before leaving Hampton Court a photograph was obtained of eighteen of the twenty-two members of our party, the enlarged photograph on page 8, giving a very good idea of the way in which we traveled and the amount of baggage carried. It is particularly pleasant to look back to this picture, taken on our first day out, for it shows that all the members at one time possessed coats, bicycle lamps, and a few other things that were afterwards discarded. It is also unique in that it shows thirty-six American tires without a single puncture. Six days after, we counted ten punctures on one tire alone.

On this and the following day we traveled over the famous old Portsmouth coaching road, leaving it after passing Guildford, to make a side trip to the little Norman church at Compton. At Guildford we climbed the steep incline of the High Street, passing under the great overhanging clock of the Town Hall, and visited Archbishop Abbot's Hospital, a building similar in style to much of the brick work at Hampton Court. We enjoyed our rest in the ancient dining room or kitchen, seated around an old tradesman who told us stories of the customs of the place. Tempted by the good coast down High Street, we rode too far down, and then climbed the wrong hill in search of

Guildford's old Norman castle, now situated in the public garden of the town. The ancient keep of the castle rises about seventy feet above the surrounding ruins, and is built of regular courses of herring-bone work, flints, and sandstone that can all be clearly identified. After a time, finding the right way out of town, we passed through a delightful bit of English country, bowling along over splendid roads until the cobblestones of Godalming were reached. All the way along the route we passed picturesque cottages, thatched and half-timbered, that repeatedly tempted our amateur photographers. A comfortable night at the hospitable Angel at Godalming closed our second day. The following morning sketches were made of the picturesque court-yard of the inn, our landlord's strawberries duly appreciated, the Town Hall visited in company with the senior alderman of the town, and then wheels were brought out for the ride to Compton, Elstead, and Waverley Abbey, on the way to Farnham.

HIGH STREET AND TOWN HALL, GUILDFORD.
Photographed by E. B. H.

The little church at Compton possesses a particularly interesting Norman interior, and we secured a few sketches of capitals, and photographs of the primitive timber roof. The kind old lady who showed us the church could not understand why we did not know her son who had gone to America, but at last, finding that he was located somewhere in Kansas, we tried to explain a little United States geography, but with only indifferent success. After our lunch at Elstead, where our landlord of the Golden Fleece, who also dealt in grain, hay, and coal, personally waited on table in his shirt sleeves, we climbed the long grade to Crooksbury Common, and, later on, descended into the valley of the River Wey, stopping to visit the ruins of Waverley Abbey. The remaining walls of the abbey are scattered over broad meadows, in which the haymakers were busy at the time of our visit, and show that the ancient Cistercian monastery must have been very extensive. Little now remains, although the vaulting under the chapel is still in fairly good condition.

THE VILLAGE CHURCH, COMPTON.

Our way for the next day ran almost parallel with the Alton branch of the London & Southwestern Railroad, and, as expected, passed through open, rolling country quite in contrast to the picturesque portion of Surrey just passed. But at the village of Chawton we had a diversion, and cameras were brought out to photograph a little Italian boy and lively monkey. The thatched roofed houses of this village were particularly attractive. Taking the wrong fork of the road, we had to inquire our way of one of the bright little fellows of the village school just out for recess, and then journeyed on through Abbotsford and the Worthy's, down the beautiful valley of the winding Itchen, until toward evening we rode into the ancient town of Winchester.

OLD AND NEW TRUSSES OVER THE NAVE OF WINCHESTER CATHEDRAL.

Photographed by E. B. H.

The following morning we visited some of the buildings of the famous old town, and, after looking through the cathedral, were particularly fortunate in obtaining permission to climb the long ladder leading to the nave roof, where the obsolete form of roof truss is being replaced by a stouter modern construction. The old roof does not all date from the eleventh century, but the great tie beams, upon which the two men are sitting, have been retained from the earlier truss work of the time of William the Conqueror, and will be carefully preserved in the new roof. As they are too short for the present form of truss, and are also worm-eaten and decayed at the ends, only the middle part of solid wood is to be saved. Bits of the old oak and the large wrought-iron rails that fastened the lead covering were quite in demand by members of our party, but few relics survived the Normandy hills and fewer still are now treasured in America.

DOUBLE ARCH AT ST. CROSS HOSPITAL CHURCH, WINCHESTER.

As we walked through these trusses, above the great recesses of the fourteenth-century stone vaulting which forms the true ceiling of the interior, we could hear the organ beginning the morning service, and therefore had to descend long before we had finished our notes and researches. We had intended to spend more time in this city, but an extra day in London had to be made up by cutting at Winchester, so we were obliged to leave without doing it justice, as far as sightseeing was concerned. But we remember very pleasantly our stop at St. Cross Hospital, founded 1136, just outside of Winchester, where, after entering the quiet quadrangle, surrounded by the houses and the church buildings, we were shown through the church by a delightful old gentleman, one of the thirteen old men who live at the hospital. The church has remarkably rich late Norman decorations in the interior and also has a unique double arch in an angle at the rear. As can be seen, the original doorway under this arch is now filled in. The attractions here were so great that we arrived at Romsey at quite a late hour. After an unsatisfactory dinner, we spent a short time at Romsey Abbey, then some of the party took train for Salisbury, while the others, with a strong wind behind, quickly covered the eleven-mile ride to Southampton.

Taking the night boat from Southampton across the Channel, we found, after a quiet passage and good night's rest, that we were well into the harbor of Havre, and by eight o'clock we were all through the custom house and searching for breakfast. Our party attracted much attention at Havre, and we were all kept busy answering questions while waiting for money and letters.

Our English Cyclists' Touring Club badges served us well at Havre, for, after showing them, we were permitted to pass the custom house without any question as to duties. We also found in England that the Touring Club discounts were readily given at all the hotels, and that our tickets made quite a saving in our daily expenses; in some cases as much as twenty-five per cent. on the regular rates.

But trouble had already begun with our bicycles, as our American tires were not heavy enough to stand the flint roads. For this reason our first few days' riding in France was absolutely discouraging. In spite of the splendid surfaces of the roads so many flints were encountered that among our twenty-two men we counted thirty punctures during the four days' riding between Havre, Rouen, and Lisieux. Only a few of the party escaped without striking the sharp flint edges. In fact, several new tires had to be ordered from Paris, for some of the old tires were beyond even the most careful treatment. But shortly after leaving Lisieux we were thankful to find that the flints had disappeared, and we only encountered them again as we neared Paris.

Stopping at noon on our first day in France at Lillebonne, we were surprised to see the extent of the Roman theater and to find that so much of the Roman masonry remains in apparently good condition. On the opposite side of the theater one of the arches still stands, the restored portion on the right clearly showing its construction of tile and rubble work. After mounting the steep side of the valley through which the River Bolbec flows we traversed the rolling upland, following an excellent third-class road. Here, on the steep, winding descent to Caudebec, the first bad tumble occurred, one of the men failing to make a three-quarter curve because of too much speed, but fortunately no bone's were broken. A new rim was fitted on over night and all was right again in the morning.

ARCH IN ROMAN THEATER, LILLEBONNE.

Photographed by E. B. H.

Caudebec is exceedingly quaint, having many little crooked streets and old timber houses, but its church rises above the architectural level of the other buildings and is an excellent example of the rich flamboyant style. After breakfast we watched the "Mascaret," the great tidal wave, sweep up the Seine; and then, with the genial proprietor of the Hotel de la Marine as guide, rode out to St. Wandrille Abbey, where we saw many bits of late Gothic and Rococo architecture under the guidance of a courteous and well-informed priest; then on to Jumièges Abbey, whose magnificent arches and masses almost overpowered us. Jumièges, founded in the 7th century, is one of the best examples of the early heavy Norman style, and one rarely finds

South Transept, St. Ouen, Rouen.

such an imposing group of ruins. Returning over the branch road about three kilometers, we followed the main road around a wide bend of the Seine, and at last came in sight of the abbey towers of St. Georges-de-Boscherville. There we spent some two hours sketching and studying the interior of the church. This is a fine example of late Norman design and construction, but, as with all the recently restored churches in France, the interior seems a little cold because of the freshness of the stone and too great care in jointing the stonework. We arrived near Rouen just before sunset, in time to have a magnificent view of the entire city, with its great amphitheater of surrounding hills, from the heights of Canteleau.

Rouen was crowded, in preparation for the great horse races that were to be held the next Sunday afternoon, but good accommodations were found at the Hotel de France on the quay. As expected, it was impossible to do any drawing here, for there was so much to be seen during our short stay that our time was fully occupied in tramping about the city and trying to appreciate the rich Gothic and Renaissance architecture for which Rouen is so justly famous. St. Ouen impressed all by the magnificence of its south transept, rich lantern, and grand interior. The trip around the triforium and over the roofs was particularly interesting, the unconsciously mysterious and impressive manner with which our guide pointed out the beauties of the building adding greatly to our enjoyment.

Our ride to Elbeuf, Brionne, and Bernay proved to be a hard day's journey. We crossed several rivers and the hills lying between, but notwithstanding many punctures and consequent delays, we all arrived in time for dinner. After sipping our coffee and singing songs in the court of the hotel, all were glad to retire early.

Lisieux was reached on the following day, and there we remained for two days, making sketches of the old timber houses and of the interior of the cathedral. This quaint town is full of woodwork of the fourteenth to sixteenth centuries, and one cannot walk in any direction near the Grande-Rue without finding splendid examples of the carpentry of this period. One well-known house in this street is particularly attractive, and has the reputation of drawing a sketch from every artist or architect who visits the town. It is needless to say that we all felt its influence. The most picturesque street is, perhaps, the Rue au Fevres, where we found the famous "House of the Salamander," built in the time of Francis I, and having the richest carved front in the town.

OLD HOUSE, GRANDE-RUE, LISIEUX.

On leaving Lisieux we arranged to lunch at the village of Crevecœur, but arriving there we found a village fair in full swing and the hotel unable to accommodate all its patrons. After two hours' patient waiting we at last obtained a miserable lunch and departed firmly resolved to make future arrangements only in the larger towns, for even a village fair loses its attractions when one is really hungry.

The excellent road leading to Caen was then passed over in the face of a hard head wind, the last member of the party arriving just in time to escape the heavy rain that continued all that night and the next day. This is a very good example of the national roads of this section (see next page), for though running for miles through the open country they are kept in perfect condition, the surfaces being even superior to many of our park roads. Our day at Caen was wet and uncomfortable, but while sketching in the interior of the church of the Abbaye aux Dames the morning passed quickly. St. Nicholas, of the eleventh century, and St. Stephen, built by William the Conqueror, were visited, and notes made in St. Stephen of the peculiar sexpartite vaulting of this transitional period.

ON THE NATIONAL ROAD BETWEEN LISIEUX AND CAEN.
Photographed by E. B. H.

St. Nicholas is now used as a government storehouse for hay and grain, and visitors are not admitted ; but it was found that a franc used in the right way removed all barriers. In the same city the ruined Old Church of St. Etienne is also now turned into a storehouse, and many fine bits of stone detail are deposited there for the Caen Antiquarian Society. Several drawings of these fragments were secured during the time it was necessary to remain under cover. The delicate late Gothic apse of St. Sauveur is one of the most graceful Gothic designs with which I am acquainted, but it is only one example taken from many beautiful and impressive buildings that enrich this Norman city.

The Town and Monastery of Mont St. Michel.

We finally started for Bayeux with clearing skies, and after a delightful run along the by-roads leading to the villages of Norrey and Audrieu, a little south of the main road, spent the night in the city still famous for its old tapestries. At Bayeux we changed our daily program, deciding to do our sketching in the morning and ride in the afternoon, as the fatigue of riding prevented the best work. This arrangement was followed for the next few days, and St. Lô, Coutances, Granville, and Avranches were in turn visited, the distances between these towns requiring only a small part of each afternoon.

The Fourth of July was spent at St. Lô, and there on the Place in front of the cathedral, high above the city, we sang patriotic songs by the light of a small bonfire of straw and leaves and tried to think that we were helping America celebrate her noisy day.

All eyes were now turned toward Mont St. Michel, and we hoped to see the great rock from the top of the cathedral at Coutances, but as the horizon was hazy the first glimpse was obtained two days later, as we passed over the hills at Genets on the northern shore of the bay on the way to Avranches. We could, however, see Granville from the top of Coutances Cathedral directly over the tower of St. Pierre, and late in the afternoon, after a quick ride over excellent roads, we arrived in time to take a refreshing afternoon bath in the blue waters of the Atlantic.

At Mont St. Michel, after wheeling along the causeway and passing the gauntlet of hotel criers, we were comfortably housed at the Poulard Aînè, taking the whole of the Maison Blanc for our quarters. A delightful two days was spent in this famous place. Thanks to our permits from the French Government, the keys of the monastery were given us and we could wander at will from the dark dungeons cut in the solid rock to the rich flying buttresses of the Gothic church. Sketches were made in the Salle des Chevaliers, and during the quiet afternoons many bits of picturesque stonework were transferred to the drawing paper. In the evenings long walks were taken on the sands, as it was the season of low tides. The magnificent effects of the setting sun on the ancient walls, and the glorious views of the sunsets from the walls themselves, will long be remembered. Mont St. Michel was a climax to which we had unconsciously looked forward, and our parting cheer for the Poulard Aînè closed a very pleasant section of our summer trip.

The country south of this resting place is, for architectural students, somewhat bare and uninteresting. With the exception of occasional bright spots it was passed over without incident. Fougères possesses an enormous castle of which the outer walls alone remain; but its high walls and numerous towers, and the surrounding old portions of the town, are very picturesque. The greater part of the mediæval walls are now destroyed, but in the lower part of the city the old gate is one of the few remaining fragments of this ancient and strongly fortified town.

HALL OF THE CHEVALIERS. MONT ST. MICHEL.

But as a town Vitré is far more interesting than Fougères, its splendid chateau and fine old houses making it even more attractive than Lisieux. While possessing several streets lined with picturesque wooden houses, it also seems to be a very prosperous modern place, quite in contrast to the slumbering towns visited in Normandy. The chateau entrance is very striking and original. One passes over the drawbridge spanning the wide moat and enters a fairly spacious open court, containing at the farther end a picturesque little building decorated with a good oriel window of Renaissance design. We tried to obtain a measured drawing of this window, but as it is just back of the modern prison wall we found that the city authorities had to be consulted. The red tape encountered proved to be too much for our short visit. At Vitré the hot weather seemed to set in in earnest and we again changed our riding hours, avoiding the hottest part of the day.

On Sunday, after attending service for a short time at Notre Dame, a Gothic church with a beautiful outside pulpit, a small party wheeled over to the little village of Champeaux, and felt well repaid for the hot ride while visiting the chateau and church formerly belonging to the Chevalier de l'Epinay. The chateau still possesses its wide moat, but the surrounding walls have almost entirely disappeared and the whole place is overgrown with trees. Although the church is about one mile away, tradition says that the buildings are connected by an underground passage used by the family in troublesome times.

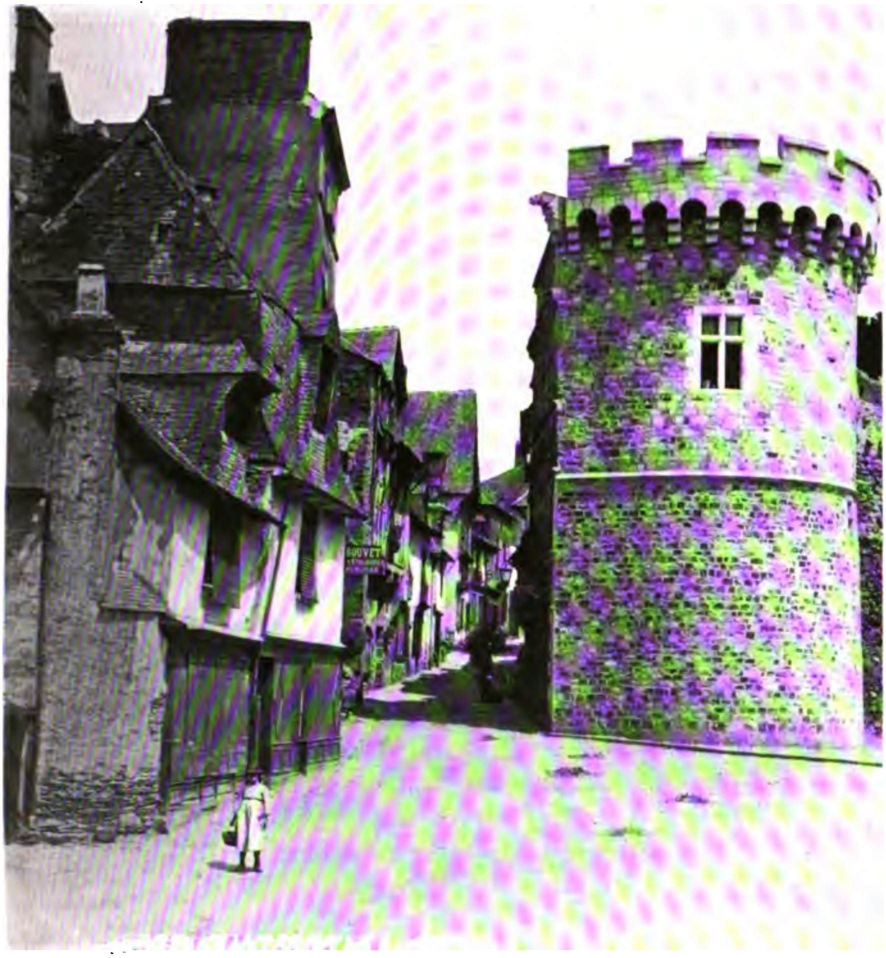
THE CASTLE ENTRANCE. VITRÉ.

Photographed by E. B. H.

ORIEL IN COURT OF CASTLE. VITRÉ.

We certainly saw the top of stone vaulting in the driveway of the chateau, and were told that a hole in the wall, in the crypt of the church, was the other end of the tunnel, but the deep valley and rocky hills lying between the two buildings made us sceptical about the connecting links.

Leaving Vitré early on the morning of the 13th we soon reached the Château des Rochers, famous as the residence of Madame de Sévigné, and for its gardens planned by Le Notre, the most famous landscape gardener of the seventeenth century.



OLD STREET AT VITRÉ.

We now had two of our longest rides before us, through a country that presented little that was interesting in the way of varied scenery. Village after village was passed on our morning ride to

La Guerche, where we rested during the hottest hours of the day. The afternoon run would have been uneventful if we had not unexpectedly seen the façade of the church at the little village of La Roë.

This was our first taste of the rich Romanesque architecture of Anjou and gave us a good idea of the dignified designs common to the southwestern part of France. There are, undoubtedly, some drawbacks to touring by bicycle, but the finding of this architectural gem, in such a little, out-of-the-way place as the village of La Roë, made up for all the inconveniences of our ride on that very hot day.

West Façade of Church at La Roë.

Photographed by E. B. H.

We then pushed along, up and down the rolling hills and even grades of the great national road, traveling due east in a straight line until Château Gontier was reached. In fact, so accustomed to regular and monotonous leg work did we become, that some of us ran through the town and five kilometers beyond before realizing that we had passed our stopping-place for the night. That was the hottest day and

Tower of Chateau at Chemazé.

the longest ride of the trip, but we felt quite refreshed after a swim in the sluggish and not too clean waters of the Mayenne.

The 14th proved to be about as hot as the preceding day. Making an early start the party divided, some taking the direct national road to Angers and others going on a venture about five miles out of the way to see the chateau at Chemazé. We were amply repaid for the side journey, for this chateau possesses some of the best early Renaissance detail. It was our first building of this character and we were soon busy with our cameras. Although we arrived at eight in the morning, and the owner was then at home, we easily obtained permission to visit the larger rooms, thoroughly enjoying our glimpse into the well-arranged half-modern, half-ancient interior. The square tower is particularly beautiful in detail and, combined with the transitional dormers, makes an unusually rich façade for a country house. We climbed the winding tower staircase, admiring the delicate interior carvings as we went, and from the top obtained a fine view of the wide rolling country across which we were traveling.

Leaving Chemazé with many regrets, we wandered through the winding country roads, surprising numerous flocks of geese as they fed by the roadside, until we at last met the great national road. Then it was push up hill and coast down the other side, mile after mile, riding directly south under a broiling sun, until at last we reached the down grade that told us we were in the valley of the Loire and that Angers was not far off.

Our arrival at Angers closed a period of fatiguing riding. We had traveled ninety-six miles in two days, pushing our heavily loaded wheels along monotonously straight roads that seemed to reflect an enormous amount of heat from their white surfaces. We were therefore glad to rest for a day or two at the comfortable Cheval-Blanc, even although Angers did not prove to be as rich in ancient and interesting architecture as we had hoped. The photograph clearly shows the splendid surface of this great road and the rolling, almost level, character of the country. It was taken about ten miles from Angers. The distance from the turn near the horizon to the top of the hill in the foreground was exactly six kilometers, according to the government measurements indicated on the kilometer stones at the side of the road, and it ran over five hills in that space of three and three fourths English miles.

Among the modern buildings of the prosperous city of Angers

NATIONAL ROAD NEAR ANGERS.

Photographed by E. B. H.

only a few relics of the older time still remain. The ancient Tour St. Aubin, now standing alone among the commonplace houses of the modern streets, was once a part of a great monastery which covered a large section of the city. Another fragment of the monastic buildings was discovered some years ago when a wall in the Préfecture was torn down. To-day this mutilated arcade, enriched with early almost barbaric sculpture, is perhaps one of the richest examples of decorative work of the Romanesque period, and is carefully treasured by the city and national authorities. In contrast to this primitive work, the delicate Renaissance detail of the Hotel Pincé (1535) furnishes the other extreme. Situated in the business part of the city, near the post office and theater, it still retains its small garden, which pushes it back from the general line of the shop fronts. Its delicate carvings now seem entirely out of place with its changed surroundings.

But the most interesting building in Angers, from a constructional point of view, is the Cathedral St. Maurice, commenced in the 11th century, as it is one of the transitional examples showing the beginning of the change from the domical vaulting found in cities a little farther south to the developed vaulting of the northern cathedrals. Several photographs were taken to illustrate the peculiarities of its interior, but on account of the uncertain light they were not entirely successful. Angers also possesses a few quaint streets and old modern houses, but much has long been destroyed by the fires that from time to time have swept the town.

Our stay at the Cheval-Blanc was so thoroughly enjoyable, after the indifferent hotels of the towns through which we had passed, that about half the party decided to remain in safe quarters, and later on take the shortest road instead of running the chance of a wetting by starting early in the morning of the 16th. The adventurous half only succeeded in reaching the outskirts of the city when the rain descended and the floods came upon us. But we were fortunate enough to escape a thorough drenching by taking refuge in a large modern church, storing our bicycles in an old corn mill near by. After a tiresome wait we donned our rubber capes for the first time

HOTEL PINCÉ. ANGERS.

Photographed by E. B. H.

PREHISTORIC DOLMEN. GENNES.

Photographed by E. B. H.

CHURCH OF TREVES-CUNAULT.

and ventured to ride through the flooded streets, quite enjoying the experience until the mud thrown by the rear wheels began to creep up our backs and over our heads, as mud will fly even with careful riding. The sun coming out we were soon forced to discard our capes on account of the heat and travel slowly until the roads were fairly dry. We then had a delightful run over the winding country roads, through vineyards and wet fields, on the way from Brissac to Gennes.

Lunching at Gennes and afterwards climbing the side of the valley to look at its old prehistoric dolmen, a little way out of the town, we were soon running over a smooth and almost level road along the left bank of the Loire. That was a most remarkable afternoon's ride, for the numerous small villages passed, each with its old Romanesque church and quaint old houses stretching along the river banks, gave us a foretaste of the rich architectural treasures of the Loire Valley. Cunault is perhaps the richest of these churches, since it possesses a beautiful tower or primitive spire that is quite in contrast to the plain walls of the other parts of the church. The capitals and paintings of the interior are also particularly quaint and grotesque.

Some three miles before reaching Saumur we discovered a large party of horsemen to the left of our road, and found that the students of the famous Saumur Military School were preparing to cross a branch of the river without boats, and that their instructors and friends were in attendance to witness the attempt. To effect the crossing fodder bags were filled with hay and fastened together by light sticks, and upon these frail rafts saddles and bridles were placed. Not more than four men could sit upon the pile at one time and succeed in keeping their immaculate clothes dry while pulling across the stream. The horses were driven into the river and after more or less encouragement swam across.

Without staying long at Saumur we continued our ride up the beautiful Loire Valley, stopping at noon at Chinon. Another bad tumble occurred on this run, for one of the men ran into a flock of sheep; or, to be more accurate, the sheep and dog ran into him, and completely ruined his front wheel. Fortune again favored us, however, for although quite a distance from any village an accommodating Frenchman arrived upon the scene in his English dogcart, and, seeing our plight, kindly carried the wounded rider and broken wheel all the way to Chinon. We had a delightful ramble among the ruins of the three castles that crown the hill far above the quaint old houses of this town, and stood for a time within the walls that once formed the hall where Joan of Arc had her audience with Charles VII. The Château of Chinon is full of surprises, its towers, bridges, deep moats, and underground passages affording endless opportunities for the venturesome traveler. The view of the valley, as we stood upon the edge of the projecting tower with the Vienne far below us, was most extensive and very beautiful in its combination of soft colors, but the view was entirely beyond our cameras.

After climbing the valley and leaving Chinon we encountered the worst stretch of road that I ever tried to ride over. The maps show a third-class road running directly from Chinon to Azay-le-Rideau, but I wish to warn any one from attempting that route, for the road is not only abominably hilly but for miles is covered with loose gravel and broken stone. Riding sometimes in a narrow rut, sometimes on the grass and little side paths, it was a wonder that our machines were not completely disjointed by the constant wrack and strain. Azay was finally reached and the rough experience soon forgotten in the interest awakened by the charming chateau.

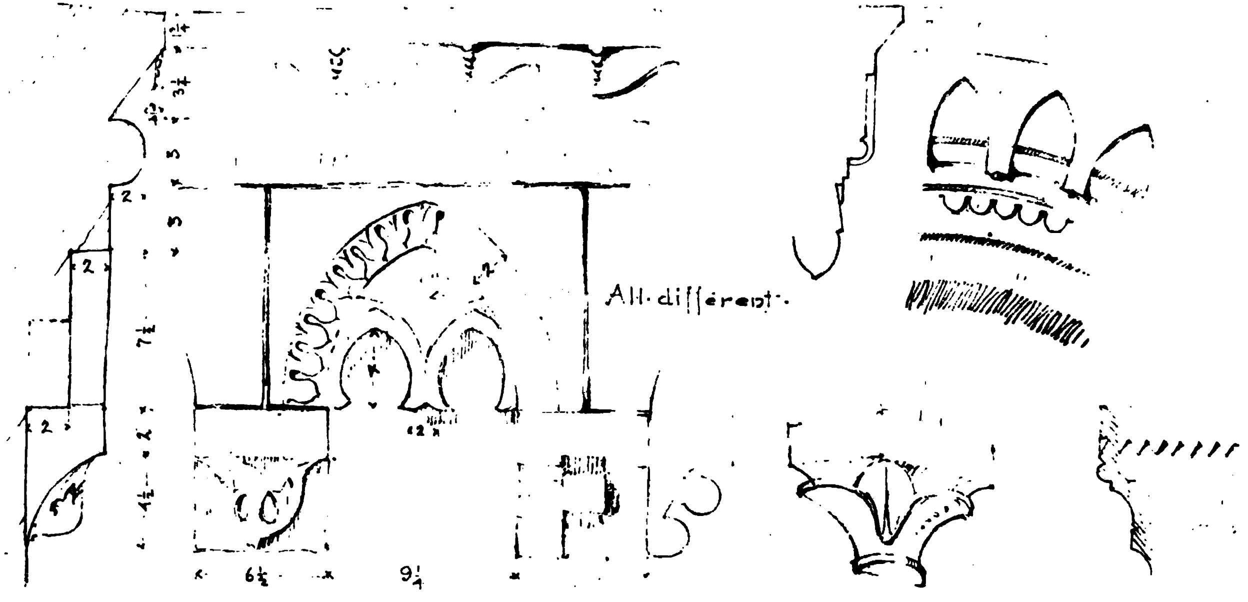
The homelike, comfortable character of Azay is in marked contrast to the more formal appearance of the larger Renaissance chateaux, and our day spent in sketching this delightful building is one of the pleasantest that we remember. We were fortunate in gaining admission to the interior and in having an opportunity to see some of its rich historical treasures. The large salon on a lower floor, and the bedroom of Francis I directly above, were two of the most interesting rooms. The views from the windows of this room also showed the work of the landscape gardener to the best advantage. The great amount of interesting Renaissance detail that this chateau possesses is especially attractive, the delicate treatment of doors, windows, and dormers adding greatly to the charm and beauty of the building. Riding on up the wide valley, close to the banks of the Loire, we crossed the splendid stone Pont de Tours and were at once in the prosperous modern city.

One needs to know Tours thoroughly in order to locate its remaining historical buildings among the host of modern houses. Henry James's little book was here far more useful to us than our guidebooks, and thanks to its directions, we discovered a very delicate fragment of Renaissance design near the modern church of St. Martin. Only five or six of the beautiful arches of the arcade of this convent now remain, and these are in a mutilated condition ; but as the "Lit-

CHATEAU OF AZAY-LE-RIDEAU.

tle Tour in France" justly states: "Such a piece of work is the purest flower of the French Renaissance; there is nothing more delicate in all Touraine."

Leaving Tours Sunday noon, we had another delightful ride through the valley of the Indre, where we were many times forced to stop and gaze at quaint pastoral scenes along the banks of the



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Some·details·in·the·Chapter·Room·

Church·of·St·Martin·

Bocherville · June 26th 96 ·

- A.H. Spahr·

river. These river roads are particularly attractive. Always bordered by green fields or the welcome shade of tall trees, their winding surfaces are in marked contrast to the monotonous national roads which traverse the open hills without variety.

Loches was reached without further incident, and the following day we visited the quaint Church of St. Ours, the castle, and the palace. St. Ours has two peculiar conical vaults over the nave that give the church a very unusual appearance. Viewed from the street the roofs are picturesque and perplexing, but seen from the top of the castle walls the whole arrangement of the church is at once apparent. This castle is not only used as a prison to-day — the guide locking the door after you have entered — but possesses some of the

One of the Arches in the Convent near St. Martins Church. Tours.

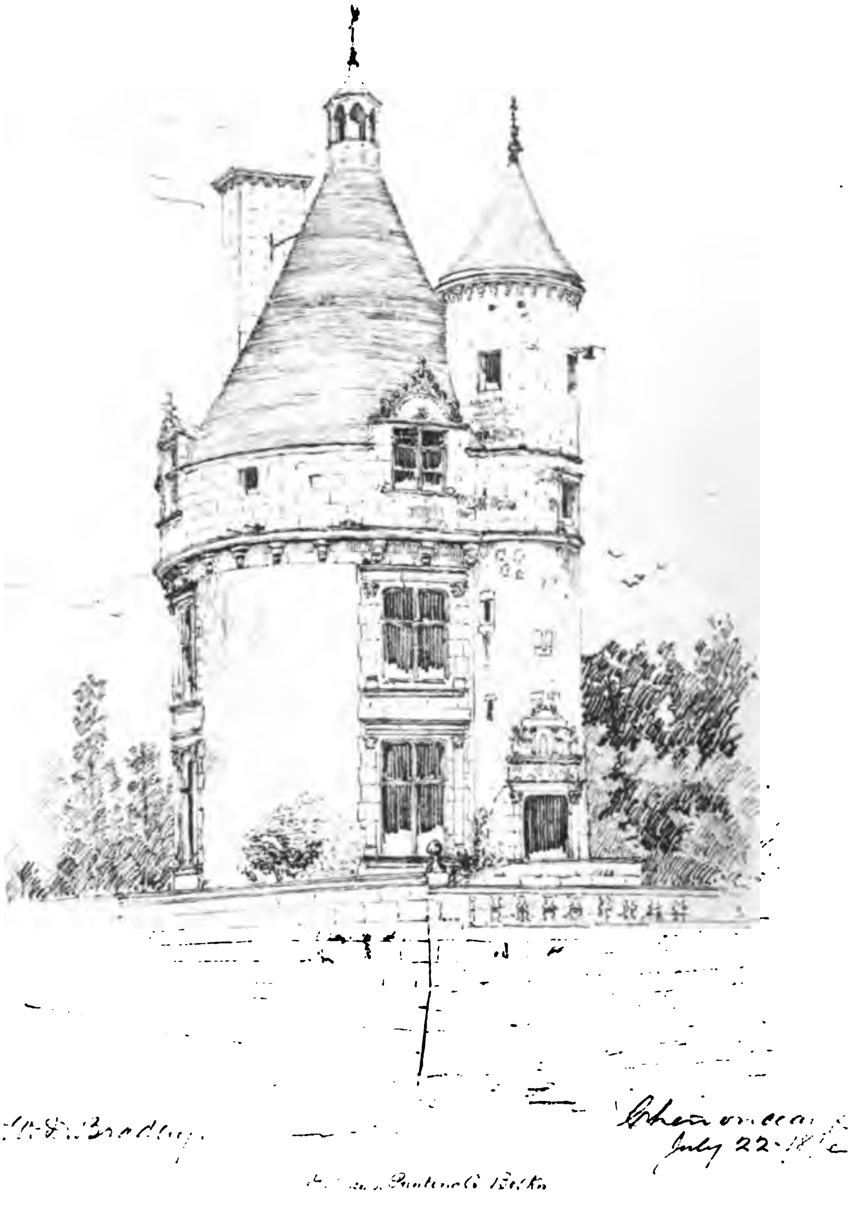
Photographed by E. B. H.

strongest and darkest subterranean dungeons of any of the castles of the Middle Ages. In its famous Martelet Tower, Ludovico Sforza, Duke of Milan, was confined for nine years.

The first break in our numbers occurred at Loches, for one of the students was obliged to set out for Germany, and later on another, who was too sick with an attack of malaria to enjoy riding, decided to cover the remaining ground by train. At the departure of the evening train the students stirred up the town, tramping to the station to the inspiring tune of "Marching thro' Georgia," played upon cornet, cymbals, snare, and bass drum, all hired from a neighboring cheap theater for the sum of five francs. The departing student marched in state, with bicycle and valise carried in front, and arriving at the station was promptly assisted by the guard into a first-class compartment, for which he had to pay excess fare upon arriving at Tours, as he could only show a third-class ticket.

CHURCH OF ST. OURS. LOCHES.

Photographed by E. B. H.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Leaving picturesque Loches behind, we crossed the hills to Chenonceaux, racing before a coming storm at a scorching pace; but the storm which we could see behind us passed down the valley that we had just left and we arrived at Chenonceaux without the expected wetting. We were here allowed to go all about the grounds and make sketches of the exterior of the chateau, but permission could not be obtained to visit the interior or the great picture gallery which extends almost across the river. The whole building stands upon piers built in the bed of the Cher, and entrance is obtained only by the drawbridge in front of the picturesque tower that serves as an advance guard for the main building. Around the chateau the walks through the woods are very carefully laid out, but the large garden is too symmetrical and conventional to be pleasing.

CHATEAU OF CHENONCEAUX.

Before leaving Chenonceaux we discovered that we had not money enough in the party to pay the hotel bill, our expenses through this section being about 250 francs, or $50, each day, so as some of the party wished to go on to Amboise six of us made a night ride, one starting by train for Blois early the next morning, obtaining the necessary funds, and returning in time to settle all accounts before the hotel people discovered that the treasurer had barely enough money to tip the waiters. Carrying our money by letter of credit and American Express notes, we should have fallen by the wayside quite often if each man had been obliged to look out for himself, but united we were strong enough for any emergency.

VALLEY OF THE LOIRE FROM THE TOP OF THE GREAT TOWER, CHATEAU OF AMBOISE.
Photographed by E. B. H.

The chateau at Amboise is now undergoing extensive restorations, so that we could not clearly see the whole building. In the center of the walls, overlooking the river, rises one of the massive towers 130 feet high, containing the great spiral plane by which horses and carriages reach the level of the courtyard of the chateau. From the street of the town this tower rises far above the surrounding houses, while from its top a fine view is obtained of the wide valley; but the black and white of the photograph does not do justice to the panorama, since it leaves out all the soft effects of green foliage and blue water which the painter alone could suggest.

St. Hubert's Chapel. Amboise.

Photographed by F. B. Heathman.

The gem of Amboise is the little chapel of St. Hubert, perched high on the southwestern side of the wall. To reach it one passes through the great inclined tunnel in the angle of the wall, and arrives by various passages on the general level of the chateau grounds. The commanding location of the chapel is seen best from the top of the large south tower, the enormous sub-structure of the walls lifting the terrace high above the houses of the town. This little building, without any reservation, is externally one of the most beautiful examples of Gothic design, for although attached to the massive stonework of the wall it shows a delicacy and refinement that is almost marvelous. The rich doorway, with its bas-reliefs illustrating scenes from the life of St. Hubert, is also one of the gems of Gothic sculpture.

CHATEAU OF CHAUMONT.

Photographed by E. B. H.

Crossing the river on leaving Amboise, we took the road under the hills on the right bank of the Seine and found many charmingly situated chateaux of a smaller type. Of these, Du Plessis was one of the most interesting. Turning off this road at Onzain, we crossed the wooden bridge over the Loire and leaving our wheels at the hotel climbed the long walk to the chateau of Chaumont. The courtyard of this vigorously designed building commands a wide view of the valley that rivals the view at Amboise. The rooms to which we were admitted were very richly hung with tapestries and full of souvenirs of Dian de Poitiers and Catherine de Medici. Remaining on this left side of the river we soon covered the distance to Blois, and passing over the highly crowned stone bridge were soon at our hotel near the famous chateau, the principal building of its class in France.

So much has been written about Blois that I will not attempt here to describe its beauties. The Francis I wing is justly famous for its exterior, and for its richly carved court façade with its elaborate spiral staircase. But to me the quieter Louis XII side of the court is far more pleasing and more thoroughly graceful in architectural effect. It is one of the few buildings that one wants to sit down before and quietly let it tell its own story.

After two days at Blois, principally spent in the chateau, we journeyed on, spending a short time among the complicated roofs of the vast, barren chateau of Chambord. The night was spent at Orleans, and from there began the most fatiguing ride of the trip, the thirty-five miles to Chateaudun, through monotonous grain fields, against a heavy head wind. That all were well tired is shown by the fact that our party of young men, hardened by forty days' continuous riding, turned in for a nap directly after obtaining a much-needed lunch. The old, deserted castle of Chateaudun was wandered over late in the afternoon and all were impressed by the desolate character of its great rooms. This castle possesses a donjon of the 12th century, having a remarkably substantial timber roof, and also shows much rich Renaissance detail around the interior courtyard.

THE LOIRE AT CHATEAUDUN.

Photographed by E. B. H.

The Loire is here quite small and unimportant, although very pretty just as it enters the town near the base of the chateau, but it is hard to think that the beautiful river at this point is particularly filthy. The washing stands seen by the riverside everywhere in France are quite common in this town. There is, however, such a suggestion of sewage in the discolored waters, that one wonders how the laundry can come home as clean and fresh as it always appears.

Lunching at the village of Bonneval, where it seems that Americans are rarely seen, we later on reached Chartres. There we spent our time principally in the magnificent cathedral, the most imposing Gothic building in France; but I can only very briefly mention its grand interior, beautiful towers and porches, or its wealth of magnificent stained glass.

MAIN AVENUE OF THE GARDENS. PALACE OF VERSAILLES.

Along the valley of the Villette we had our last picturesque ride, and at the charming chateau at Maintenon obtained permission to enter the gallery of the Noailles family portraits. Leaving this beautifully situated place we had a hard journey to Rambouillet, over a military road two thirds cobblestones and one third rough gravel and mud.

We were now within a short distance of Versailles and Paris, where our journey was to end. Reaching Versailles, the magnificent exterior of the great palace could not fail to impress us, but one at first feels out of place in the midst of so much cold, monumental grandeur, and our short trip through the galleries and gardens gave us all the impression that a great amount of money had been lavishly expended with questionable success. It is needless to say that many of the little village scenes through which we had passed were more picturesque and effective and could be more quickly grasped.

A quick afternoon ride from Versailles led us through the Bois de Boulogne, past the Arc de l' Etoile, down the crowded Champs-Elysées, to the little comfortable hotel in the Rue de Bac, and our Summer School of '96 was ended.

During our stay abroad much information was gained in regard to the European styles of architecture. In fact, so great an advance in the appreciation of good architecture was made, that all who took part in the tour look back upon it as completely enjoyable and profitable. At this distance, our days of monotonous riding and all our difficulties are forgotten.

THE VISCOSITY OF MERCURY VAPOR.

By A. A. NOYES, Ph.D., and H. M. GOODWIN, Ph.D.

Received October 6, 1896.

The uncertainty which attaches to the specific heat ratio of gases as a means of distinguishing between monatomic and polyatomic molecules has been recently made evident by the extended discussions of the significance of that property in connection with the atomic weights of argon and helium. It is, therefore, of great interest to investigate other properties which may be expected to be related to the atomicity of the molecule. Of such properties those dependent on the volume or cross-section of the molecules seem most promising. We have, therefore, undertaken the investigation of one of these, the viscosity or internal friction, in order to determine whether a marked difference in its value exists in the case of gases with monatomic and those with polyatomic molecules. To this end we have made comparative measurements of the viscosity of hydrogen, carbon dioxide, and mercury vapor at the boiling temperature of the last named substance. According to the Kinetic Theory of Gases the viscosity coefficient η has the theoretical significance expressed by the following equation:[1]

$$\eta = \frac{1}{\pi} N m L c$$

in which N is the number of molecules in the unit of volume, m the mass of a single molecule, L the mean free path, and c the mean velocity. Moreover the mean free path L is dependent solely on the number of molecules N and the mean cross section q of a single molecule, or of its sphere of action:[2]

$$L = \frac{1}{4\sqrt{2}\,Nq}$$

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[1] O. E. Meyer. Kinetische Theorie der Gase. 1st ed. pp. 130, 139.

[2] O. E. Meyer. Kinetische Theorie der Gase, pp. 206, 218. The symbol Q used by the author represents the total cross section of all the molecules in the unit of volume, and is, therefore, evidently equal to Nq.

whence it follows that

$$\eta = \frac{1}{4\pi\sqrt{2}}\ \frac{mc}{q}$$

or for any two different gases:

$$\eta_1 : \eta_2 : : \frac{m_1c_1}{q_1} : \frac{m_2c_2}{q_2}$$

But, since for any two gases at constant temperature:

$$m_1c_1^2 = m_2c_2^2$$

the above proportion may be simplified to the following equation:

$$\frac{q_1}{q_2} = \frac{\eta_2}{\eta_1}\sqrt{\frac{m_1}{m_2}} \qquad (1)$$

from which it is evident that the relative mean cross sections of the molecules of the two gases are readily calculated from their molecular weights and viscosity-coefficients. It was thought by us that monatomic molecules might prove to be much smaller than polyatomic ones, since it seems *a priori* not improbable that the spaces between the atoms of the latter are large in comparison with the dimensions of the atoms themselves. The experiments to be here described show, however, that no marked distinction exists between monatomic and polyatomic gases in this respect.

Experiments on the viscosity of mercury vapor, and especially on the effect of temperature upon it, have been made already by S. Koch,[1] who calculated that at 300° the volume of the mercury molecule is 4.4 as great as that of the hydrogen molecule. As this calculation was not based on direct comparative experiments made by passing the two gases through the same capillary, but was an indirect one involving the measurements of different experimenters and the dimensions of the capillaries used by them, it seemed desirable to subject the matter to further investigation in the direct manner indicated. Moreover, the author does not discuss the significance of his result in its bearing on the relative magnitude of atoms and molecules.

The method used by us in determining the relative viscosity consisted in measuring the quantities of the different gases which, under a constant difference of pressure, passed in a given time through the

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[1] Wied. Ann. Phys. Chem. 19, 857 (1883).

same capillary kept at a definite constant temperature. O. E. Meyer[2] has derived the following formula for calculating the viscosity coefficient η of a gas from its rate of flow through a capillary tube:

$$\eta = \frac{\pi}{16} \frac{R^4}{\lambda} \frac{(p_1^2 - p_2^2)\, t}{p_1 V_1}$$

where λ is the length and R the radius of the tube, t the time, p_1 the pressure at which the gas enters, p_2 that at which it leaves the tube, and V_1 the volume of the transpired gas measured at the pressure p_1. In the case of comparative experiments made with the same capillary on two different gases, the following proportion holds true:

$$\eta_1 : \eta_2 :: \frac{(p_1^2 - p_2^2)_1\, t_1}{n_1} : \frac{(p_1^2 - p_2^2)_2\, t_2}{n_2} \qquad (2)$$

in which n_1, n_2, represent respectively the number of gram molecular weights of the two gases transpired (since n is proportional to the product $p\ V$).

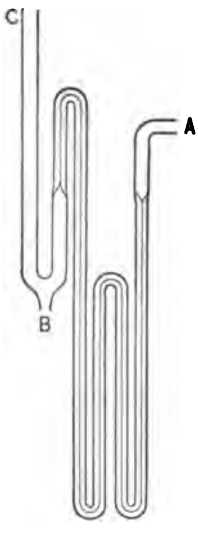

Fig. 1.

The apparatus and experimental method that we employed were necessarily quite different from the usual ones, and they will, therefore, be briefly described. The capillary used in the most complete series of experiments consisted of a glass tube about 74 cm. in length, and 0.34 mm. in internal diameter (determined by measuring the volume of a known length by means of mercury). A smaller capillary about 49 cm. in length and 0.22 mm. in diameter was used in a preliminary series. The capillary was bent in the manner shown in Figure 1, except that as actually constructed, it was made much more compact. To its ends were fused pieces of ordinary glass tube as shown in the figure; one of these was provided at the point A with a ground glass joint. The capillary was placed in a vertical position in a heavy steel cylinder (see Figure 2), 30 cm. high, 2.8 cm. internal diameter, having a small orifice at the side, through which the ground joint protruded for a distance of about one centimeter. The

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[2] Pogg. Ann., 127, 269.

capillary was held in position in the orifice by packing with loose asbestos. Although the capillary was vertical, the influence of gravity was eliminated by reason of the fact that the ascending and descending parts were made equal in length. The top of the cylinder was closed by an iron plate screwed down with a nut *N*; the nut and the plate were perforated in the center, and into the latter was welded an open iron tube *B* projecting upwards, 25 cm. in length, and 1½ cm. in diameter. The cylinder was covered, except on the bottom, with a jacket of asbestos about 5 cm. thick, and the projecting tube *B*, which was to serve as a condenser, was wound with spirals of copper wire to increase the cooling surface. Pure mercury was placed in the cylinder and boiled vigorously by means of a number of lamps beneath. The capillary was thus kept at the boiling temperature of mercury under atmospheric pressure. No regard was paid to the variations of temperature arising from changes in barometric pressure, as their effect would evidently be entirely negligible.

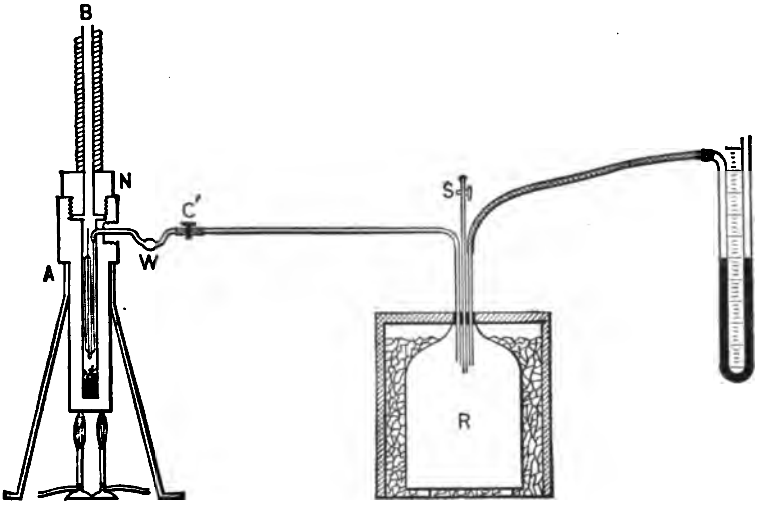

Fig. 2.

Any desired difference of pressure at the two ends of the capillary was attained by inserting a tube in the ground joint and connecting it with a large air reservoir *R* which was itself connected through the cock *S* with a suction pump, and with an open mercury manometer *M*. The gas or vapor entered at the other end of the capillary, always under atmospheric pressure. The whole apparatus in the form used for measuring the rate of transpiration of the mercury vapor is shown in Figure 2.

In making the experiments, the rate of flow of the mercury vapor was first determined in the following manner: While the cylinder was being heated, carbon dioxide was forced through the capillary to prevent the condensation in it of liquid mercury and the formation of its oxide. After the mercury was boiling actively, and its vapor entirely enveloped the capillary as shown by a mercurial thermometer inserted in the tube *B*, Figure 2, it was connected with the suction pump and mercury vapor drawn through for half an hour. The carefully ground end of a weighed bulb *W* was then inserted in the ground joint and its other end being connected by means of a clamped rubber tube *C*, with the air reservoir, in which the desired reduction of pressure had been produced. At a definite moment the clamp *C* was opened and the time noted. As the volume of the condensing bulb *W* was very small compared with the volume of the air reservoir, no sensible change in the pressure was thus produced. The mercury vapor was found to be completely condensed in *W* about two to three centimeters from the ground point. It was found that a slight and unavoidable leakage[1] through the ground joint occurred, and it was, therefore, necessary to readjust the pressure occasionally. It could easily be maintained constant to 0.2 or 0.3 mm. or even closer. After a sufficient time, usually sixty minutes, the clamp was closed, and at a noted instant the bulb removed and subsequently weighed. Check experiments were made in this way at each of two or three other different pressures.

The capillary was now removed from the cylinder, and the opening *B* (Figure 1) carefully closed by fusion. A glass tube, long enough to project beyond the upper end of *B* (Figure 2), was also fused onto the end *C*, and the capillary was then ready for the experiments with carbon dioxide and hydrogen. It was replaced in the cylinder as before, and the glass tube projecting through *B* connected through suitable wash-bottles with the gas generator. The carbon dioxide was made

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[1] In the case of the mercury experiments, no error could arise from this source, as the leakage was inward. In the case of those with carbon dioxide and hydrogen, it was proved by blank experiments that the amounts of carbon dioxide and water which leaked in were less than 1 per cent. of the total weight.

in a Kipp generator by the action of dilute sulphuric acid on lumps of pure fused sodium carbonate, and was dried by passing through two Allihn gas wash-bottles containing strong sulphuric acid. The hydrogen was prepared from pure Bertha zinc and dilute sulphuric acid, was washed with caustic soda solution and dried by sulphuric acid as in the case of the carbon dioxide. In order to maintain the gas entering the capillary at atmospheric pressure, a T tube was inserted between the wash-bottles and the capillary, and its perpendicular arm was turned downward and caused to dip into sulphuric acid barely below its surface. The cock of the generator was opened sufficiently to cause the gas to bubble out steadily through the sulphuric acid.

The transpiration measurements were made as in the case of the mercury. The carbon dioxide, flowing through in a definite time, was determined by absorption in weighed tubes filled with lumps of soda lime. The hydrogen was burnt by passing it over hot copper oxide contained in hard glass tubes from which the air was previously displaced by carbon dioxide, and the water collected in weighed calcium chloride tubes.

The results are presented in the following table: In the first column is given the symbol of the substance; in the second, the atmospheric pressure p_1; in the third, the difference in pressure $(p_1 - p_2)$; in the fourth, the time t expressed in hours; in the fifth, the weight w in grams of the substance weighed; in the sixth, the mean weight transpired in one hour as computed from the separate check experiments, and in the last, the quotient obtained by dividing this weight by the molecular weight m of the substance, the time, and the pressure function $(p_1^2 - p_2^2)$[1]. (See expression (2) on page 48. As the headings indicate, the first of these two series of experiments was made with the smaller, and the second with the larger capillary. It will be seen that in the second series two sets of determinations are given for mercury vapor; the first of these was made before, and the second one after the experiments with carbon dioxide and hydrogen, and their agreement shows that the capillary had undergone no change by stoppage or otherwise, during the course of the experiments with it.

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[1] In the calculation of this quantity the same mean value of p_1 was used in all the experiments of each series, namely, 760 for those with the smaller capillary, 765 for those with the larger.

SERIES I. (Small Capillary.)

	p_1	$p_1 - p_2$	t	w	$w : t$	$\frac{w \times 10^{10}}{tm(p_1^2 - p_2^2)}$
Hg . .	753	200	1½	0.738		
	753		1½	0.740		
	756		1½	0.745	0.494	93.6
	755	300	1	0.685		
	755		1	0.686	0.686	93.6
	754	400	1	0.834		
	754		1	0.831	0.833	92.9
CO_2 . .	752	200	1	0.237		
	752		1	0.239		
	752		1½	0.357	0.238	205
	759	300	1	0.329		
	759		1	0.327		
	766		1	0.324	0.327	203
	766	400	1	0.400		
	766		1	0.396		
	759		1	0.396	0.397	202

SERIES II. (Large Capillary.)

	p_1	$p_1 - p_2$	t	w	$w : t$	$\frac{w \times 10^{10}}{tm(p_1^2 - p_2^2)}$
Hg . . .	769	150	1	1.548		
	769		1	1.548	1.548	374
	769	300	1	2.763		
	769		1	2.764		
	769		1	2.739	2.755	373
CO_2 . .	756	150	1	0.704		
	765		1	0.706	0.705	774
	765	300	1	1.267		
	765		1	1.264	1.265	779
H_2 . . .	766	150	1	0.557		
	766		1	0.557	0.557	1517
	766	300	1	1.009		
	766		1	1.006	1.008	1496
Hg . . .	766	300	1	2.728		
	766		1	2.746		
	764		1	2.743	2.739	371

Attention may be first called to the agreement of the values of the last column in the case of the transpiration of the same substance under different differences of pressure, thus proving that the effect of pressure is in close accordance with that required by the formula, and consequently that the capillaries are of sufficient length and small enough bore to give the true values of the viscosity coefficients.

Of the two series of experiments, the first one made with the smaller capillary is to be regarded as less reliable by reason of the fact that owing to an accident to the capillary check experiments with mercury vapor after completion of those with carbon dioxide could not be made as in the former case, in consequence of which it is not certain that a stoppage did not occur in the course of the series. While there was nothing to indicate that such was the case, yet on account of its extremely small bore it was much more liable to stoppages than the larger capillary. We consider the experiments with the latter to be certainly accurate within 2 per cent.

Nevertheless, the agreement between the results of the first and second series is perhaps as close as could be expected with capillaries so different from each other in character. The relative viscosity coefficients of the different gases were calculated from the values of the last column in the table by means of formula (2). The results are as follows:

First series,

$$\frac{\eta_{Hg}}{\eta_{CO_2}} = 2.17.$$

Second series,

$$\frac{\eta_{Hg}}{\eta_{CO_2}} = 2.08. \quad \frac{\eta_{Hg}}{\eta_{H_2}} = 4.04. \quad \frac{\eta_{CO_2}}{\eta_{H_2}} = 1.94.$$

The relative values for mercury and carbon dioxide agree within about 4 per cent. That of the second series is, however, more reliable, for the reason above stated, and will be used in the subsequent calculations. It may be noted that the value of the ratio $\eta_{CO_2} : \eta_{H_2}$ at ordinary temperature is 1.72,[1] somewhat smaller than that found by us at 357°, a result which is in accordance with the greater temperature coefficient of carbon dioxide established by several investigators.

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[1] O. E. Meyer. Kinetische Theorie der Gase, 142.

The corresponding values of the relative mean cross-sections as calculated by formula (1) are:

$$\frac{q_{Hg}}{q_{CO_2}} = 1.02. \quad \frac{q_{Hg}}{q_{H_2}} = 2.48.$$

That is to say, the average cross-section of the mercury molecule or atom is very nearly the same as that of the carbon dioxide molecule, and is about 2½ times as large as that of the hydrogen molecule. This last result does not differ very greatly from that (2.68) corresponding to the relative molecular volumes of mercury and hydrogen as calculated for 300° by Koch.

These results indicate that *atoms and molecules are of the same order of magnitude* and that the spaces between the atoms within the molecule, if any exist, are not large in comparison with those occupied by the atoms themselves. And consequently the viscosity of gases, or any other property which like it is dependent only on the size or form of the molecules, is not adapted for distinguishing between monatomic and polyatomic molecules.

In considering the significance of the above values of the cross-section, the different masses of the various molecules, to be sure, ought not to be entirely disregarded. The mercury and carbon dioxide molecules have, as we have seen, the same cross-section, and, therefore, assuming both to be of the same general form, they occupy the same volume. The mass of the former is, however, 4.55 times as great as that of the latter. The density of the mercury molecule is consequently greater in this same proportion. But this difference is not marked enough to make it necessary to attribute it to free spaces within the carbon dioxide molecule. For it is not improbable that the inherent density of massive atoms, like those of mercury, may be considerably greater than that of light atoms, such as those of carbon and oxygen.

In closing, we desire to point out that the principle here established that atoms and molecules are of the same order of magnitude, and that no considerable free interatomic spaces exist within the molecule, is in accordance with the remarkable fact that the molecular cross-section of most comparatively simple molecules is approximately an additive property calculable from certain constant values of the atomic cross-section.[1] This fact would be unintelligible, were the principle

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[1] See O. E. Meyer. Kinetische Theorie der Gase, 209.

not correct; for if considerable spaces existed between the atoms, it is not to be supposed that those spaces would be the same in entirely dissimilar molecules — that, for example, the space between the hydrogen and chlorine atoms in hydrochloric acid would have any relation to the space between the atoms in the elementary gases hydrogen and chlorine.

ROGERS LABORATORY OF PHYSICS.
September, 1896.

THE SCIENTIFIC WORK OF THE BOSTON PARTY ON THE SIXTH PEARY EXPEDITION TO GREENLAND.

I.

INTRODUCTORY NOTE.

On the 29th of April, 1896, the undersigned received a letter from Lieutenant Robert E. Peary, Civil Engineer U. S. N., inviting him to organize a small party to carry on some line of scientific research in Danish Greenland, this party to be quite independent in its organization and equipment from the main body of the expedition, but to be transported to and from its destination by Lieutenant Peary's steamer. A similar proposition was made to Professor Ralph S. Tarr, of Cornell University. These two separate parties of six men each were to be landed with boats and camp equipments at different points on the west coast of Danish Greenland, there to remain and to carry on their investigations until the return of Lieutenant Peary's steamer in the latter part of the season, when they were to be taken on board and brought back to the port of sailing. This plan was a variation from former expeditions, and was designed to enable the members of these parties to prosecute their studies uninterruptedly for five or six weeks at localities affording the best opportunities for their chosen lines of work.

Both parties were organized and equipped, and they sailed with Lieutenant Peary from Sydney, Cape Breton, on the steamer Hope, July 16, 1896. Lieutenant Peary had obtained permission from the Danish home government for the landing of these parties on the Greenland coast. The entire plan as proposed was carried out almost without a single deviation. Each party was landed and called for on scheduled time, and too much praise cannot be given to Lieutenant Peary and Captain Bartlett, of the steamer Hope, for the excellent arrangements made for the comfort and safety of their passengers.

Through the kindness of the Secretary of the Treasury and of the Superintendent of the United States Coast and Geodetic Survey, the Boston party was fortunate in securing the detail of Assistant G. R. Putnam with full instrumental equipment for making pendulum and magnetic observations. The other members of the party were college professors and students. The expenses of the party were mainly borne by the members themselves. The undersigned, however, wishes to express his sincere gratitude to Mrs. Francis H. Williams, Mrs. John C. Phillips, Mr. George Wigglesworth, and others, for their aid and financial assistance, without which the work of the party would have been seriously hampered. To Mr. A. M. Ritchie, of Brookline, the party is indebted for the gift of a complete thermophone outfit for the determination of air, ice, and water temperatures, and to the Institute of Technology for the loan of scientific instruments.

The Boston party wishes to acknowledge with hearty appreciation the courtesy and generous assistance extended to them throughout their work by the Danish officials, and especial thanks are due to Inspector Andersen, of Godhavn, and to Governor Knuhtsen, of Umanak.

The account of the scientific work accomplished will be given in the following reports by the members of the expedition.

Report A. Magnetic and Pendulum Observations, by Mr. G. R. Putnam, Assistant United States Coast and Geodetic Survey.

*Report B.** Observations of Glacial Phenomena, by Assistant Professor G. H. Barton, Massachusetts Institute of Technology.

*Report C.** Measurements of the Motion of the Great Karajak Glacier, by Professor A. E. Burton, Massachusetts Institute of Technology.

*Report D.** Studies of the Eskimos of Baffin's Land and Umanak Fjord, Their Costumes and Habitations, by Mr. Russell W. Porter, a student, Massachusetts Institute of Technology.

Although the two remaining members of the expedition, Mr. John C. Phillips, a student of Harvard University, and Mr. A. M. Dodge, a student of Harvard Medical School, do not submit written reports of their work, it should be said that much of the success of the plans of this expedition is due to their hearty coöperation in the work, and to their practical knowledge of camp life. Messrs. Porter, Phillips, and Dodge, by their skill in the use of the camera, enabled the party to obtain a most excellent photographic record of the expedition.

A collection of furs, native costumes, kayaks and implements of the chase was made, and much of it has already been presented to various museums and public collections.

ALFRED E. BURTON, S. B.,
Professor of Topographical Engineering, Massachusetts Institute of Technology,
In charge of the Boston party.

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*Owing to lack of space, reports *B*, *C* and *D* will be published in the next number of the TECHNOLOGY QUARTERLY.

REPORT A. MAGNETIC AND PENDULUM OBSERVATIONS IN CONNECTION WITH THE GREENLAND EXPEDITION OF 1896, UNDER CHARGE OF PROFESSOR A. E. BURTON.[1]

BY G. R. PUTNAM, M.S.,
ASSISTANT U. S. COAST AND GEODETIC SURVEY.

Received January 18, 1897.

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PART III. PENDULUM OBSERVATIONS.

PART IV. EXAMPLES OF OBSERVATIONS AND COMPUTATIONS.

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[1] Published by permission of the Superintendent of the United States Coast and Geodetic Survey.

PART I. INTRODUCTION.

SECTION 1. *Scope and Object of Work.* — Among the objects of research included in the plan for the expedition to the west coast of Greenland organized by Professor A. E. Burton in the summer of 1896, were magnetic and pendulum observations, and the writer was invited by Professor Burton to undertake this part of the work. On the recommendation of the Superintendent of the United States Coast and Geodetic Survey, permission was granted by the Secretary of the Treasury for the writer to accompany the expedition, and to take with him the necessary instrumental outfit belonging to the Survey, on the condition that the Survey should bear no part of the expense. The party was to be transported to and from its destination by Lieutenant R. E. Peary, United States Navy, the well known Arctic explorer, who combined the transportation of several such scientific parties with the other objects he had in view in planning this northern expedition. As Lieutenant Peary proposed to make a number of intermediate stops both going and returning, it was the plan of the writer to make observations at all such places as time and circumstances would permit, and thus accumulate as much data as possible in regard to these branches of terrestrial physics, in regions not frequently visited. In the recently published report[1] of Professor Helmert to the International Geodetic Association on gravity determinations made in various parts of the world, no observations are shown in the region covered by this voyage, so that pendulum observations here will help to fill a gap in the investigation of the variations of the force of gravity over the earth's surface, which is among the lines of research undertaken by the various countries represented in that association. One of the objects of these investigations is the study of the figure of the earth, as to which evidence is furnished by the variations in the force of gravity from the equator to the poles; and the fact that comparatively few such observations have been made in the polar regions where they have great weight in this problem, renders additional data there of especial importance. The study of the local variations of gravity is also of much interest, furnishing evidence of the differences of

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[1] "Bericht über die relativen Messungen der Schwerkraft mit Pendelapparaten," by Professor Helmert, in "Verhandlungen der elften allgemeinen Conferenz der Internationalen Erdmessung," at Berlin (1895). See map No. 7.

density near the earth's surface, and affording one of the few experimental means of investigating that important problem of terrestrial physics, the condition of the earth's so-called crust.

Magnetic observations have been made from time to time by various expeditions to these regions. The repetition of such observations at identical stations after suitable intervals of time, has long been considered an object of prime importance in the study of terrestrial magnetism, as by this means only can the changes constantly in progress in all the magnetic elements be intelligently studied. The direct practical bearing of these observations in connection with navigation and surveying, is the knowledge they afford of the variation of the compass from true north, and the possibility of predicting what the variation will be for at least a few years in advance. It was fortunate that at a number of places it was possible to reoccupy the stations of earlier magnetic observers, in two cases the identical points being found. The advantage of this, of course, is that the local variation which exists in the vicinity of many points is eliminated in deducing the rate of change of the magnetic elements from successive observations.

On account of the ready portability of the magnetic instruments it was possible to take advantage of nearly all the stops of the ship to make magnetic observations. The pendulum apparatus, however, being much more elaborate, and requiring the obtaining of star observations for time on at least two nights, could only be set up where the longer stops were made, and complete observations were obtained only at the points of starting and destination, with partial observations at two intermediate places. Because of the diversified interests comprised in the various expeditions on the ship, the short time available, and the exigencies of Arctic voyaging, the stops could not be arranged either as to time or place, to especially accommodate the magnetic and pendulum observations, but the convenience of this work was considered by Lieutenant Peary in arranging the plans, and the work promoted in every way practicable.

The present report on this work includes many details and illustrative examples of observations, and historical references to former work, which are embodied here with the purpose of giving a more complete idea of the methods and objects, as well as of the actual results obtained; to do this it is evidently necessary to repeat some data that have been published in earlier reports.

SECTION 2. *Narrative of the Expedition as Relating to these Observations.* — The starting point of the steamship "Hope," which was to carry the parties north, was Sydney, Cape Breton. In order to personally see to the transfers *en route* of the valuable instrumental outfit I left Boston by boat on July 4, 1896, reaching Halifax, Nova Scotia, on July 6. Here by permission of the British officers in charge, I made magnetic observations at the Naval Dock Yard, which is one of the most valuable secular variation stations in North America, the series of magnetic declination observations in this vicinity extending back nearly three centuries. Leaving Halifax July 8, on the steamer "Harlow," and passing through the remarkable Bras D'Or lakes, Sydney was reached on July 10. Magnetic, pendulum, and astronomical instruments were set up the same day, and work commenced that evening. Complete observations were obtained at this point, the instruments being located in the yard and basement of the Sydney Hotel, through the courtesy of Mr. J. P. Fairbanks. All the parties and outfit were embarked at this point on board the "Hope," a stanch Newfoundland sealing steamer of 322 tons, full rigged and especially adapted for work in the Arctic regions, and under the command of Captain John Bartlett, an experienced Arctic voyager. Professor Burton's party comprised, besides the writer, the following persons: Professor A. E. Burton, Massachusetts Institute of Technology, in charge, Professor G. H. Barton, geologist, Mr. R. W. Porter, artist, both also of the Institute, Mr. A. M. Dodge, Harvard Medical School, and Mr. J. C. Phillips, Lawrence Scientific School. The writer is indebted to these gentlemen for much assistance in preparing stations and for helping in other ways. Professor Burton, besides making the topographical sketches at several of the points, constantly facilitated and encouraged the work.

The "Hope" sailed from Sydney on July 16, our course being across the Gulf of St. Lawrence, through the Straits of Belle Isle, and along the Labrador coast. On July 20, a few hours' stop was made at Turnavik, where magnetic observations were made over the exact spot occupied by Lieutenant Very, United States Navy, fifteen years previously. For most of the distance along the Labrador coast floe ice was encountered, which became so heavy in the vicinity of Cape Chudleigh as to seriously impede the progress of the ship. Hudson Strait was entered on July 23, and found comparatively free from ice. Our party was landed at Ashe Inlet, Big Island, on July 25, and the various instruments were set up in the vicinity of the partially destroyed house marking the site of the Canadian meteorological station established ten years ago, in connection with the Hudson Bay expedition under Lieutenant A. R. Gordon, Royal Navy. Magnetic, pendulum, and one night's time observations were made here, but the second night's time observations were prevented by an easterly gale and rain which also interfered with the magnetic work. The "Hope," which had gone to the mainland, called for our party on July 27, and no further time was available at this point. We passed out of Hudson Strait on July 29, and were prevented from entering Cumberland Sound, as planned, by heavy ice which apparently blocked the whole width of the entrance. On July 31 the course was changed for Greenland, the coast of which was sighted on the evening of August 1. Steaming northward along that coast we entered the harbor of Godhavn on the evening of August 2, and were cordially welcomed by the Danish officials. By permission of Mr. Andersen, the Inspector of North Greenland, I made magnetic observations the next morning in a location between the Inspector's and Governor's houses, and probably very close to the former stations, which are referred to as being in the Inspector's garden, or near the flagpole. Later the magnetometer was taken across the harbor to the west side of Watson's Bay, and a few observations made there. This is thought to be in the vicinity of the "Discovery's" station of 1875. Leaving Godhavn on the afternoon of August 3, the "Hope" steamed through the remarkable passage inside of Disco Island, known as the "Vaigat." Entering Umanak Fjord on August 4, our destination at Umanak settlement on the little island of the same name was reached on August 5, and our party was disembarked, and the "Hope" proceeded on her more northern voyage. By the courtesy of Mr. Hjalmar Knuhtsen, the Governor of the Danish district of Umanak, an unused house known as the "Gamle Præstebolig" (old parsonage) was placed at our disposal, for storage and living purposes. Throughout our stay here the Danish officials were most courteous and hospitable, and facilitated our work in every way. The pendulum apparatus was set up in a corner of this house, and the meridian telescope and magnetic instruments in tents close by. By August 21 the observations at this point had been completed, and duplicate records prepared, which as a precaution were sent to America by the last Danish ship of the season, the "Peru" of the Royal Greenland Trade. After this the writer accompanied one of the several expeditions which were made by the party to the glaciers and the edge of the inland ice, at the heads of the fjords. Because of the limited transportation facilities available, it was considered inexpedient to attempt to include pendulum or magnetic observations in the plan of these exploring trips, which were made in small boats. The party returned to Umanak on September 8, and on the following day the "Hope" arrived on her homeward journey, and all were reëmbarked. The same general course was followed on the return trip, omitting the voyage into Hudson Strait. The afternoon of September 11 was spent at Godhavn, and magnetic observations were again made at the same point in the village. A northerly gale was encountered that night, and on the 12th, in crossing Davis Strait. On the evening of the 13th the "Hope" ran into floe ice above Cape Mercy, which proved so heavy that practically no progress was made except the drifting with the floe until the 16th, when, the pack loosening, the ship was worked out and steamed into Cumberland Sound, which was found quite free of ice. On September 17 we reached the whaling station at Umanaktuak, or Blacklead Island, in the midst of a gale and snowstorm, so that difficulty was encountered in procuring an Eskimo pilot from shore. We then proceeded to Niantilik, or Winter Harbor, where the ship remained at anchor for about thirty hours. The magnetic, pendulum, and astronomical apparatus were set up on a low promontory on a small island just west of the anchorage. Magnetic and pendulum observations were made, but no star observations for time could be obtained because of a snowstorm, and the shortness of the stay. This point and Ashe Inlet were the nearest of this series of stations to the magnetic north pole, distant approximately 850 miles (1,370 kilometers). Leaving Blacklead on the morning of the 19th, a clear and favorable passage was had across to and along the Labrador coast, and again through the Straits of Belle Isle to Sydney, which was reached on September 26, after an absence of seventy-two days and a voyage of about 5,000 miles (8,000 kilometers). A few additional observations were made this day at Sydney, at Lieutenant Very's station of 1881, in the rear of the English Church. The instruments were then shipped to Washington, where the periods of the pendulums were carefully determined, October 15 to 17. They had been determined at Washington just previous to starting on this expedition, on June 22 to 24. The mean period of the three pendulums in October differed only .0000001 of a second from that determined in June, a very satisfactory test of the constancy of the pendulums and their

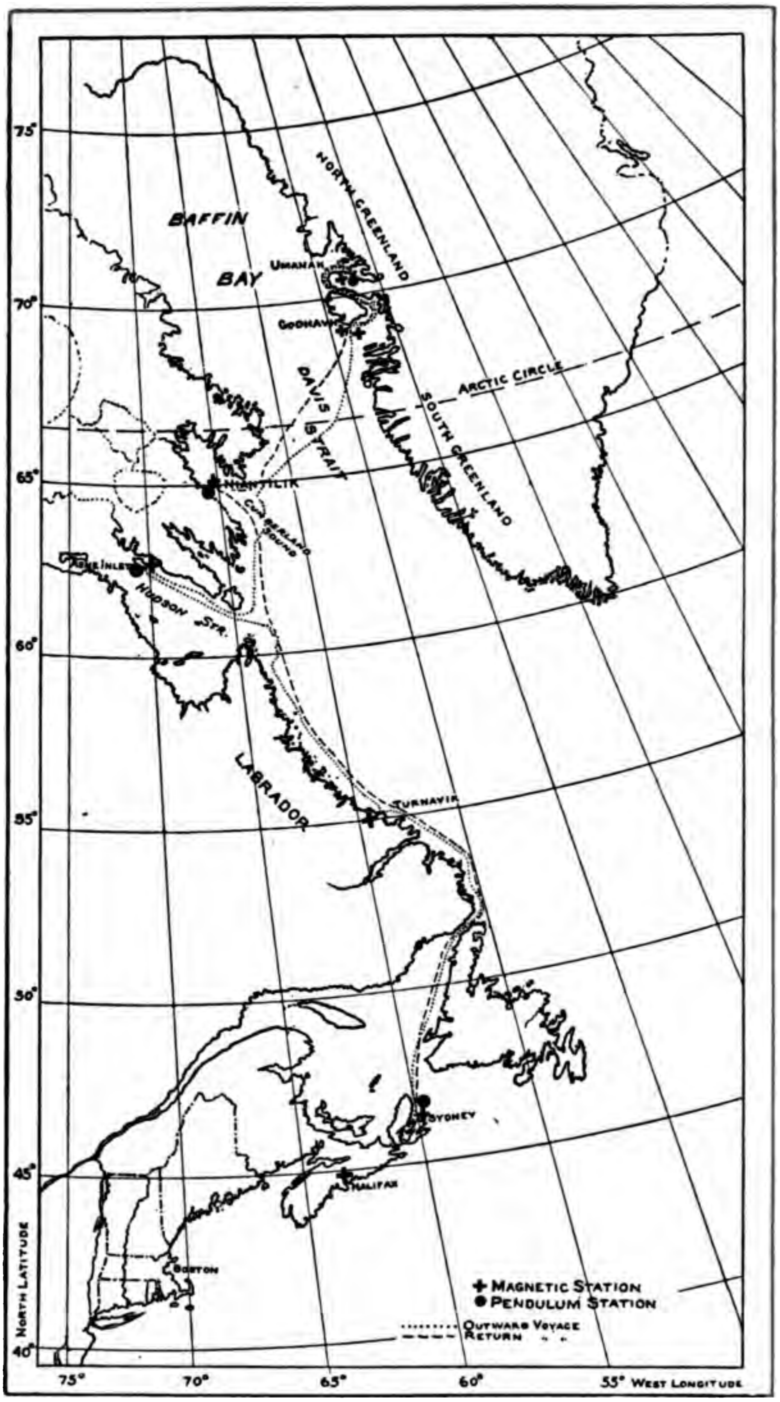


FIG. 1. SKETCH SHOWING GENERAL ROUTE OF THE EXPEDITION AND LOCATION OF MAGNETIC AND PENDULUM STATIONS.

freedom from injury on this journey. In this brief outline of the history of this expedition, only such details are referred to as affected these particular lines of work.

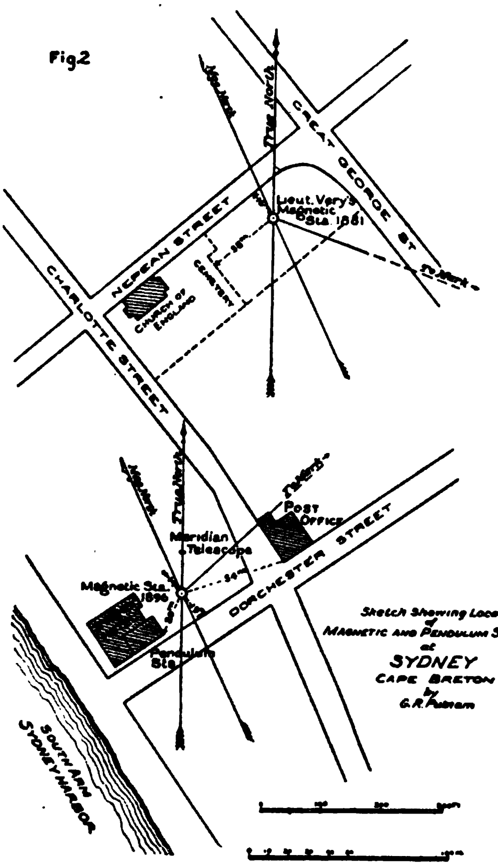
SECTION 3. *Description of Stations.* — There were in all eleven magnetic stations, in seven distinct localities. There were five pendulum stations (including the base station at Washington), at two of which the observations were incomplete. The route of the expedition and the points of observation are shown on the accompanying map, Figure 1, and the local positions of the various points on the separate sketches Figures 2 to 8. For further identification, the following brief description of the various points is added :

Washington, D. C. Pendulum station, in pendulum room in southwest corner of basement, Coast and Geodetic Survey Office on Capitol Hill.

Sydney, Cape Breton, Nova Scotia. Pendulum apparatus in front part of basement of Sydney Hotel. Magnetometer (station 1896) in open lot belonging to Sydney Hotel, and between it and Post Office.

Sydney, Cape Breton, Nova Scotia. Magnetic station of 1881, about 188 meters north, and 43 meters east of preceding. This station was occupied by Lieutenant S. W. Very, United States Navy, in 1881, and the wooden post left by him was found. It is in the rear of the Church of England, Figure 2.

Fig.2



Sketch Showing Location of Magnetic and Pendulum Stations at SYDNEY CAPE BRETON by G.R. Putnam

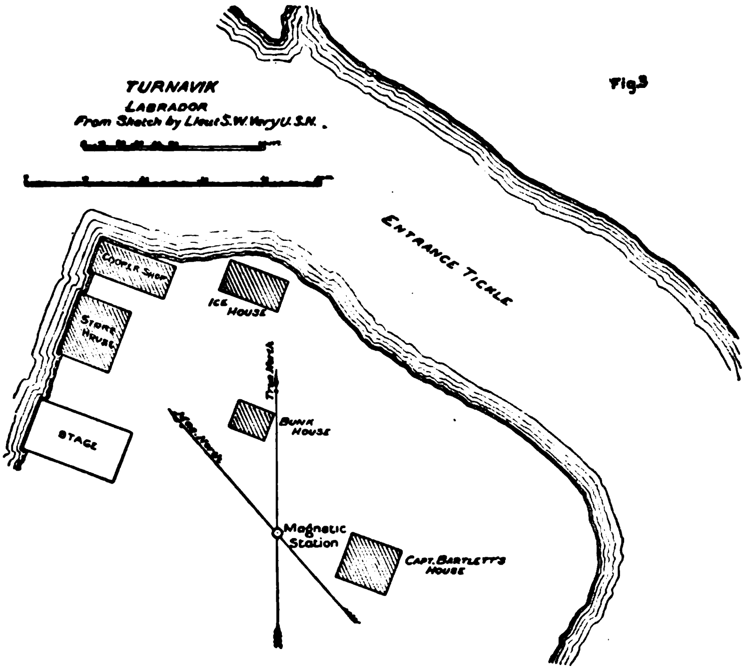

TURNAVIK
LABRADOR
From Sketch by Lieut S. W. Very U. S. N.
ENTRANCE TICKLE
COOPER SHOP
STORE HOUSE
ICE HOUSE
STAGE
BUNK HOUSE
True North
Mag. North
Magnetic Station
CAPT. BARTLETT'S HOUSE

Fig. 3

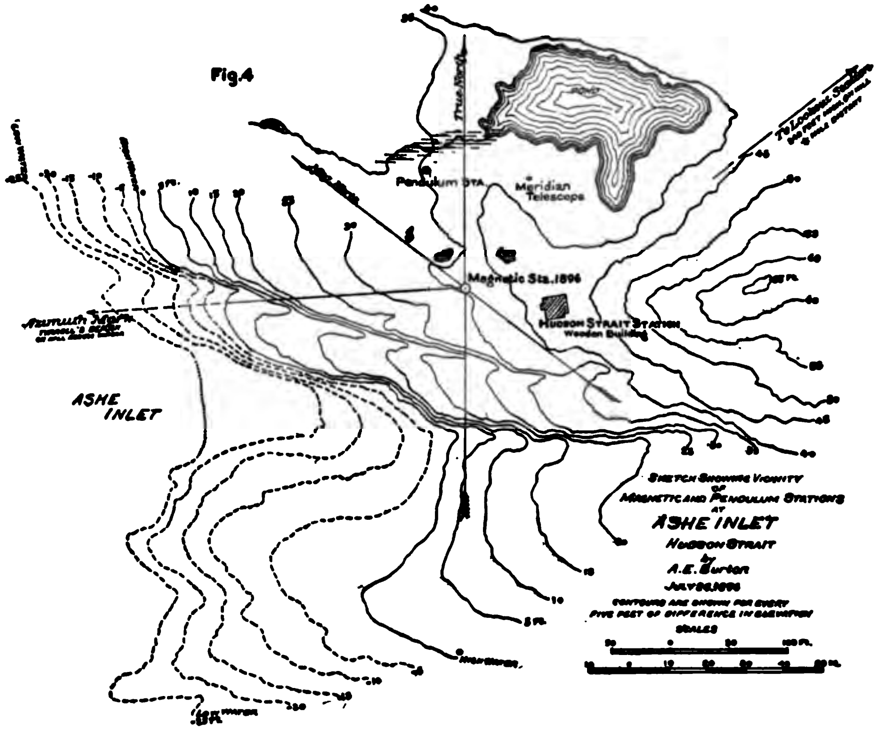

Pond
True North
Mag. North
Pendulum Sta.
Meridian Telescope
Magnetic Sta. 1896
Hudson Strait Station
Wooden Building
To Lookout Station
Azimuth Mark
ASHE INLET
High Water
Low Water
SKETCH SHOWING VICINITY OF MAGNETIC AND PENDULUM STATIONS AT ASHE INLET HUDSON STRAIT by A. E. Burton JULY 26, 1896
CONTOURS ARE SHOWN FOR EVERY FIVE FEET OF DIFFERENCE IN ELEVATION
SCALES
100 Ft.

Fig. 4

Turnavik, Labrador. Magnetic observations were made at the identical point occupied by Lieutenant Very, in 1881, on West Turnavik Island, in the midst of the small fishing settlement under charge of William Bartlett. This station is marked by a deep drill hole in the bare rock about half way between Bartlett's house and the house in which his men live, Figure 3.

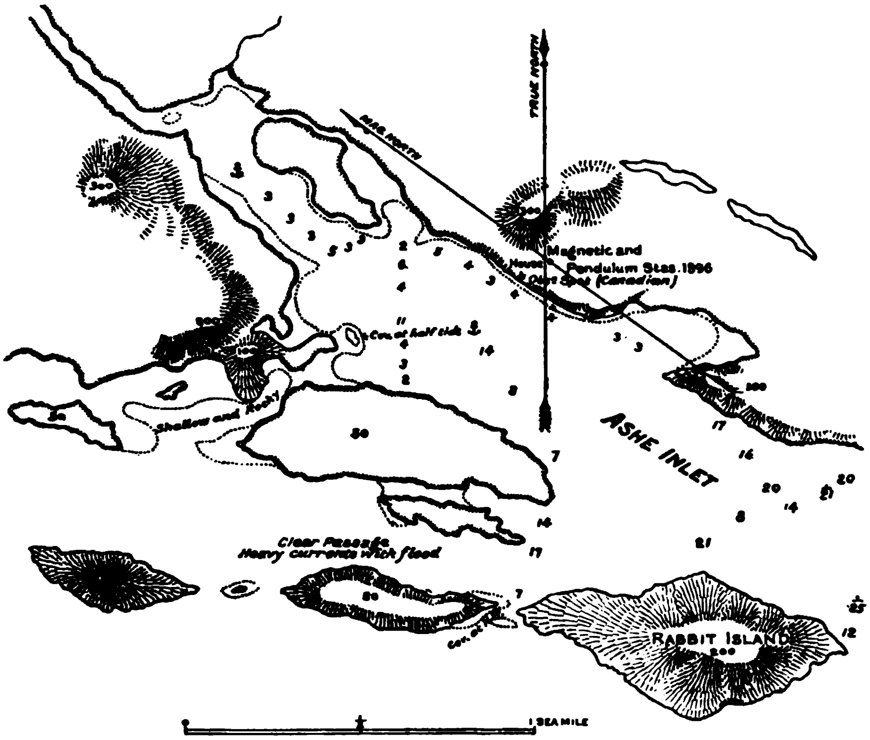


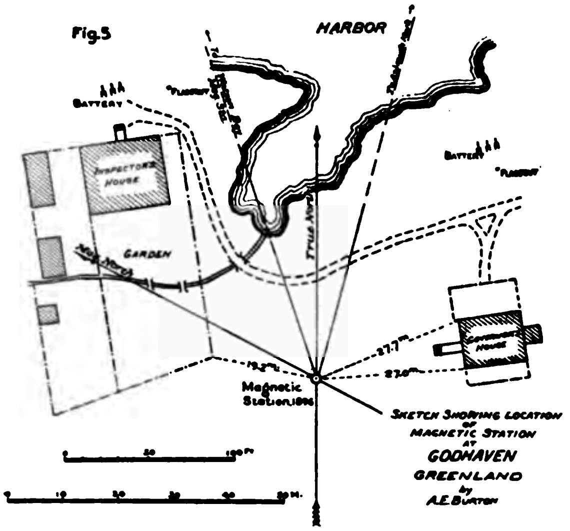
FIG. 4A. SKETCH OF ASHE INLET, HUDSON STRAIT.

From Admiralty Chart No. 1221. (1888.) *Soundings in fathoms, heights in feet.*
Observation Spot: Lat., 62° 32′ 44″ N.; Long., 70° 34′ 50″ W.

Ashe Inlet, Big Island, north side of Hudson Strait. Pendulum apparatus in low stone and turf hut northwest of Hudson Bay Expedition house on east side of Inlet. Magnetometer 23 meters west, and 5 meters north of house. Position of latter marked by drill hole 2 cm. in diameter in bed rock, Figures 4 and 4*a*.

Godhavn, Disco Island, Greenland. Magnetometer was located between the Inspector's and the Governor's houses, on slope of rocky ledge. It was quite near the flagstaff and garden probably referred to in description of previous stations. Position marked by a hole 2 cm. in diameter drilled in bed rock, Figure 5.

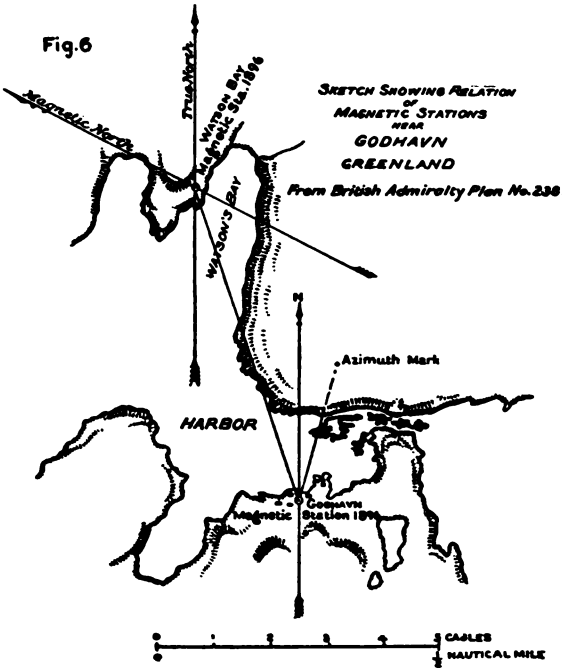
Fig. 5



Sketch showing location of Magnetic Station at Godhaven Greenland by A. E. Burton

Watson's Bay, Godhavn Harbor, Greenland. This magnetic station was located across the harbor from Godhavn, on a slight promontory on west side of Watson's Bay as shown on Admiralty plan No. 2,382. Position marked by a hole 2 cm. in diameter drilled in bed rock, Figure 6.

Fig. 6



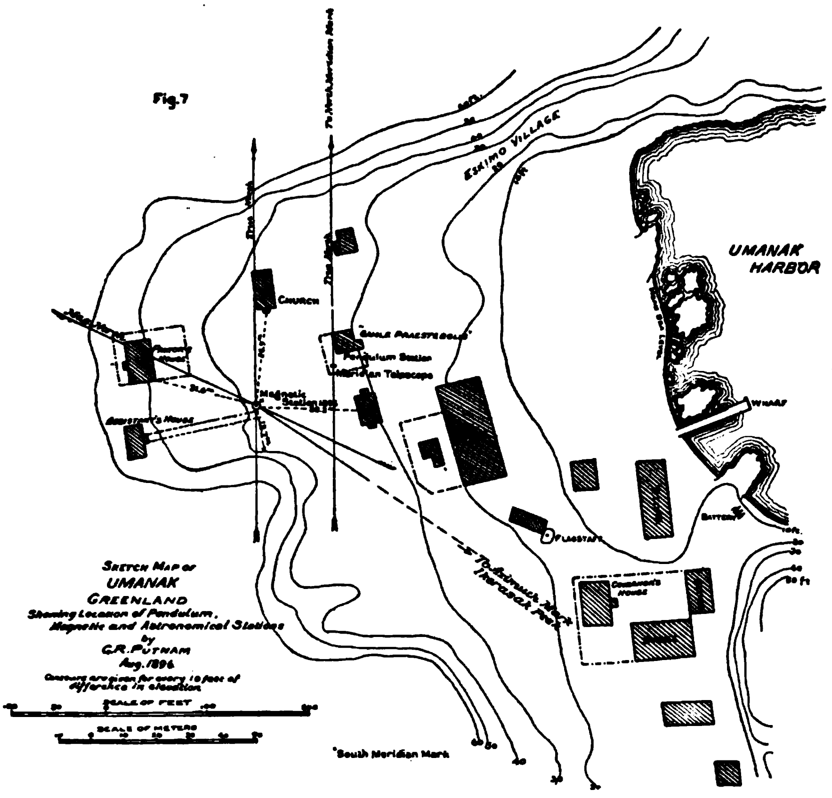
Sketch showing relation of Magnetic Stations near Godhavn Greenland

From British Admiralty Plan No. 2382

Umanak, Greenland. At Umanak village on the small island and in the district of the same name. Pendulum apparatus on ground floor of building known as "Gamle Præstebolig." Magnetometer in open space south of church. Position marked by hole 2 cm. in diameter drilled in outcropping ledge of rock. The north and south meridian stations at Umanak were on the cliffs in the meridian of the meridian telescope, 194 meters and 105 meters, respectively, north and south of the principal magnetic station, and were each similarly marked by drill holes in the rock, Figure 7. (For general vicinity see Admiralty chart No. 276).

Niantilik, Cumberland Sound. On a small island on the southwest side of Cumberland Sound, and lying just west of the anchorage known as Niantilik or Winter Harbor, and about eight kilometers (five miles) south of the whaling station and Eskimo settlement at Umanaktuak or Blacklead. Pendulum apparatus was located in a tent on a low rocky point projecting from near the center of the southeast side of the island, and nearly south of the little sailors' cemetery by which the island may be identified. Magnetometer about 22 meters southeast of pendulum station. Latter point marked by hole 2 cm. in diameter drilled in gneiss rock, Figure 8. (For general vicinity

Fig. 7



see map by Dr. Franz Boas, in Petermann's Mitteilungen, Vol. XVII, No. 80, 1885, Figure 8*a*.)

SECTION 4. *Geographical Positions and Elevations.* — The adopted values for the latitude, longitude, and elevation of the stations are given in the final tables of results (E and K). Except for Niantilik and Umanak, the latitudes are taken from the best available sources, such as records of previous observations, or from charts. At Niantilik, the latitude is from an adjustment of morning and afternoon sun observations for azimuth, checked by a rough sun observation at noon. At Umanak, observations of four pairs of stars on two nights were made with Meridian Telescope No. 13, using Talcott's method. The details of this determination are given in Section 17.

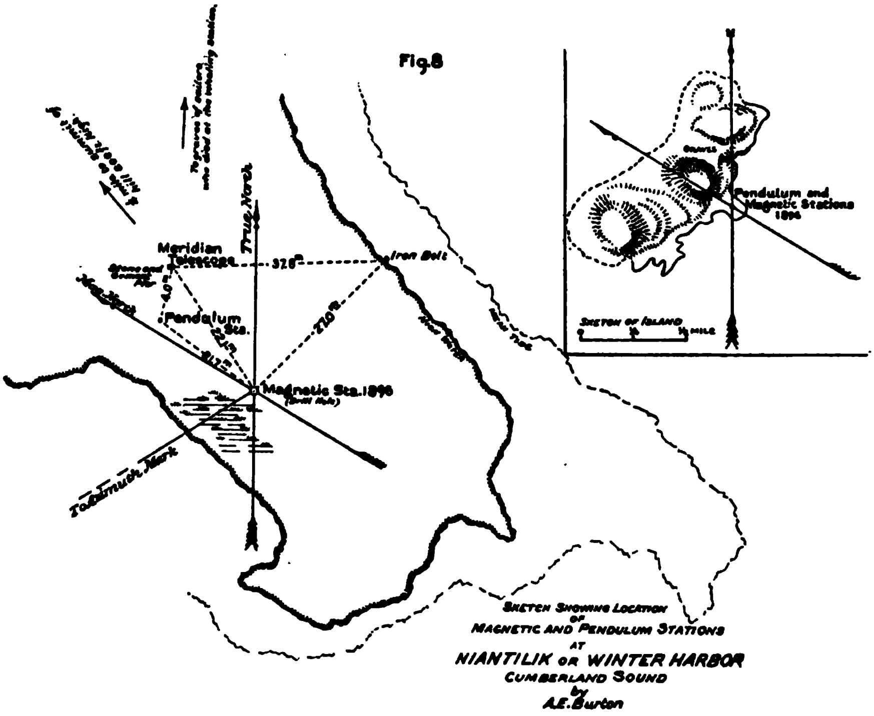


Fig.8

SKETCH SHOWING LOCATION OF MAGNETIC AND PENDULUM STATIONS AT NIANTILIK OR WINTER HARBOR CUMBERLAND SOUND by A.E. Burton

The longitudes of all the intermediate stations have been computed from the three chronometers, Numbers 1,823, 1,842, and 177, which were carried on the expedition, and are based on Sydney, Cape Breton, as a starting point, and Washington, D. C., as an ending point. The stationary rates were determined at Sydney, Umanak and Washington, and the traveling rates computed for the balance of the time. The local time for comparison with the chronometers was obtained at Ashe Inlet and Umanak, from star observations with the meridian telescope, and at the other points from the sun observations made with the theodolite magnetometer. The longitude results cannot be considered as very reliable for several reasons; the longitude of Sydney is uncertain, probably by a second of time; the chronometers were subjected to a considerable variety of temperature and other conditions, including the jarring effect when pushing through the ice during many days; there was a long railroad journey from Sydney to Washington before they were last rated; and the magnetometer theodolite time determinations may be uncertain by several seconds. Nevertheless, the results by the three chronometers are fairly accordant, and agree well with previous values except for the two Greenland stations. The following table (A) gives the results by the three chronometers,

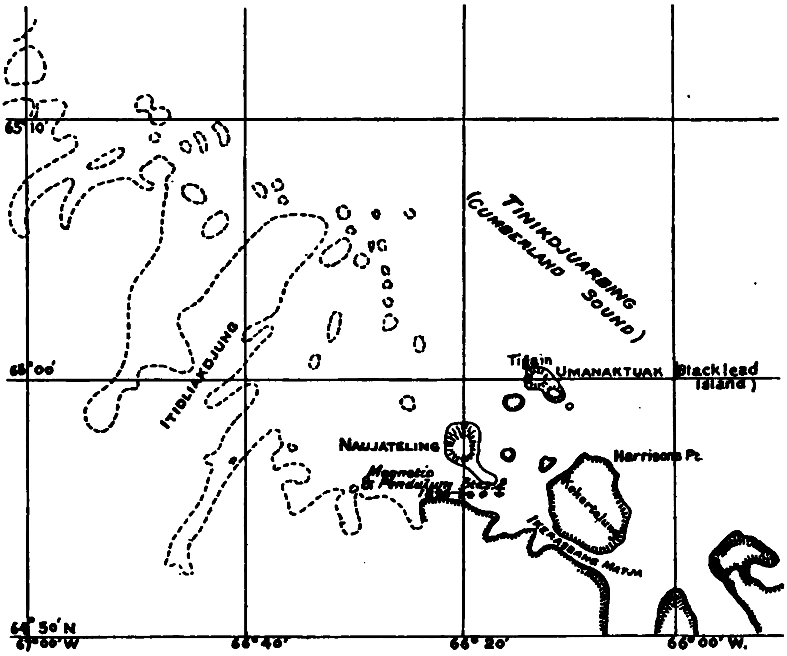


FIG. 8A. SKETCH OF A PORTION OF CUMBERLAND SOUND, SHOWING VICINITY OF MAGNETIC AND PENDULUM STATIONS OF 1896.

From map by DR. FRANZ BOAS, *Petermann's Mitteilungen*, Vol. 17, *Ergänzungsheft* No. 80, 1885.

and a comparison with previous values. Because of its unsatisfactory performance, a weight of only one third is given to the results by chronometer 177. It will be noted that the discordances at the two Greenland stations between different authorities are considerable. At these two, the values determined in 1896 have been adopted, while at the other points the means of the present and earlier results have been used. In Section 18 is given as an example the computation of the longitudes by one of the chronometers.

The elevations of the pendulum stations were determined by hand level, using a Casella pocket alt-azimuth instrument. This instrument was found very convenient for the approximate leveling which fully answers the requirements of this work. Using as a base the height of the eye above the ground, picking up some natural object in the same horizontal plane, and following up grade in this manner, the difference in elevation to the nearest foot of points not distant may be obtained by one person almost as fast as he can walk between them. The mean sea level to which the elevations are referred was obtained by rough tidal observations, the mean of succeeding high and low waters being taken.

TABLE A.

SUMMARY OF RESULTS FOR LONGITUDE AND COMPARISON WITH PREVIOUS VALUES.

Station.	Reference point.	LONGITUDE WEST OF GREENWICH.				Previous values of longitude.†
		Chronometer.				
		1823. Weight 3.	1842. Weight 3.	177. Weight 1.	Weighted mean.	
		h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Turnavik, Labrador	Magnetic station.	3 57 22.2	3 57 20.6	3 57 24.5	3 57 21.8	3 57 20.4 (1)
Ashe Inlet, Hudson Strait . .	Meridian telescope.	4 42 22.5	4 42 24.0	4 42 26.3	4 42 23.7	4 42 18.6 (2)
Godhavn, Greenland	Magnetic station.	3 34 04.8	3 34 05.2	3 34 03.0	3 34 04.7	3 33 36.5 (3) 3 34 48.0 (4)
Umanak, Greenland	Meridian telescope.	3 28 34.0	3 28 32.8	3 28 33.2	3 28 33.4	3 27 55.8 (5) 3 29 00.0 (6)
Niantilik, Cumberland Sound.	Magnetic station.	4 25 17.6	4 25 22.2	4 25 13.3	4 25 19.0	4 25 17.6 (7)
Sydney, Cape Breton.* . . .	Magnetic station, 1881.	4 00 42.8	4 00 45.8	4 00 28.8	4 00 42.1	4 00 46.9 (8)

* Sydney is included here only as a check. These longitudes are based on Sydney as a starting point, and Washington as an ending point.

† References for the previous values given.

Numbers 1, 2, 4, and 6, from British charts and plans.

Number 3. Bowditch, Practical Navigator.

Number 5. Meddelelser om Grönland, 4th part.

Number 7. Dr. Franz Boas' map.

Number 8. U. S. Hydrographic office chart.

Fig. 9. Dip Circle.

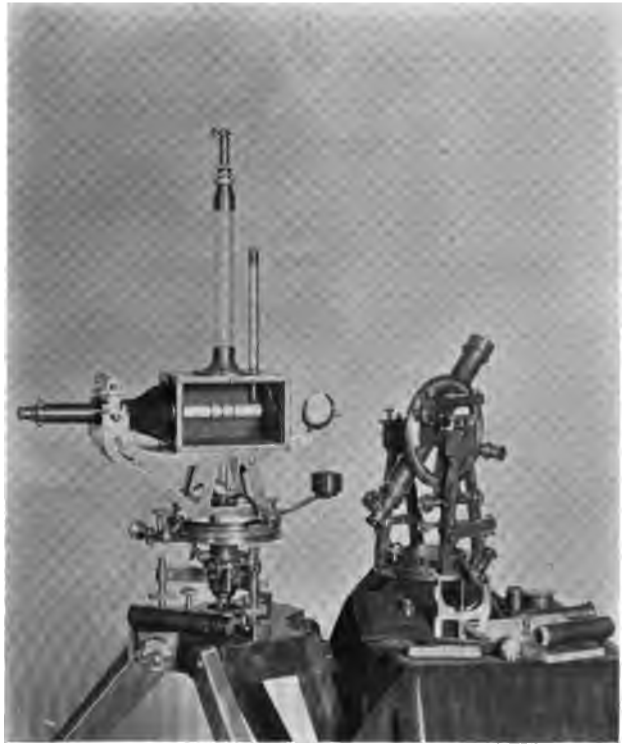


Fig. 10. Magnetometer and Theodolite.

PART II. MAGNETIC OBSERVATIONS.

SECTION 5. *Magnetic Instruments and Constants.* — A portable magnetic outfit was used, consisting of dip circle and magnetometer belonging to the Coast and Geodetic Survey. The dip circle (No. 4,655 by Casella) was of the ordinary Kew pattern, suited for work in high latitudes, with the supports for the needle horizontal, so as to permit of reading dips near 90°. It is shown in Figure 9. Its dimensions were horizontal circle 12.2 cm., vertical circle 14.4 cm. The magnetometer (No. 19) was one of the new instruments constructed at the Coast and Geodetic Survey Office in 1893, and is shown in Figure 10. It is of the general form long used in this country, and differing somewhat from the Kew magnetometer. It is a combination magnetometer and theodolite; the magnet box and attached small theodolite may be quickly removed from the base and horizontal circle, and replaced by the theodolite for determining the azimuth from the sun or otherwise. These new instruments have a horizontal circle of 11.2 cm. diameter, and vertical circle 9.8 cm., and have several improvements in detail greatly increasing the convenience of their use. The magnet is octagonal in shape, and is held in a similarly shaped stirrup, thus facilitating its reversal to obtain the axis. The suspension fibers (usually two fine silk fibers) hang from the adjustable torsion head at the top of the glass tube above the magnet box, and are attached to an arm extending upward from the stirrup. By this method the point of suspension is so high above the center of gravity of the magnet that the latter is little affected by dip, and will hang sensibly horizontal in ordinary latitudes. The principal magnet (19L) is a hollow steel bar about 7.4 cm. in length, and 1.1 cm. between opposite faces. It has a graduated scale in one end, and in the other a lens of such shape as to bring the scale into focus in the small observing telescope when the latter has the proper focus for a distant mark. This telescope is mounted eccentrically on the same support as the magnet box, and is provided with collimation and wye adjustments. The terrestrial reference mark may be observed with this telescope directly through the box, by lowering the magnet out of the way, turning aside the glass window at the further end of the box and lowering the light reflector outside. The hood between the end of the telescope and the magnet box enables the latter to be entirely closed against air currents when the magnet is being observed, and at the same time renders it possible to observe both magnet and mark without looking through glass windows of any sort. For removing the torsion of the suspension fiber, a brass bar of the same weight as the magnet is provided. To support the magnet when it is used as a deflector, there are arms (not shown in the illustration) which are inserted beneath the magnet box, and which have a slider which supports the deflector at the height of the auxiliary suspended magnet, and at any desired distance.

The constants of this magnetometer and of magnet 19L were determined by the writer in December, 1893, as follows (in C. G. S. units):

Scale value magnet (19L) 1 division = 2.′00 of arc.
Corrected distance on deflecting bars, at mark 35 cm. = 35.020 cm.
Corrected distance on deflecting bars, at mark 49 cm. = 49.020 cm.
Temperature coefficient $q = 0.00049$ for 1° C.
Induction coefficient $h = 0.0125$.
Distribution coefficient $P = -4.55$.
Moment of inertia at 10.°5 C. $M = 178.38$.

These values were used in the computations, excepting that for P. This coefficient was computed from the present series of observations, with the result $P = -3.80$. The mean of this and the preceding determination, or $P = -4.18$, was used.

For fear that the great dip in these high latitudes might affect the horizontal force determinations by drawing the oscillating magnet out of the horizontal plane, in some of the observations at Ashe Inlet, Godhavn, and Umanak, the south end of magnet 19L was weighted with a small copper balancing ring, whose weight was 0.349 grams, outer radius 14.0 mm., inner radius 12.0 mm., length 0.9 mm. At Ashe Inlet and Godhavn the distance from center of ring to center of magnet was 20 mm., and at Umanak 22.5 mm., the endeavor being to so place it as to make the magnet horizontal. For the first distance, the moment of inertia was computed to be 1.693, and for the second, 2.064, using the formula $I = W\left[\frac{1}{3}(x_2^2 + x_2 x_1 + x_1^2) + \frac{1}{4}(r_2^2 + r_1^2)\right]$, where r_2 is outer radius of ring, r_1 inner radius, x_2 distance center of oscillation to outer end of ring, and x_1 to inner end. Where the balancing ring was used, its moment of inertia must of course be added to that of the magnet and stirrup, in the formula for time of oscillation. A comparison of results for the horizontal component of the earth's magnetic force (H) from observations on the same day, made with and without the balancing ring, indicates that the error due to lack of horizontality is at least very small.

	Results for H (in dynes).	
	With ring.	Without ring.
Godhavn, August 3	0.0819	0.0819
Umanak, August 14	0.0783	0.0782
Umanak, August 15	0.0783	0.0782
Umanak, August 18	0.0791	0.0792

Besides the magnetic instruments proper, the chronometers and other auxiliary instruments belonging to the pendulum apparatus were used when required. The observing tent, which was suitable for astronomical or magnetic work, was used for the latter purpose at only one point (Umanak). At the other points the magnetic instruments were in the open air, either because the time was too short, or the tent was otherwise employed. Several times this arrangement was not satisfactory because of the high winds and otherwise unfavorable weather.

SECTION 6. *Magnetic Observations and Computations.* — For the complete determination of the three magnetic elements, declination, dip and horizontal force, the system generally employed in the field work of the Coast and Geodetic Survey with portable instruments was followed. Illustrative examples (taken from this season's work) of each of the steps involved, both in the observations and computations, are given in Part IV of this report, Sections 19–22. Complete instructions for such observations, adjustments of instruments, etc., are given by Mr. Schott in Appendix No. 8 of the Report United States Coast and Geodetic Survey for 1881. The theory of the various corrections involved (with the exception of that for induction[1]) is given by Professor Nipher in his little volume on the "Theory of Magnetic Measurements."

The operations included in a complete day's observations were as follows, about in the order named: 1. Early in the morning, reading of the horizontal magnet at intervals of about fifteen minutes to obtain the easterly elongation, which occurs between 7 and 9 A. M. in ordinary latitudes, but is quite variable in these northern regions. The positions of the magnet were of course referred to some terres-

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[1] For this, reference may be made to Report Coast and Geodetic Survey for 1869, App. No. 9, p. 200; also Proc. Royal Society of London, 26, p. 221; also Lamont's "Handbuch des Erdmagnetismus," p. 152.

trial mark which was observed before and after the magnet readings. 2. Observations of the sun's azimuth and altitude (near the prime vertical if possible) to obtain the azimuth of the mark, usually made during some interval of the declination observations. 3. Determination of the axis of the magnet by alternate readings in direct and inverted position. 4. Determination of the time of oscillation of the magnet. 5. Measurement of the angle of deflection of the auxiliary magnet, as caused by the principal magnet at right angles to it, usually two sets at different distances, and followed if time permitted by another set of oscillations. 6. Determinations of the dip, complete sets with two independent needles. 7. Commencing about noon horizontal magnet readings, repeated at intervals of about fifteen minutes, to obtain the afternoon westerly elongation which occurs in ordinary latitudes from 1 to 2 P. M. 8. Sun observations for azimuth repeated late in the afternoon, for the reason that a combination of morning and afternoon azimuths eliminates the effect of an uncertainty in latitude.

Weather conditions and the limited amount of time available, rendered changes and curtailments of this program necessary in some cases. In others the plan was enlarged, the observations extended to two or three days, and the declination observations continued at somewhat irregular intervals throughout the day. At the northern stations it would have been of interest to continue the latter throughout the twenty-four hours to study the daily changes in declination, but this was not practicable with the other work on hand. At Umanak the true meridian was derived from a meridian line laid out with the meridian telescope. At Turnavik, Ashe Inlet, and Niantilik (second observation) only oscillation observations were made to determine the horizontal force. These were treated relatively, comparing the time of oscillation of the magnet at each of these stations with that at both the preceding and following stations where the force was completely determined, and allowing for the progressive change in the magnetic moment of the magnet. The rates of the chronometers for reducing the oscillation observations were obtained from the star observations with the meridian telescope in connection with the pendulum work at Sydney and Umanak, and for the remaining stations were derived from the intermediate traveling rates of the chronometers.

SECTION 7. *Results of Magnetic Observations.* — The results of the magnetic observations for the different elements separately and for each day of observation are given in Tables B, C, and D, and a general summary of all the results is given in Table E. In Table B, when the extreme declinations observed were assumed to be the elongations for the day, they are indicated by an asterisk (*), and in such cases the mean of the two elongations is taken as the mean declination for the day. When because of lack of time it was impossible to obtain these elongations, the declinations have been reduced to the mean of the day from such comparative data at other stations as was available, the references being given in the footnote. Where the declination observations were made more or less continuously, covering any considerable part of the day, the average declination for this interval is given in the table, this average being obtained graphically by plotting the observed values. For five days, on each of which the readings covered an interval of about twelve hours, the results are shown in the diagram (Figure 11), plotted to the same scale for the different places. The diagram for Niantilik indicates a considerable magnetic disturbance on the date of observation, as was also very apparent when the observations were in progress, for the needle would frequently move out of range of the telescope, necessitating the changing of the azimuth circle. There was a change of over three degrees in twenty minutes; at 7 h. 35 m. A. M., the needle pointed 60° 35′ W. of N., while at 7 h. 55 m., it pointed 63° 50′ W. of N., and the total range for the day was over four and a half degrees. Such disturbances, however, are not unprecedented in Arctic experience.[1] An inspection of the magnetograph records[2] of the United States Naval Observatory at Washington, for the dates corresponding to those on which observations were made at the northern stations, shows that there were no considerable magnetic disturbances at these epochs, excepting on September 18, 1896. On this date there was an unusual magnetic storm, the extreme range in declination at Washington being 38′ for the entire day, and 19′ for the portion of the day corresponding to

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[1] In The Manual of Natural History, Geology and Physics of Greenland (London, 1875), it is stated that McClintock observed a change of 15°, and Sir Edward Belcher noted a disturbance of 27.°6 accompanying an aurora.

[2] Copies of these records for the dates in question were furnished by Commodore Phythian, Superintendent of the Naval Observatory.

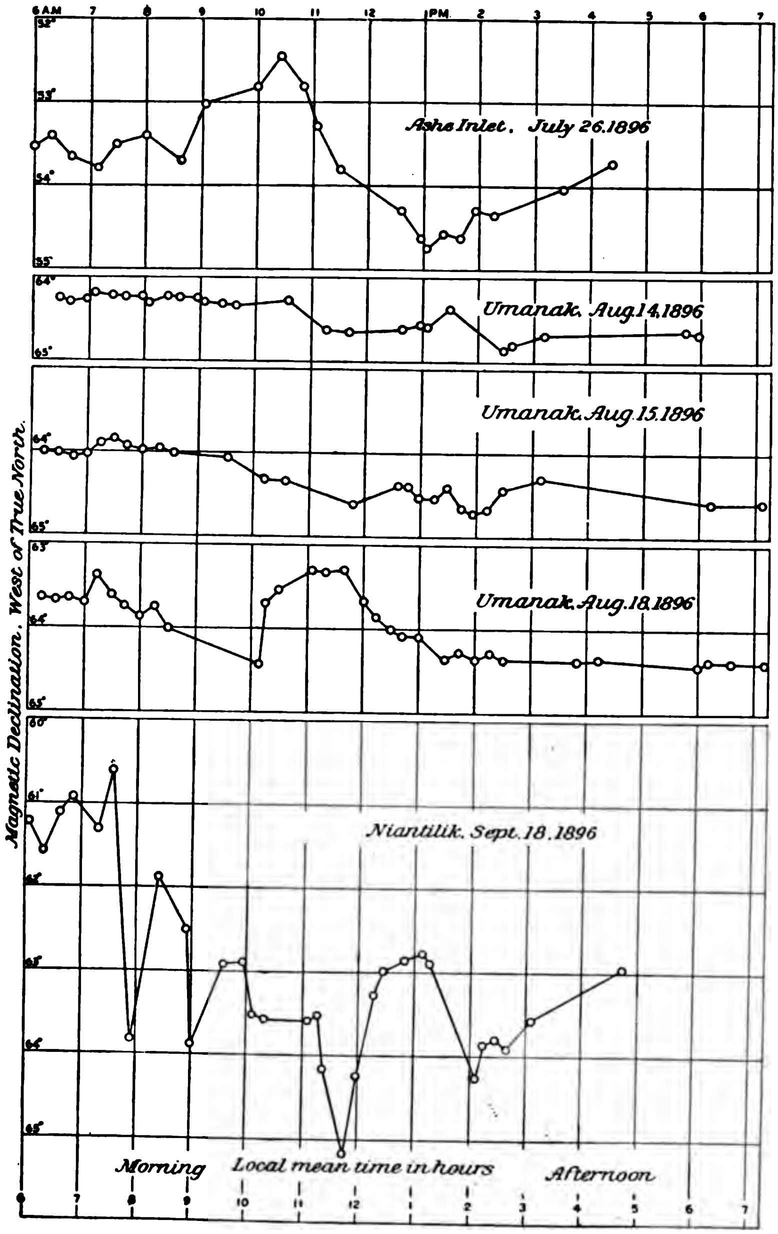

FIG. 11. DIURNAL CHANGES IN MAGNETIC DECLINATION.

the interval during which observations were made at Niantilik. The tracing for this latter interval is shown in Figure 11A, reduced to the same scale as is used in Figure 11, and there is also given the curve for part of a more normal day, July 26, the date on which observations were made at Ashe Inlet. It will be noted that the range in declination at Niantilik was nearly fifteen times as great as at Washington during the same interval. As the diagrams for the northern stations are plotted from individual observations at irregular intervals, they are of course not comparable in detail with the continuous Washington records. The last column in Table B gives the diurnal range for the

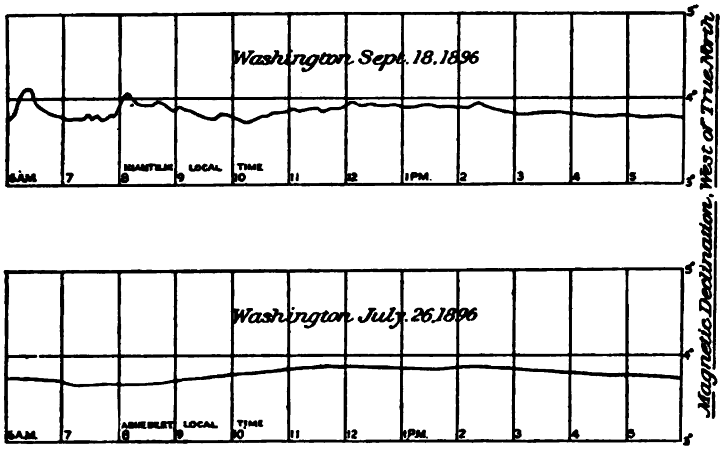

FIG. 11A. DIURNAL CHANGES IN DECLINATION AT WASHINGTON, D. C.

days on which elongations were obtained. These ranges cannot be considered as average values for the respective localities, being possibly affected by abnormal conditions on these particular days, as is evident in the case of Niantilik. At Umanak, Godhavn, and Sydney, declination observations were made at two or three neighboring points. At Sydney, the difference between the station of 1896 and Very's (1881) was insignificant for dip as well as for declination. At Umanak[1] the westerly declination increases about half a degree in going

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[1] A considerable number of compass observations of declination were made about Umanak Fjord by Danish officers (Assistant Steenstrup and Lieutenant Hammer) in 1878 and 1879. The following passages translated from "Meddelelser om Grönland," 4th Part, p. 177 (Copenhagen, 1883), give some instances of the irregularity of the declination noted by them

from one to two hundred meters either north or south from the principal magnetic station. Near Godhavn the declination is slightly greater across the harbor at Watson's Bay than in the village, though the difference is not so great as was indicated by the English observations in 1875, which may have been made in somewhat different localities.

The total force (F) in the last column of Table E is derived from the horizontal force (H) and dip (θ) by the relation $F = \frac{H}{\cos\theta}$. All the results for H, F, and m are stated in C. G. S. units.

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in this region: "It is a familiar saying that the magnet needle on these shores is nearly dead, and that the magnetic declination, especially in trap rock regions, is so variable that for geographical measurements it is necessary to determine it for every bearing, for it changes with every setting up of the compass. Thus a small movement, only some few feet, effected on the Shades Islands a change of 5° in the measured declination; indeed, at Igdlorsuit upon Ubekjendt Island a movement from the houses up to the top of the mountain about 1,500 feet high, lying about 2,000 feet away, was sufficient to change the declination from 74.°0 to 34.°9. . . . In gneiss regions the local effect is not near so strong, but while the trap generally causes greater declinations than one would expect from the geographical position, gneiss on the contrary not unusually appears to give less declinations." It is further remarked that normal conditions can often be found only upon the ice.

TABLE B. — SUMMARY OF RESULTS OF MAGNETIC DECLINATION OBSERVATIONS.

	STATION.	DATE. (Civil.) 1896.	EASTERLY EXTREME.		WESTERLY EXTREME.		AVERAGE DECLINATION DURING TIME OF OBSERVATION.		Correction to reduce to mean declination.†	Adopted mean declination.	Diurnal range in declination.
			Local mean time.	Declination.	Local mean time.	Declination.	Interval included. Local mean time.	Average declination.			
			h. m.	° ′	h. m.	° ′				° ′	° ′
1.	Halifax	July 6–7	7 31 A.M.	20 35.5* W.	12 46 P.M.	20 41.6* W	....	....	....	20 38.6 W	0 06.1
2.	Sydney. (Station 1896) .	July 11	7 40 A.M.	24 41.4*	1 25 P.M.	25 01.3*	....	....	....	24 51.4	0 19.9
	Sydney. (Station 1896) .	July 13	8 44 A.M.	24 49.8*	2 00 P.M.	25 01.1*	....,	....	....	24 55.4	0 11.3
	Sydney. (Station 1896) .	Mean.	....	....	....	....	....	....	....	24 53.4	0 12.4
							h. m. h. m.	° ′			
3.	Turnavik	July 20	8 53 A.M.	38 17.2	12 03 P.M.	38 34.4	8 53 A.M. to 12 03 P.M.	38 28.4 W.	— 2.0′	38 26.4	....
4.	Ashe Inlet	July 26	10 23 A.M.	52 29.4*	1 08 P.M.	54 40.7*	6 07 A.M. to 4 28 P.M.	53 45.9	....	53 35.0	2 11.3
5.	Godhavn	Aug. 3	3 17 A.M.	63 33.8	9 04 A.M.	61 37.3	2 08 A.M. to 9 21 A.M.	62 43.5	— 1.9	62 41.6	....
6.	Watson's Bay	Aug. 3	....	....	....	....	10 05 A.M.	63 12.2	— 5.3	63 06.9	....
7.	Umanak	Aug. 14	7 15 A.M.	64 06.6*	2 30 P.M.	64 49.2*	6 37 A.M. to 6 00 P.M.	64 26.8	....	64 27.9	0 42.6
	Umanak	Aug. 15	7 30 A.M.	63 46.6*	2 00 P.M.	64 44.1*	6 20 A.M. to 9 05 P.M.	64 19.8	....	64 15.4	0 57.5
	Umanak	Aug. 18	11 05 A.M.	63 16.1*	6 00 P.M.	64 28.8*	5 55 A M. to 8 05 P.M.	64 04.3	....	63 52.5	1 12.7
	Umanak	Mean.	....	....	....	....	....	....	....	64 11.9	0 57.6
8.	Umanak, S. Meridian .	Aug. 21	....	....	....	....	5 30 P.M.	65 07.5	—22.5	64 45.0	....
9.	Umanak, N. Meridian .	Aug. 21	....	....	....	....	6 00 P.M.	65 06.0	—28.0	64 38.0	....
5.	Godhavn	Sept. 11	2 07 P.M.	63 14.0	6 20 P.M.	63 52.5	2 00 P.M. to 6 30 P.M.	63 34.4	—20.6	63 13.8	....
10.	Niantilik	Sept. 18	7 35 A.M.	60 35.3*	11 40 A.M.	65 09.4*	5 35 A.M. to 3 40 P.M.	62 54.9	....	62 52.4	4 34.1
11.	Sydney. (Station 1881) .	Sept. 26	....	....	....	....	4 25 P.M.	24 56.7	— 1.4	24 55.3	....

* The extreme declinations marked thus were assumed from their relation to the other observed values to be the eastern and western elongations respectively for the day. Where these elongations were obtained, their mean is taken as the mean declination for the day, without further correction.

† The corrections to reduce to mean declination were derived as follows: Turnavik, July 20. From table of corrections for Toronto (C. and G. S. Report, 1881, App. 8), allowing for difference in *H*. Godhavn and Watson's Bay, August 3. By comparison with three days' observations at Umanak. Umanak, S. and N. meridian, August 21. By direct comparison with principal magnetic station, Umanak. Godhavn, September 11. By comparison with three days' observations at Umanak. Sydney, September 26. From table of corrections for Toronto.

TABLE C.—SUMMARY OF RESULTS OF MAGNETIC DIP OBSERVATIONS.

Station.	Date. 1896.	Epoch. Local mean time.	MAGNETIC DIP.		Mean of two needles.	Difference. No. 1–No. 2.
			Needle No. 1.	Needle No. 2.		
		h. m.	° ′	° ′	° ′	′
1. Halifax	July 6	5 36 P.M.	73 53.2 N.	73 54.9 N.	73 54.0 N	−1.7
2. Sydney. (Sta. 1896.)	July 11	11 50 A.M.	74 40.8	74 40.0	74 40.4	+0.8
Sydney. (Sta. 1896.)	July 13	11 16 A.M.	74 37.2	74 36.4	74 36.8	+0.8
Sydney. (Sta. 1896.)	Mean.	....	74 39.0	74 38.2	74 38.6	....
3. Turnavik	July 20	11 19 A.M.	79 32.9	79 28.8	79 30.8	+4.1
4. Ashe Inlet. . . .	July 26	12 09 P.M.	83 54.0	83 59.6	83 56.8	−5.6
5. Godhavn	Aug. 3	5 14 A.M.	81 47.2	81 46.5	81 46.8	+0.7
7. Umanak	Aug. 14	6 54 P.M.	82 03.2	82 01.7	82 02.4	+1.5
Umanak	Aug. 15	11 16 A.M.	82 04.0	82 00.5	82 02.2	+3.5
Umanak	Aug. 18	9 26 A.M.	81 55.6	81 55.9	81 55.8	−0.3
Umanak	Mean.	....	82 00.9	81 59.4	82 00.1	....
5. Godhavn	Sept. 11	4 34 P.M.	81 40.2	81 41.0	81 40.6	−0.8
10. Niantilik	Sept. 18	10 42 A.M.	83 55.0	83 54.5	83 54.8	+0.5
11. Sydney. (Sta. 1881.)	Sept. 26	4 52 P.M.	74 35.8	74 38.2	74 37.0	−2.4

TABLE D.—SUMMARY OF RESULTS OF HORIZONTAL FORCE OBSERVATIONS.

Station.	Date, 1896.	Epoch. (Local mean time.)	Horizontal magnetic force *H*.	Magnetic moment of magnet 19L. *m* at $16^{\circ}.7$ C.*
		h. m.	Dyne.	
1. Halifax	July 6	4 24 P.M.	0.1631	418.5
Halifax	July 6	4 30 P.M.	0.1633	418.1
Halifax. (Means.) .	.....	......	0.1632	418.3
2. Sydney	July 11	10 25 A.M.	0.1548	416.3
Sydney	July 11	10 32 A.M.	0.1546	416.5
Sydney	July 13	9 48 A.M.	0.1548	416.6
Sydney	July 13	10 08 A.M.	0.1548	416.4
Sydney. (Means.) .	.....	......	0.1547	416.4
3. Turnavik	July 20	10 44 A.M.	0.1074	......
Turnavik	July 20	11 48 A.M.	0.1074	......
Turnavik. (Means.) .	.....	......	0.1074	......
4. Ashe Inlet †	July 26	11 24 A.M.	0.0637 ‡	......
5. Godhavn	Aug. 3	2 58 A.M.	0.0819 ‡	413.6
Godhavn	Aug. 3	3 21 A.M.	0.0819	413.7
Godhavn. (Means.) .	.....	......	0.0819	413.6
7. Umanak	Aug. 14	10 32 A.M.	0.0782	413.1
Umanak	Aug. 14	11 18 A.M.	0.0783 ‡	412.3
Umanak	Aug. 15	9 17 A.M.	0.0783 ‡	411.7
Umanak	Aug. 15	9 32 A.M.	0.0779	410.0
Umanak	Aug. 15	10 14 A.M.	0.0785	411.9
Umanak	Aug. 18	6 35 P.M.	0.0793	410.5
Umanak	Aug. 18	7 13 P.M.	0.0791 ‡	411.5
Umanak	Aug. 18	7 26 P.M.	0.0790	411.1
Umanak (Means.) .	.....	......	0.0786	411.5
5. Godhavn	Sept. 11	3 15 P.M.	0.0825	412.6
10. Niantilik	Sept. 18	6 47 A.M.	0.0653	410.1
Niantilik	Sept. 18	2 57 P.M.	0.0668	......
Niantilik. (Means.) .	.....	......	0.0660	......

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* The magnetic moment of this magnet as determined in December, 1893, soon after the completion of the instrument, and before its use in the field, was 491.3 at $16.^{\circ}7$ C.

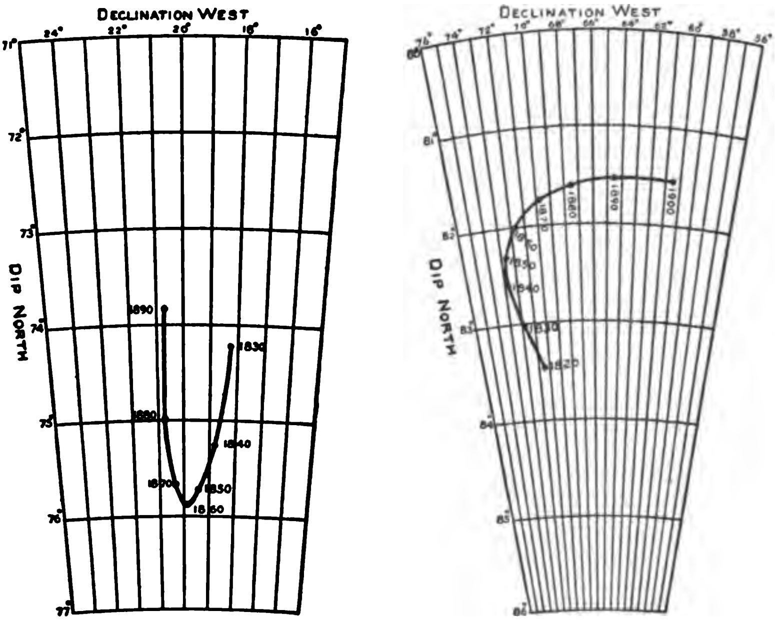
† Only a portion of a set of oscillations was obtained at this station.

‡ In the observations marked thus, the south end of the magnet was weighted with a small balancing ring.

TABLE E. — SUMMARY OF RESULTS OF MAGNETIC OBSERVATIONS.

Station.	Latitude, north.	Longitude west of Greenwich.	No. of days observations.	Date.	Declination.	Diurnal range in declination.	Dip, θ.	Horizontal force, H.	Total force, F.
	° ′	° ′		1896.	° ′	° ′	° ′	Dyne.	Dyne.
9. Umanak, Greenland, N. Meridian . . .	70 40.6	52 08.4	1	Aug. 21.	64 38.0 W.	......	......	.....	.....
8. Umanak, Greenland	70 40.5	52 08.4	3	Aug. 14, 15, 18.	64 11.9	0 57.6	82 00.1 N.	0.0786	0.5649
7. Umanak, Greenland, S. Meridian . . .	70 40.4	52 08.4	1	Aug. 21.	64 45.0	......	......	.....	.....
6. Watson's Bay, Greenland	69 14.6	53 31.7	1	Aug. 3.	63 06.9	......	......	.....	.....
5. Godhavn, Greenland	69 14.1	53 31.2	2	Aug. 3, Sept. 11.	62 57.7	......	81 43.7	0.0822	0.5714
10. Niantilik, Cumberland Sound	64 53.5	66 19.5	1	Sept. 18.	62 52.4	4 34.1	83 54.8	0.0660	0.6224
4. Ashe Inlet, Hudson Strait	62 32.8	70 35.3	1	July 26.	53 35.0	2 11.3	83 56.8	0.0637	0.6040
3. Turnavik, Labrador	55 14.6	59 20.3	1	July 20.	38 26.4	......	79 30.8	0.1074	0.5901
11. Sydney, Cape Breton. (Station 1881.) . .	46 08.6	60 11.7	1	Sept. 26.	24 55.3	......	74 37.0	.....	.....
2. Sydney, Cape Breton. (Station 1896.) . .	46 08.5	60 11.8	2	July 11, 13.	24 53.4	0 12.4	74 38.6	0.1547	0.5842
1. Halifax, Nova Scotia	44 39.5	63 35.0	1	July 6, 7.	20 38.6	0 06.1	73 54.0	0.1632	0.5885

SECTION 8. *Comparison with Earlier Magnetic Observations.* — In Table F is given a collection of former magnetic observations made at or in the vicinity of these stations.[1] For many of these points it is probable that this data is quite incomplete, for results of this nature are published in a wide range of local literature often difficult of access. With the exception of Halifax and Godhavn the observations are scarcely complete enough, nor do they cover a sufficiently long interval of time to give satisfactory analytical expressions for the secular variation of the declination and dip. For most of the stations, however, the data is sufficient to clearly indicate the present tendency in the change of the magnetic elements. It appears that at all these points (omitting Niantilik, for which no earlier information was found)



HALIFAX, NOVA SCOTIA
$\phi = 44° 40' N., \lambda = 63° 35' W.$

GODHAVN, GREENLAND
$\phi = 69° 14' N., \lambda = 53° 31' W.$

FIG. 11B. SECULAR CURVES, REPRESENTING THE MOTION OF THE NORTH END OF A FREELY SUSPENDED MAGNETIC NEEDLE.

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[1] The writer is indebted to Dr. L. A. Bauer, editor of "Terrestrial Magnetism," for information in regard to some earlier observations.

the westerly declination is diminishing, the northerly dip is diminishing, the horizontal force is increasing, and the total force is decreasing.

Analytical expressions for the change of declination and dip for Godhavn and Halifax[1] were derived from the results given in Table F, after applying an estimated correction to the observations at Whalefish Islands to refer them to Godhavn. With these formulas the declination and dip were computed for each tenth year, and the curves shown in Figure 11B plotted, representing the motion of the north end of a freely suspended needle (half length 61 cm. or 24 inches) as viewed by an eye at the center of the needle. This method of representation shows the movements in declination and dip in their proper relation. For both these stations the motion of the needle is in a clockwise direction, thus agreeing with the general law deduced by Dr. L. A. Bauer.[2]

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[1] Mr. Schott has derived the following expression (which was used) for the change of the magnetic declination at Halifax: $D = +\ 16^\circ.18 + 4^\circ.53 \sin (1^\circ.0\ m + 46^\circ.1)$ where D is the declination at a desired time, t expressed in years and fractions of a year (+ for westerly declination), and $m = t - 1850.0$ (Report U. S. C. and G. Survey for 1888, App. No. 7, p. 224). For 1896-7 this formula gives $D = 20^\circ\ 42'$ W., differing only $3'$ from the observed value.

[2] "Beiträge zur Kenntniss des Wesens der Säcular-Variation des Erdmagnetismus," Berlin, 1895; also "On the secular motion of a free magnetic needle," Physical Review, Vol. II, No. 12, Vol. III, No. 13.

TABLE F.—COLLECTION OF MAGNETIC OBSERVATIONS AT OR NEAR STATIONS OCCUPIED IN 1896.

No.	Date.	Declination.	Dip.	Horizontal force.	Total force.	Observer.	Remarks and References.
	Umanak, Greenland. Latitude, 70° 40′ N. Longitude, 52° 08′ W.						
		° ′	° ′	Dyne.	Dyne.		
1	1823–4.	70 50 W.	......	......	......	Graah	Meddelelser om Grönland, 4th Part, p. 282.
2	1878.	67.9	......	......	......	Steenstrup and Hammer.	Meddelelser om Grönland, 4th Part, p. 252. Steenstrup and Hammer give several other observations of declination in this vicinity, as follows: 1879, ½ mile north of Umanak, on ice, 70°.2 W. 1878, Umanak, Little Lookout, 68.6. 1879, Umanak, Little Lookout (mean two obs.), 67.8. 1879, Umanak, on ice (mean three obs.), 69.3.
3	1896, Aug. 14–18.	64 12	82 00 N.	0.0786	0.5649	Putnam	
	Godhavn, Greenland. Latitude 69° 14′ N. Longitude, 53° 31′ W.						
1	1824.5.	70 24	82 54	....	....	Parry	At Whalefish Islands, lat. 68° 59′ N.; long. 53° 18′ W. Phil. Trans. Royal Society, Vol. 90, p. 414.
2	1836.5.	....	82 23	....	....	James Ross	
3	1848.5.	....	82 24	....	....	Ross and Robinson	
4	1850.5.	....	82 12	....	....	Allen	
5	1851.5.	....	....	....	0.5602	Ommanney	
6	1852.5.	70 47	82 10	....	....	Belcher	
7	1853.5.	....	81 48	....	0.5634	Bellot	Phil. Trans., Vol. 90, p. 414.
8	1858.5.	73 28	....	....	....	McClintock	At Whalefish Islands. Phil. Trans. Vol. 90, p. 414.
9	1861, Aug. 31–Sept. 7.	....	81 51	0.0812	0.5731	Radcliff	Station in garden rear of Inspector's house. Hayes' Polar Expedition. Smithsonian Contrib., Vol. 15, p. 105.
10	1875, July 9–13.	67 13	81 48	0.0832	0.5789	"Alert"	Near flagstaff.
11	1875, July 8–12.	68 20	81 52	0.0816	0.5740	"Discovery"	Opposite side of harbor to flagstaff.
12	1876, Sept. 27.	68 20	....	....	....	"Discovery"	Arctic Expedition of 1875–76. Proc. Royal Society, Vol. 29, p. 29. Remark on p. 29: "The values of the declination and inclination observed at various stations around the harbor of Godhavn showed considerable differences, evidently caused by local magnetic disturbance."
13	1884, July 8.	65 35	....	....	....	Sebree	Greely Relief Expedition, Naval Prof. Papers No. 19, p. 94.
14	1896, Aug. 3, Sept. 3.	62 58	81 44	0.0822	0.5714	Putnam	Near Inspector's garden.
15	1896, Aug. 3.	63 07	....	....	....	Putnam	Opposite side of harbor at Watson's Bay.
	Niantilik, Cumberland Sound. Latitude, 64° 54′ N. Longitude, 66° 20′ W. No record found of previous observations.						
	Ashe Inlet, Hudson Strait. Latitude, 62° 33′ N. Longitude, 70° 35′ W.						
1	1884. Aug. 2.	....	84 16	....	....	Gordon	Report of Second Hudson's Bay Expedition, 1885, p. 78.
2	1888.	55 30	....	....	....		British Admiralty chart, No. 1221.
3	1896, July 26.	53 35	83 57	0.0637	0.6040	Putnam	

FIG. 12. MERIDIAN TELESCOPE.

FIG. 13. PENDULUM APPARATUS, GENERAL VIEW.

TABLE F.—COLLECTION OF MAGNETIC OBSERVATIONS AT OR NEAR STATIONS OCCUPIED IN 1896.—*Continued.*

No.	Date.	Declination.	Dip.	Horizontal force.	Total force.	Observer.	Remarks and References.
	Turnavik, Labrador, Latitude, 55° 15′ N. Longitude, 59° 20′ W.						
		° ′	° ′	Dyne.	Dyne.		
1	1881, July 28, 29.	40 23 W.	79 56 N.	0.1034	0.5916	Very	Report U. S. C. and G. Survey, 1881, p. 192.
2	1896, July 20.	38 26	79 31	0.1074	0.5901	Putnam	
	Sydney, Cape Breton. Latitude, 46° 09′ N. Longitude, 60° 12′ W.						
1	1848.5.	23 41	....	....	....	Keely	Position given, latitude 46° 17′, longitude 60° 23′. Phil. Trans. Vol. 90, p. 384.
2	1862.5.	....	76 03	....	....	Shadwell	Position given, latitude 46° 16′, longitude 60° 08′. Phil. Trans. Vol. 90, p. 384.
3	1881, Oct. 21, 22.	25 12	75 10	0.1515	0.5918	Very	Report U. S. C. and G. S., 1881, p. 192.
4	1896, July 11, 13.	24 53	74 39	0.1547	0.5842	Putnam	
5	1896, Sept. 26.	24 55	74 37	....	....	Putnam	At Very's station of 1881.
	Halifax, Nova Scotia. Latitude, 44° 40′ N. Longitude, 63° 35′ W.						
1	1604-1612.	16¾ W.	....	....	....	Champlain	All of the values for Halifax excepting the last one are taken from two papers by Assistant C. A. Schott, Report C. and G. Survey for 1888, App. No. 7, p. 191, and Report C. and G. Survey for 1885, App. No. 6, p. 226. The individual references are there given.
2	1630 about.	14	....	....	....		
3	1700.	13 12½	....	....	....		
4	1750.	12	....	....	....		
5	1756.	12 50	....	....	....		
6	1775.	13 35	....	....	....		
7	1798.	16 30	....	....	....		
8	1818. (?)	17 28	....	....	....		
9	1821, June-Nov.	17 36	....	....	....		
10	1833.	17 30	....	....	....		
11	1834, May 27.	....	75 33	0.1485	0.5966	Home	
12	1837, June 7.	....	74 58			Home	
13	1838.5.	....	74 45	....	....	Estcourt	
14	1847.5.	....	75 37	....	0.6026	Keely	
15	1852-53.	18 10	....	....	....	Bayfield	
16	1852-53.	18 51	....	....	....	Hill	
17	1860, July 22.	19 55	....	....	....	Orlebar	
18	1866, April.	21 06	....	....	....		
19	1873, May 13-16.	21 35	74 48	0.1561	0.5954	Maclear and Bromley	
20	1879, Sept. 8, 10.	20 43	74 39	0.1592	0.6012	Baylor	
21	1881, Nov. 2.	....	74 29	0.1595	0.5962	Very	
22	1896, July 6, 7.	20 39	73 54	0.1632	0.5885	Putnam	

PART III. PENDULUM OBSERVATIONS.

SECTION 9. *Instruments for the Measurement of the Relative Force of Gravity.* — The apparatus belonging to the Coast and Geodetic Survey used for this purpose, was nearly the same as was employed in recent work in the United States, and more particularly in the trans-continental series of observations in 1894. It comprised the following:

Meridian Telescope No. 13 (Figure 12), aperture 5.1 cm.; focal length, 65.8 cm.; magnifying power, 46. This is a very portable combination instrument with folding frame, and is suitable for either time altitude or azimuth observations.

Chronometers Nos. 1,823 (sidereal), 1,842 (mean time), and 177 (mean time). All were provided with electrical break-circuit attachments, for use with the pendulum flash apparatus; also with condensers to prevent sparking.

Pendulum apparatus "*A*" (Figures 13 to 22) comprising three invariable half-second pendulums *A*4, *A*5, and *A*6, one dummy or temperature pendulum, an air-tight brass case, thermometers, manometer, air pump, flash apparatus, dry cells, and weight, pulley and microscope for measuring flexure. There was also a small astronomical observing tent in which the meridian telescope was mounted. At one point a small circular tent was used for the pendulum apparatus.

The essential requisite in pendulum observations for the measurement of the relative force of gravity, is the determination of the period of oscillation as precisely as may be, and also of all the variable conditions that affect that period. Because these conditions can thus be controlled very much better, this apparatus includes an air-tight case in which the pendulums are swung. The pendulums are made of an alloy of copper and aluminum, weighing approximately 1,200 grams each, and having a length of about 248 mm. from center of bob to point of suspension (the three in the set are intentionally slightly different in length). Their shape is such as to give them strength, and small resistance to the air in oscillating. They have an agate plane set in the head which rests on the agate knife-edge on which they are swung. This so-called knife-edge is formed by carefully ground planes meeting at an angle of 130°, thus insuring greater permanency than could be expected with a sharper edge. The knife-edge is set in a solid metal plate (*m* Figure 15) which is secured to the shelf *n* in the pendulum case. As a check in case of injury there are two such knife-edges with this apparatus, marked *I* and *II*, each in its own plate, either of which may be set in the case. Pendulum *A*4 was always swung on knife-edge *II*, and *A*5 and *A*6 on knife-edge *I*, the advantage in using several distinct knife-edges as well as distinct pendulums being that by the relation between the independent results thus obtained, a continual check on the constancy of the instruments is furnished. The pendulum may be lowered on to the knife-edge or lifted from it without opening the case, by means of the screw *q* which presses against the arm *o*. This arm is rigidly attached to the frame *l* which carries two points on its extremity which lift the pendulum off the edge, fitting into corresponding sockets in its head. The pendulum is set in oscillation or brought to rest by the arm *r*, which is controlled by a lever arm on the outside of the case. There is a scale below the pendulum, and a telescope (not shown) mounted on the side of the case for reading the arc of oscillation. The case is supported by three large foot screws resting on heavy foot plates which are to be cemented to the foundation. The case is leveled in the plane of oscillation by the pendulum itself as shown by the reading of the tip of the pendulum on the scale beneath. In the transverse plane it is

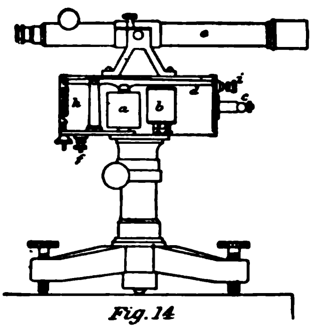


Fig. 14
Flash Apparatus

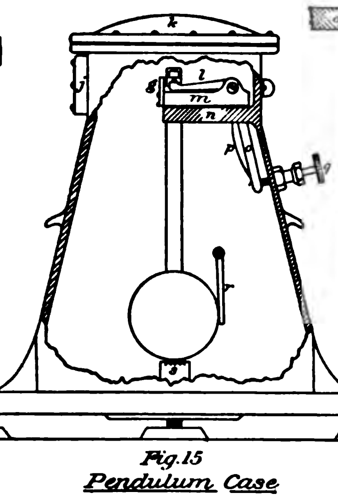


Fig. 15
Pendulum Case

Fig. 16

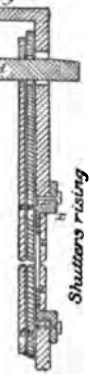
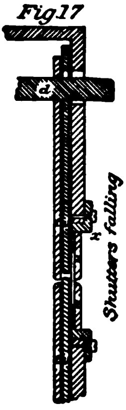


Fig. 17



leveled by a small level mounted in a short pendulum (Figure 20), which may be reversed on the knife-edge. On the opposite side of the case and parallel with the swinging pendulum, there is hung a "dummy" or temperature pendulum (Figure 18), so held that it cannot oscillate. This dummy is of the same material, mass, and general shape as the pendulums, and has mounted on its stem a thermometer whose bulb is buried in the stem near the bob, being packed with metal filings to bring it into close contact, the endeavor being in this way to obtain as near as possible the actual temperature of the swinging pendulum. Near the dummy is also placed a free thermometer and a mercury manometer which shows pressures from 10 cm. down. The case is provided with windows on three sides for observing purposes, and with a removable cover which forms an air-tight joint, with a little oil and tallow rubbed on the carefully ground contact surfaces. The air is exhausted through stop cocks on the side of the case. With the new portable air pump, weighing only about 6 pounds (2.7 kilograms), the pressure in this case may be reduced to the standard (about 6 cm.) in two or three minutes.

The flash apparatus (shown in Figures 13 and 14) is used in observing coincidences between the pendulum and a break-circuit chronometer, from which coincidences the time of oscillation is obtained in terms of the chronometer. The break-circuit chronometer has attachments so that it can be included in an electrical circuit, and is provided with mechanism that will break that circuit at the end of each second (or sometimes each even second). The chronometer is made to throw a flash of light every second by means of the electro-magnet *a*, the armature *d*, and the two shutters carried by the end of this armature and shown in the enlarged sections (Figures 16, 17). When the circuit is broken, the spring *h* causes the armature *d* to rise, and for an instant the slits in the shutters *t* and *v* are in line with the slit in the front of the box *z* (as in Figure 16), and a flash of light is thrown, this light being reflected by the mirror *b* from a lamp mounted on the side of the box; when the circuit is closed the shutters in descending so interfere as to cut off the light (as shown in Figure 17) so that the slit is only illuminated for a brief instant at each break of the circuit. The flash apparatus carries above it a telescope *e*, and is mounted at a convenient distance from the pendulum case in such position that the illuminated slit may be seen in the telescope as reflected from a mirror which is carried on the head of the pendulum,

FIGS. 18–22.

Fig. 18. Dummy or Temperature Pendulum with Thermometer.
Fig. 19. Pendulum and Knife-edge Plate, showing mode of suspension.
Fig. 20. Leveling Pendulum.
Fig. 21. Half-second Pendulum, side view.
Fig. 22. Half-second Pendulum, front view.

and which is seen through the window j in the front of the case. There is also a fixed mirror g attached to the knife-edge plate, but adjustable in position. This is so adjusted that the image of the slit as seen in the telescope, reflected from the fixed mirror, shall be in the same horizontal line and slightly overlapping that reflected from the pendulum mirror when the pendulum is hanging freely at rest. When the pendulum is swinging, the image as reflected from the pendulum mirror will change its position relatively to that of the fixed mirror as seen in the field of the telescope, because of the fact that the pendulum makes a double oscillation in a little more than a sidereal second, and hence will be found slightly behind its former position at the end of each second when the flash is thrown. The moving image will, therefore, appear to travel up and down across the field of the telescope by successive jumps, and coincidences are observed by noting the time when the two images are in the same horizontal line. It is evident that in the interval between two occurrences of this phenomenon the pendulum has made one less than twice as many oscillations as the chronometer has beat seconds, and that in an interval of time between the first and last of a number of coincidences, the number of oscillations of the pendulum will be twice the number of seconds (s) less the number of coincidence intervals (n), so that the time of a single oscillation is readily derived from the relation $P = \frac{s}{2s - n}$. The elegance of the coincidence method lies in the fact that a small error in noting the time of coincidence has little effect on P. At the northern stations the period of the pendulums was so shortened because of the increased force of gravity, that it closely approached the sidereal half second, so that the coincidence intervals would have been inconveniently long. Mean time chronometers were therefore used at these points. The pendulums are faster than the mean time half second, and therefore gain one oscillation in a coincidence interval, and the formula for the period becomes $P = \frac{s}{2s + n}$.

SECTION 10. *Methods of Observation with Pendulum Apparatus.* — The plan proposed to be followed in this work was the same as that used before, to begin the swings of the pendulum immediately after star observations for time were obtained, and to end them after star observations forty-eight hours later, or in case these failed, to continue until time observations were obtained. This plan permitted of the making of six swings each eight hours in length, each of the three pendulums being swung in reversed and direct positions. Unfavorable weather and other conditions, of course, modified this plan; thus at Umanak and at Washington in June the swings were continued for four days because the time observations were lost on intermediate nights, and at Ashe Inlet and Niantilik but three swings covering a single day were made, and no complete time observations were obtained. An example of the observations and computations for a single swing is given in Section 24. The pendulums were swung under as nearly uniform conditions as possible at the various stations. The pressure in the case was reduced to about 60 mm., the total arc of oscillation to commence with was about 53′, falling off to about 20′ at the end of the swing, and the apparatus was mounted on stable foundations, and when practicable in places where the variations of temperature would be small. In general, two chronometers were used, coincidences being noted alternately with each by means of a suitable switch arrangement. Only sufficient coincidences were observed at the beginning and end of the swing, so that the total number which had occurred might be correctly estimated. Intermediate coincidence and temperature observations were made when the variations in conditions were large. Since with the small arcs used the movement of the image from second to second is slow, the times of contact and separation between the moving and fixed images were noted, and the mean taken for the time of coincidence. To eliminate possible errors of adjustment, coincidences were observed with the image moving in opposite directions, "up" and "down," and all results are based on a combination of these. The flexibility of the support was measured statically by noting with an independently supported microscope the movement of a scale mounted above the knife-edge when a horizontal force of 1.5 kilograms was applied in the plane of oscillation of the pendulum. This force was applied by having a weight suspended by a cord running over a pulley, the other end of the cord being attached immediately behind the knife-edge. The movement of the scale in microns was noted when the weight was alternately applied and relieved. The following table gives the support for the pendulum case and the flexure at the various stations, the values for Ashe Inlet and Niantilik being estimated by comparisons with similar conditions elsewhere. The flexure in all cases was quite small, due to the low and solid supports.

Station.	Support.	Flexure microns.
Washington, D. C.	Massive brick pier with capstone	1.0
Sydney, Cape Breton . . .	Low brick and cement pier against foundation wall .	1 5
Ashe Inlet, Hudson Strait .	Bed rock	[1.0]
Umanak, Greenland	Low brick and cement pier on stone floor	2 0
Niantilik, Cumberland Sound,	Bed rock	[1.0]

SECTION 11. *Time Observations and Chronometer Rates.*—The chronometer corrections were determined by star observations with an astronomical transit instrument set in the meridian, the transits across the meridian of about eight stars each evening being observed, half in each position of the instrument. An example of one night's time observations and the computation is given in Section 23. At Washington a large longitude transit was used and the observations recorded on a chronograph. At the northern stations a smaller meridian telescope was employed, and the observations made by the eye and ear method, that is, the beats of the chronometer were noted by ear while the eye followed the movement of the star across the lines of the telescope. The latter instrument was set in the meridian by use of a table giving the azimuth and altitude of Polaris for any hour angle.[1] By setting the telescope at the given altitude and moving it slowly near the supposed position, Polaris could be readily found, even before sunset, and then the angle of its azimuth set off on the horizontal arc provided for that purpose. Of course only one chronometer was used in the time observations, and the comparisons with the others were obtained by noting by ear the coincidences of beats between mean time and sidereal chronometers. This is an accurate and convenient method, such coincidences coming at intervals of a little over three minutes, because of the gain of sidereal on mean time.

As already mentioned, the time observations at Ashe Inlet and Niantilik failed because of unfavorable weather and the limited length of stay. The adopted rates at these points were obtained by combining the rates at the preceding and following stations and the traveling rate, giving equal weight to the chronometers. In each case it is estimated that the adopted rate is uncertain by at least a second of time, which would correspond to an uncertainty of about $\frac{1}{40000}$ in g (or .025 dyne or cm.). As the temperatures at Ashe Inlet and Niantilik were lower than the average, and chronometers usually run slower at low temperatures, it is probable that these adopted rates are too fast, and

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[1] See Appendix 10, Report U. S. C. and G. Survey for 1895.

that consequently the periods of the pendulums are too small, and the resulting force of gravity too large for these two stations.

The rate at Ashe Inlet was derived as follows:

	Chronometers.		
	1823 S. T	1842 M. T.	177 M. T.
	s.	s.	s.
Rate at Sydney, July 10–12	+1.62	—0.24	....
Traveling rate July 16–October 3 (omitting Umanak),	+2.51	+2.17	+3.70
Rate at Umanak, August 7–August 20	+2.29	+1.43	+4.82
Means	+2.14	+1.12	+4.26
Rates of mean time chronometers, derived from above average rate of 1823, and comparisons before and after pendulum observations		+0.80	+4.20
Adopted rates (weighted mean giving half weight to latter values, so as to give equal effect to all three chronometers)		+1.01	+4.24

The rate at Niantilik was derived as follows:

	Chronometers.	
	1833 S. T.	1842 M. T.
	s.	s.
Rate at Umanak, August 7–20	+2.29	+1.43
Traveling rate, July 16–October 3 (omitting Umanak), ...	+2.51	+2.17
Rate at Washington, October 6–15	+1.91	+1.59
Means	+2.24	+1.73
Rate of 1842 derived from above average rate of 1823 and comparisons before and after pendulum observations		+0.82
Mean, adopted rate		+1.28

Table G gives a summary of the rates of the chronometers which were used directly in the pendulum observations at the different stations. In some cases two chronometers were employed, and in others only one. At Sydney one mean time and one sidereal chronometer were used, and at the other three northern stations mean time chronometers exclusively were used in the pendulum observations directly. This became necessary because the increase in the force of gravity so diminished the period of the pendulums that it approached closely to the sidereal half second, and the coincidence intervals with a sidereal chronometer would have become inconveniently long, but the pendulums were enough faster than a mean time chronometer to give convenient coincidence intervals with it. The rates are all referred to sidereal time by adding +236.555 to the mean time rate, as expressed in mean time seconds on mean time, after reducing the latter to sidereal seconds by adding the necessary small correction from Table III of the *American Ephemeris.*

TABLE G.—SUMMARY OF CHRONOMETER RATES.

Station.	Interval.	Daily Rate on Mean Time. (+ losing — gaining.)		Daily Rate on Sidereal Time. (+ losing — gaining.)				
		Chronometer number		Chronometer number.				
		1842	177	1842	177	1824	1823	1829
	1896.	s.	s.	s.	s.	s.	s.	s.
Washington . .	June 22–June 26	....	....	....	....	....	....	+2.95
Sydney	July 10–July 11	—0.29	....	+236.26	....	....	+1.59	....
Sydney	July 11–July 12	—0.18	....	+236.37	....	....	+1.66	....
Ashe Inlet . . .	July 25–July 26	+1.01	+4.24	+237.57	+240.81	....	....	....
Umanak . . .	Aug. 8–Aug. 11	+1.48	+4.81	+238.04	+241.38	....	....	....
Umanak . . .	Aug. 11–Aug. 12	+1.53	+4.88	+238.09	+241.45	....	....	....
Niantilik . . .	Sept. 17–Sept. 18	+1.28	....	+237.84	....	....	....	....
Washington . .	Oct. 15–Oct. 16	....	....	....	....	+0.82	+1.74	....
Washington . .	Oct. 16–Oct. 17	....	....	....	....	+0.67	+1.60	....

SECTION 12. *Reduction of Pendulum Observations.*—The total number of seconds between the first and last coincidences in the swing is divided by the approximate number of seconds in a coincidence interval as given by the first and last coincidences observed. Then reversing the process, the total number of seconds (s) is divided by the total number of coincidence intervals, to obtain the average number of seconds in one interval. The uncorrected period (P) is then obtained from the relations $P = \frac{s}{2s - 1}$ or $P = \frac{s}{2s + 1}$ according as the pendulum is slower or faster than the half seconds of the chronometer, or according as a sidereal or mean time chronometer is used. So as to make them comparable at different stations, the observed periods of the pendulums are next reduced to what they would have been under certain standard conditions. These conditions, which are arbitrarily adopted for convenience, are: arc infinitely small, temperature 15° C., pressure 60 mm. of mercury at 0° C., true sidereal time and inflexible support. The corrections to the observed period in seconds are as follows:

Arc correction $= -\frac{PM}{32}\,\frac{\sin(\phi + \phi')\sin(\phi - \phi')}{\log\sin\phi - \log\sin\phi'}$, where P is period, M is modulus of common logarithmic system, ϕ and ϕ' are initial and final semi-arcs. This is a formula based on theoretical conditions and on the supposition that the arc of oscillation diminishes in geometrical ratio as the time increases in arithmetical ratio. Actual experiment has proved that the dimunition of arc follows this law at least very closely.

Temperature correction $= + 0.00000837\ P\ (15^\circ - T^\circ)$, where P is the period and T the temperature in degrees centigrade. This coefficient was determined experimentally at Washington by swinging the pendulum at different temperatures. The errors of the thermometer used were carefully determined and corrections applied. Where more than two readings were made during a swing, they were weighted according to the intervening intervals.

Pressure correction $= + 0.000000101 \left[60 - \dfrac{Pr}{1 + .00367\ T^\circ}\right]$, where Pr is observed pressure in millimeters, and T° is temperature in degrees centigrade. This coefficient also was determined experimentally. The expression $\dfrac{Pr}{1 + .00367\ T^\circ}$ is simply a reduction of the air pressure to a temperature of 0° centigrade.

Rate correction $= + 0.000011574\ R\ P$, where P is period and R is daily rate on sidereal time in seconds (+ if losing, — if gaining). The coefficient is simply the relation of one second to the number of seconds in a day, or $\frac{1}{86400}$.

Flexure correction $= - 0.00000065\ D$, where D is the observed displacement of the knife-edge in microns when force of 1.5 kilogrammes is applied horizontally in the plane of oscillation. This coefficient also was determined experimentally by swinging the pendulums at Washington on supports of different degrees of flexibility. On a very flexible support the simultaneous movement of the heavy metal case was quite plain in the microscope, even when the pendulum was swinging in a small arc.

The periods, having been thus corrected, were next compared to deduce the relation of the force of gravity at the stations. The theoretical length of these pendulums is unknown, and it cannot be computed or measured with any satisfactory degree of accuracy for pendulums of such form. The pendulums were considered to be of the same length, however, at all stations, after applying the corrections above, and to prove their invariability they were swung at the base station at the Coast and Geodetic Survey Office in Washington, before and after this expedition. From the simple law of the pendulum we have for Washington $P_w = \pi \sqrt{\frac{l}{g_w}}$, and for any other station $P_0 = \pi \sqrt{\frac{l}{g_0}}$, where P is the period, l the length of the corresponding simple pendulum, and g the force of gravity. Squaring and dividing we have $g_0 = \frac{P_w^2}{P_0^2} g_w$. For g_w at Washington the value 980.098 dynes per gramme, force of gravity (= 980.098 centimeters acceleration of gravity, or 32.1554 feet in English measure) has been provisionally adopted. This is based on several absolute determinations, which, however, do not give very accordant results. In fact, relative measurements of gravity can be made with much greater facility and accuracy than absolute determinations, and it is fortunate, therefore, that the uncertainties in the latter have no effect on the value of relative measurements in connection with the question of the figure of the earth, or the condition of the earth's crust. To obtain the corresponding value of g at any other station, it is only necessary to multiply this value of g_w by the ratio of the square of the period at Washington (P_w^2) to the square of the period at the other station (P_0^2). This was done, using the results with each pendulum separately and with the mean of the three pendulums, and taking for Washington the mean of the periods determined before and after the expedition.

SECTION 13. *Results of Pendulum Observations.* — In Table H are given the details of the observations and reductions. For each swing the average number of seconds in one coincidence interval is given, the average temperature corrected for thermometer errors, the pressure reduced to 0° C., the uncorrected period and the various corrections depending on the correction formulas already given. The final corrected periods are those reduced to the standard conditions, as already explained. In Table I are collected the mean corrected periods for each pendulum and station, and the difference of each pendulum from the mean. These differences are a check on the observations and on the constancy of the pendulums, as theoretically they should be almost constant. The small variations that appear are probably in large part due to diurnal irregularities in the chronometer rates. From these mean periods gravity at the various stations was computed from the relation $g_0 = \frac{P_w^2}{P_0^2} g_w$, gravity at Washington, Coast and

TABLE H. — PENDULUM OBSERVATIONS AND REDUCTIONS.

Swing number.	Pendulum.	Position.	Knife-edge.	Date, 1896.	COINCIDENCE INTERVAL.		TOTAL ARC.		Temperature.	Pressure.
					Chronometer.					
					1829.		Initial.	Final.		
		Washington, D. C.								
					s.		′	′	°C.	mm.
1	A4	R	II	June 22.	292.86	....	53	20	22.63	58
11	A4	R	II	June 26.	294.67	....	56	21	21.41	61
2	A4	D	II	June 23.	292.50	....	55	20	22.65	60
12	A4	D	II	June 26.	294.49	....	55	21	21.38	58
3	A5	R	I	June 23.	366.29	....	53	21	22.78	61
10	A5	R	I	June 25.	369.26	....	55	19	21.55	58
4	A5	D	I	June 23.	366.23	....	52	19	22.53	60
9	A5	D	I	June 25.	369.21	....	53	21	21.75	59
5	A6	R	I	June 24.	387.24	....	52	20	22.33	61
8	A6	R	I	June 25.	389.63	....	53	20	21.83	59
6	A6	D	I	June 24.	387.96	....	52	21	22.18	57
7	A6	D	I	June 24.	389.00	....	53	19	21.98	60
		Sydney, Cape Breton.								
					1842 M. T.	1823 S. T.				
1	A4	R	II	July 11.	372.26	365.65	53	20	17.81	60
2	A4	D	II	July 11.	372.06	366.12	55	22	17.75	60
3	A5	R	I	July 11.	296.20	486.06	52	20	17.90	63
4	A5	D	I	July 11.	295.09	490.75	52	20	17.57	62
5	A6	R	I	July 12.	282.95	528.52	52	20	17.50	62
6	A6	D	I	July 12.	283.62	525.17	52	19	18.10	58
		Ashe Inlet, Hudson Strait.								
1	A4	R	II	July 25.	229.49	226.45	53	19	4.71	60
2	A5	R	I	July 26.	198.49	195.57	53	19	4.87	69
3	A6	R	I	July 26.	192.30	189.92	53	19	4.75	62

TABLE H. — PENDULUM OBSERVATIONS AND REDUCTIONS. — *Continued.*

Swing number.	PERIOD UNCORRECTED.		CORRECTIONS. (7th decimal place.)						PERIOD CORRECTED.		
	Chronometer.					Rate.			Chronometer.		
	1829.		Arc.	Temperature.	Pressure.	1829.		Flexure.	1829.		Mean.
	Washington, D. C.										
1	s. .5008551	......	−8	−320	+2	+171	....	−6	s. .5008390	s.	s. ....
11	8498	......	−9	−268	−1	+171	....	−6	8385	....	....
2	8562	......	−9	−321	0	+171	....	−6	8397	....	....
12	8504	......	−9	−267	+2	+171	....	−6	8395	....	....
3	6834	......	−8	−326	−1	+171	....	−6	6664	....	....
10	6779	......	−9	−274	+2	+171	....	−6	6663	....	....
4	6836	......	−8	−316	0	+171	....	−6	6677	....	....
9	6780	......	−8	−283	+1	+171	....	−6	6655	....	....
5	6464	......	−8	−307	−1	+171	....	−6	6313	....	....
8	6424	......	−8	−286	+1	+171	....	−6	6296	....	....
6	6452	......	−8	−301	+3	+171	....	−6	6311	....	....
7	6435	......	−8	−292	0	+171	....	−6	6300	....	....
									.5007121		
	Sydney, Cape Breton.										
1	1842. .4993293	1823. .5006846	−8	−117*	0	1842. +13654	1823. +92	−10	1842. .5006812	1823. .5006802	.5006807
2	3290	6838	−9	−115	0	+13654	+92	−10	6810	6796	6803
3	1574	5149	−8	−121	−3	+13649	+92	−10	5081	5099	5090
4	1543	5099	−8	−107*	−2	+13656	+96	−10	5071	5067	5069
5	1181	4735	−8	−104*	−2	+13655	+96	−10	4711	4706	4708
6	1201	4765	−8	−129*	+2	+13655	+96	−10	4711	4715	4713
									.5005533	.5005531	.5005532
	Ashe Inlet, Hudson Strait.										
1	.4989129	.4988984	−8	+430	0	+13719	+13906	−6	.5003262	.5003304	.5003283
2	7436	7249	−8	+423	−9	+13715	+13902	−6	1551	1551	1551
3	7033	6871	−8	+428	−2	+13714	+13901	−6	1159	1184	1172
									.5001991	.5002012	.5002002

* This correction to be increased by one unit (7th decimal place) for chronometer 1,823.

TABLE H. — PENDULUM OBSERVATIONS AND REDUCTIONS. — *Continued.*

Swing number.	Pendulum.	Position.	Knife-edge.	Date, 1896.	COINCIDENCE INTERVAL.		TOTAL ARC.		Temperature.	Pressure.
					Chronometer.		Initial.	Final.		
					1842 M. T.	177 M. T.				
		Umanak, Greenland.								
					s.	s.	′	′	°C.	mm.
1	A4	R	II	Aug. 9.	209.36	207.07	53	19	10.83	61
7	A4	R	II	Aug. 11.	209.48	206.19	53	21	10.15	64
2	A4	D	II	Aug. 9.	211.47	207.99	53	17	11.71	62
8	A4	D	II	Aug. 11.	210.55	206.49	53	19	10.72	59
3	A5	R	I	Aug. 9.	185.13	182.58	53	20	12.41	62
9	A5	R	I	Aug. 11.	184.77	181.58	53	22	11.73	60
4	A5	D	I	Aug. 10.	184.49	181.85	51	19	11.66	66
10	A5	D	I	Aug. 12.	183.76	180.78	51	20	10.86	57
5	A6	R	I	Aug. 10.	178.54	176.16	52	19	10.70	66
11	A6	R	I	Aug. 12.	178.49	176.29	53	19	10.87	62
6	A6	D	I	Aug. 10.	178.40	176.18	55	23	10.57	58
12	A6	D	I	Aug. 12.	178.85	176.77	53	21	11.62	56
		Niantilik Harbor, Cumberland Sound.								
1	A4	R	II	Sept. 17.	218.61	....	53	21	2.01	63
2	A5	R	I	Sept. 18.	189.09	....	53	30	1.22	64
3	A6	R	I	Sept. 18.	185.33	....	52	31	2.58	62
		Washington, D. C.								
					1823 S. T.	1824 S. T.				
1	A4	R	II	Oct. 15.	299.65	297.69	53	21	16.41	60
2	A4	D	II	Oct. 16.	298.89	297.06	53	21	16.63	59
3	A5	R	I	Oct. 16.	375.33	372.48	53	19	16.93	58
4	A5	D	I	Oct. 16.	376.11	372.95	52	20	16.97	60
5	A6	R	I	Oct. 17.	396.87	393.84	51	19	17.03	60
6	A6	D	I	Oct. 17.	396.02	392.62	53	27	17.15	60

TABLE H. — PENDULUM OBSERVATIONS AND REDUCTIONS. — *Concluded.*

Swing number.	PERIOD UNCORRECTED.		CORRECTIONS. (7th decimal place.)						PERIOD CORRECTED.		
	Chronometer.		Arc.	Temperature.	Pressure.	RATE.		Flexure.	Chronometer.		
	1842.	177.				1842.	177.		1842	177.	Mean.
	Umanak, Greenland.										
	s.	s.							s.	s.	s.
1	.4988087	.4987957	—8	+174	—1	+13743	+13936	—13	.5001982	.5002045	.5002014
7	8094	7904	—8	+203	—4	+13743	+13936	—13	2015	2018	2016
2	8206	8009	—7	+137	—2	+13743	+13936	—13	2064	2060	2062
8	8155	7922	—8	+179	+1	+13743	+13936	—13	2057	2017	2037
3	6532	6345	—8	+108	—2	+13738	+13931	—13	0355	0361	0358
9	6506	6270	—9	+136	0	+13738	+13931	—13	0358	0315	0336
4	6485	6290	—8	+139	—6	+13738	+13931	—13	0335	0333	0334
10	6432	6209	—8	+173	+3	+13741	+13935	—13	0328	0299	0314
5	6037	5849	—8	+180	—6	+13737	+13930	—13	.4999927	.4999932	.4999930
11	6033	5859	—8	+174	—2	+13740	+13934	—13	9924	9944	9934
6	6026	5850	—9	+185	+2	+13737	+13930	—13	9928	9945	9936
12	6061	5897	—8	+141	+4	+13740	+13934	—13	9925	9955	9940
									.5000766	.5000769	.5000768
	Niantilik Harbor, Cumberland Sound.										
1	.4988590	....	— 8	+542	—3	+13734	....	—6	.5002849	....	....
2	6813	....	—11	+575	—4	+13729	....	—6	1096	....	....
3	6547	....	—11	+518	—2	+13728	....	—6	0774	....	....
									.5001573	....	....
	Washington, D. C.										
	1823.	1824.				1823.	1824.		1823.	1824.	
1	.5008357	.5008412	— 8	—59	0	+101	+48	—6	.5008385	.5008387	.5008386
2	8378	8430	— 8	—68	+1	+101	+48	—6	8398	8397	8398
3	6670	6721	— 8	—81	+2	+101	+48	—6	6678	6676	6677
4	6656	6712	— 8	—83	0	+ 93	+39	—6	6652	6654	6653
5	6307	6356	— 8	—85	0	+ 93	+39	—6	6301	6296	6298
6	6321	6376	—11	—90	0	+ 93	+39	—6	6307	6308	6308
									.5007120	.5007120	.5007120

TABLE I. — SUMMARY OF CORRECTED PERIODS.

Station.	Date.	Periods.				Differences from mean. (7th decimal place.)		
		Pendulum A4. Knife-edge II.	Pendulum A5. Knife-edge I.	Pendulum A6. Knife-edge I.	Mean of three pendulums.	A4.	A5.	A6.
	1896.	s.	s.	s.	s.			
Washington . . .	June 22–June 24.	.5008392	.5006665	.5006305	.5007121	+1271	−456	−816
Sydney	July 11–July 12.	06805	5080	4710	05532	+1273	−452	−822
Ashe Inlet	July 25–July 26.	03283	1551	1172	02002	+1281	−451	−830
Umanak	Aug. 9–Aug. 12.	02032	0336	.4999935	00768	+1264	−432	−833
Niantilik	Sept. 17–Sept. 18.	02849	1096	.5000774	01573	+1276	−477	−799
Washington . . .	Oct. 15–Oct. 17.	08392	6665	6303	07120	+1272	−455	−817

TABLE J. — VALUES OF g COMPUTED FROM EACH PENDULUM.

Station.	g in dynes or centimeters.				Differences from mean. (3d decimal place.)		
	Pendulum A4.	Pendulum A5.	Pendulum A6.	Mean of three pendulums.	A4.	A5.	A6.
Washington. (C. and G. S.)	....	....	....	[980.098]			
Sydney	980.720	980.719	980.722	980.720	0	∓1	−2
Ashe Inlet	982.101	982.104	982.110	982.105	+4	+1	−5
Umanak	982.592	982.581	982.597	982.590	−2	+9	−7
Niantilik	982.271	982.282	982.267	982.273	+2	−9	+6

TABLE K. — SUMMARY OF GRAVITY RESULTS WITH REDUCTION TO SEA LEVEL, AND COMPARISON WITH THEORETICAL FORMULA.
(RESULTS FOR g EXPRESSED IN DYNES OR CENTIMETERS.)

Number.	Station.	Latitude. (North.)	Longitude. (West of Greenwich.)	Elevation. H.	Surface density. δ	g observed.	REDUCTION TO SEA LEVEL.			g REDUCED TO SEA LEVEL.		Theoretical value computed, g_0.	RESIDUALS.	
							Elevation $2g\frac{H}{r}$.	Attraction $2g\frac{H\,3\delta}{r\,4\Delta}$.	Topographical correction.	Bouguer's formula, g_1.	Attraction term omitted, g_2.		$g_1 - g_0$.	$g_2 - g_0$.
		° ′ ″	° ′ ″	Meters.										
1	Washington, D.C. (C. & G.S.)	38 53 13	77 00 32	14	2.3	[980.098]	+.004	—.001	.000	980.101	980.102	980.087	+.014	+.015
2	Sydney, Cape Breton . . .	46 08 32	60 11 47	11	2.35	980.720	+.003	—.001	.000	980.722	980.723	980.732	—.010	—.009
3	Ashe Inlet, Hudson Strait . .	62 32 48	70 35 20	15	2.6	982.105*	+.005	—.002	+.001	982.109	982.111	982.104	+.005	+.007
4	Umanak, Greenland	70 40 29	52 08 21	10	2.6	982.590	+.003	—.001	+.002	982.594	982.595	982.632	—.038	—.037
5	Niantilik, Cumberland Sound .	64 53 [30]	66 19 32	7	2.6	982.273*	+.002	—.001	+.001	982.275	982.276	982.271	+.004	+.005

* Approximate results only.

Geodetic Survey Office (g_w) being taken to be 980.098 dynes or centimeters, as already explained. The results for g computed separately for each pendulum and station, with the mean and differences from the mean, are given in Table J. At Ashe Inlet and Niantilik the results can only be considered as approximate because of the failure to obtain sufficient time observations, as referred to under the head of chronometer rates. In Table K is given a general summary of the results, with geographical positions and elevations of stations, estimated surface densities,[1] reduction to sea level, and comparison with a theoretical formula. The reduction to sea level is given by two different methods following the plan adopted in the last report of the International Geodetic Association,[2] first using Bouguer's formula, and second, omitting the attraction term in this formula. Bouguer's formula is $dg = + \frac{2gH}{r}\left(1 - \frac{3\delta}{4\Delta}\right)$, where dg is the correction to observed gravity, g is gravity at sea level, H is elevation above sea level, r is radius of the earth, δ is density of the matter lying above sea level, and Δ is mean density of the earth. The first term takes account of the distance from the earth's center, and the second term of the vertical attraction of the matter lying between the sea level and station, on the supposition that the latter is located on an indefinitely extended horizontal plain. Wherever the topography about a station departs materially from this condition of a horizontal plain, a third term must be added to the above formula, being a correction to the second term or to observed gravity on account of such irregularities. This is called the topographical correction, and will always be positive, as the effect of all deviations from the horizontal plain, whether hills or mountains rising above the station, or valleys or canyons lying below it, will be to diminish the force of gravity.[3] This correction is not important at any of these stations, but has been approximately

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[1] These estimates of the average density or specific gravity of the masses above sea level underlying the respective stations have been furnished by Mr. G. K. Gilbert, of the U. S. Geological Survey. The character of the rocks is as follows: Sydney, sandstone, shale; Ashe Inlet, gneiss; Umanak, gneiss; Niantilik, gneiss; Washington, sand and clay.

[2] "Bericht über die relativen Messungen der Schwerkraft mit Pendelapparaten, von Professor Helmert," Verhandlungen der elften Conferenz der Internationalen Erdmessung, Berlin, 1895.

[3] For formulas for this correction see Report U. S. Coast and Geodetic Survey for 1894. App. 1, pages 22 and 23.

estimated from the very scanty knowledge of the surrounding topography for those stations where it is thought to be appreciable.

Although the attraction of the mass above sea level at any station must be a real quantity, yet the omission of this correction, the second term of Bouguer's formula, has been advocated on the basis of certain theories of the condition of the earth's crust, as for instance, that it is in a state analogous to hydrostatic equilibrium, and hence that all elevations are compensated by deficiencies in density beneath, and the results of the pendulum observations themselves have in general, though not in particular, tended to confirm this position. This question will be referred to again. Various other methods of reduction have been proposed. As has been remarked by Professor Helmert, the reduction to sea level will also depend on the application to be made of the results. If they are to be used in connection with the problem of the figure of the earth, the normal force of gravity at the sea level will be required; if, however, it is desired to study the irregularities in density below sea level, it seems quite proper that the real attraction of the mass above sea level as represented by the second term of Bouguer's formula should be subtracted. These different methods of reduction need not be considered as necessarily conflicting, therefore, as might appear at first sight.

The values reduced to sea level in Table K are next compared with an assumed theoretical formula $g = 978.066\ (1 + .005243 \sin^2 \text{latitude})$ which is based on Clairaut's theorem, Clarke's figure of the earth (1880), and the assumption that gravity is normal on the eastern coast of the United States; the values of g by this formula being computed for the latitude of each of the stations.[1] Such comparisons are useful in showing the differences between the observed results and those based upon values for the flattening of the earth derived from other sources, and to develop the local anomalies in the force of gravity. The results of this season can be added to the constantly accumulating store of information to be used in future discussions of pen-

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[1] The most generally used theoretical formula for the variation of the force of gravity with latitude is that derived by Professor Helmert from an elaborate discussion of pendulum observations in various parts of the world, $g = 978.000\ (1 + .005310 \sin^2 \text{latitude})$ centimeters, which corresponds to the value $\frac{1}{299.3}$ for the flattening of the earth. "Die mathematischen und physikalischen Theorien der höheren Godäsie," Vol. II, p. 241. This discussion was made in 1884, and is based on pendulum observations at 122 stations, which is but a small proportion of the data that is now available.

dulum observations either with respect to the figure of the earth or otherwise. Their principal value will be in their combination with results in other parts of the world.

The possibility of an interesting application of pendulum observations suggested itself to the writer in connection with future exploration in Greenland. The remarkable ice cap covering this great island rises to an elevation of about 10,000 feet (3,000 meters), but what proportion of this elevation is ice and what land, is an unsolved and most interesting problem. It is very probable that a comparison of pendulum observations on the bare coast with others on the ice cap would throw considerable light on the subject, although it might not settle the question definitely.

SECTION 14. *Comparison of Periods at Washington.* — The constancy of the periods of pendulums being a most important matter in connection with the use of those of the so-called invariable type in relative measurements of the force of gravity, it is of interest to compare the periods of these three pendulums as given by various determinations at the base station at Washington during the past three years. Table L gives the corrected periods at Washington resulting from ten determinations from April, 1894, to October, 1896. The values for 1894 differ slightly from those previously published, because in order to render them strictly comparable with the later results, a correction of $^s.0000013$ was subtracted from the period of $A4$ to allow for the fact that it was swung on a different knife-edge, and a correction of $^s.0000003$ was added to the periods of all three pendulums to allow for improved values in the thermometer corrections. The total range in the mean period of the three pendulums for these ten determinations is only $^s.0000008$, and the means for the separate years differ by only $^s.0000001$. When it is considered that these pendulums during this interval of two and one-half years have been swung at fifty stations (including Washington) and have been transported many thousand miles by rail and ship, the permanency of period is certainly satisfactory.

TABLE L. — Summary of Periods at Washington.

Number.	Date.	Approximate average temperature.	Corrected Periods.				Differences from Mean. (7th decimal place.)		
			Pendulum A4.	Pendulum A5.	Pendulum A6.	Mean of three pendulums.	A4.	A5.	A6.
	1894.	°C.	s.	s.	s.	s.			
1	Apr. 25–Apr. 27.	16	.5008396	.5006665	.5006303	.5007122	1274	457	819
2	May 10–May 12.	19	8394	6669	6307	7123	1271	454	816
3	May 31–June 2.	17	8398	6667	6305	7123	1275	456	818
4	June 23–June 25.	23	8398	6665	6305	7123	1275	458	818
5	Oct. 31–Nov. 2.	17	8390	6659	6309	7120	1270	461	811
					Mean for 1894.	7122			
	1895.								
6	Jan. 11–Jan. 13.	11	8396	6681	6298	7125	1271	444	827
7	Aug. 2-Aug. 4.	21	8380	6662	6310	7117	1263	455	807
					Mean for 1895.	7121			
	1896.								
8	Jan. 21-Jan. 23.	11	8383	6668	6315	7122	1261	454	807
9	June 22–June 24.	22	8392	6665	6305	7121	1271	456	816
10	Oct. 15–Oct. 17.	17	8392	6665	6303	7120	1272	455	817
					Mean for 1896.	7121			

Section 15. *Notes on the Historical Development of Pendulum Apparatus.*[1] — The laws of the motion of a pendulum were first announced by Galileo in 1629. It is a disputed question as to whom belongs the honor of the discovery of isochronism, that important property of the pendulum by which it oscillates in different small arcs in nearly equal times, though tradition attributes this to Galileo, who is said at the age of twenty to have noticed the isochronism in the swinging of a chandelier in a church at Florence. This property appears to have been known as early as 1589, which epoch may be taken as the beginning of the history of the pendulum. In 1641, a year before his death, Galileo had conceived the idea of the applica-

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[1] The historical data in this and the following section are taken largely from "Collection de Mémoires relatifs a la Physique publiés par la Société Francaise de Physique, Tome IV, Mémoires sur le Pendule" (Introduction Historique, C. Wolf); also "Account of the Operations of the Great Trigonometrical Survey of India," Vol. V, "The Pendulum Operations" (Appendix, "Notes for a history of the use of invariable pendulums"); also Verhandlungen der siebenten Conferenz der Europaischen Gradmessung," Rome, 1883, "Rapport sur la détermination de la pesantéur a l'aide de différents appareils, par M. Theodore von Oppolzer."

tion of the pendulum to clocks for time-keeping purposes, but he did not develop nor publish it. The Dutch philosopher Huyghens made known and patented a pendulum clock in 1657, and thus appears to be entitled to the honor of the first practical application of the pendulum for this purpose. Huyghens also did much towards developing the mathematical theory of the pendulum. In 1644 Mersenne made the first determination of the length of the seconds pendulum. The effect of changes of temperature on the period of a pendulum was noted by Picard in 1669, and the resistance of the air to the motion was first studied by Newton in 1686. In 1735 Mairan first employed the method of coincidences in determining the period of a pendulum, noting the times when the clock and pendulum were together at the extremity of the arc instead of when they pass through the vertical together, as was the later method. The correction to pendulum observations on account of loss of weight because of being in air, was first applied by Bouguer in 1749, to whom also is due the reduction to sea level known by his name. Boscovich, in 1785, first proposed the second atmospheric correction due to the retardation of the pendulum because of the air dragged with it, and also gave the theory of the ball and wire pendulum, but made no application of it. In response to the request of the Commission of Weights and Measures, Borda in 1792, at the Observatory of Paris, made elaborate observations with the ball and wire pendulum, introducing all the improvements that had been suggested up to that time. The Academy of Sciences had decided that the length of the pendulum beating seconds at Paris should be determined at the same time with the other measurements necessary to the establishment of the metric system. In 1792 Prony proposed a rigid pendulum with three parallel axes in same plane as center of gravity of the pendulum. In 1798 he proposed the pendulum now known as the reversible, but did not construct one. In 1817, without knowledge of Prony's work, Captain Kater, charged by the Committee of Weights and Measures of the Royal Society of London to measure the length of the seconds pendulum, developed his method and constructed the pendulum known by his name, a reversible pendulum with movable weights, and hence called convertible. The theory of the reduction to a vacuum, and of the effect of air on a pendulum, has been studied elaborately by Bessel, Buat, Poisson, and Stokes. Laplace in 1816 first called attention to the influence that the form of the knife-edge would have on the true length of the pendulum. On account of the complicated atmospheric effects, and the uncertainty of the knife-edge, Bessel concluded that it was impossible to accurately measure the length of the seconds pendulum by means of the simple ball and wire. Because of its lack of symmetry Kater's pendulum also failed to eliminate the atmospheric effects. In 1827 Bessel elaborated the conditions necessary for the reversible pendulum, the most important being the external symmetry of the two ends of the pendulum, but an instrument following these ideas was employed for the first time by Plantamour in 1866, as constructed by Repsold. Various modifications of this type of pendulum have been widely used since that time, more particularly in absolute measurements of the force of gravity. In his well-known experiments at Königsberg in 1826, Bessel first introduced a differential method in determining the length of the seconds pendulum; a ball and wire pendulum was used, the length of the wire being varied by an amount exactly equal to a standard toise. Only the difference of the length of the two pendulums was required, and the differential method was supposed to eliminate many of the constant errors in the effect of the suspension and otherwise. Although this source of error had previously been suspected, Peirce in 1875 first proved that the time of oscillation of a pendulum was affected by the flexibility of its support, and he investigated this question both experimentally and mathematically. About 1887, Defforges introduced in the "Service Geographique" of France a differential method of determining the absolute force of gravity, using two symmetrical reversible pendulums of the same weight but of different lengths, with interchangeable knife-edges.

The variation of the rate of clocks, when transported from place to place, early suggested the use of the invariable pendulum to measure the relation of the force of gravity at different points. The first instrument designed for this purpose seems to have been that of Graham, a celebrated clock maker of London, who in 1731 used an invariable pendulum connected with wheel work arranged to register the number of oscillations. This was rated in London and in the island of Jamaica. This instrument was used by Sabine as late as 1820, although it was unsatisfactory on account of the variable effect of the wheel work on the pendulum. Bouguer and LaCondamine used an entirely free invariable pendulum of such mass that it would oscillate an entire day, on the expedition of 1735 to 1743 to measure the Peruvian arc. Malaspina, on a Spanish expedition from 1789 to

1794, employed a pendulum having a wooden rod, steel knife-edge and copper lenticular bob. About 1817 Kater constructed an invariable pendulum which he used at various stations of the Ordnance Survey in England. Many copies of this pendulum were made, some of which were employed at wide intervals of time and up to a very recent date. They are simple in design, consisting of a flat brass bar over five feet in length, having a large flat circular brass bob and a hard steel knife-edge. A radical change in invariable pendulums was introduced in 1882, when Von Sterneck employed a half second pendulum in Austria, together with an elegant electrical arrangement for observing coincidences between a clock or chronometer and a pendulum. When it is considered that a half second pendulum is only about one-fourth the length of a seconds pendulum (which was previously the almost universal length) and that the older methods of observing coincidences could not be used with a chronometer, the important effect of this step on the facility of gravity research may be realized. In 1890 a form of half second pendulum apparatus, differing in important respects from that of Von Sterneck, was designed by Mendenhall, who also in 1894 designed a quarter second pendulum apparatus, the most portable instruments of the kind yet constructed, the air-tight case in which the pendulums are swung being only 17 cm. (6.7 inches) high. A pendulum which is called "reversible inversible" was designed by Defforges and first used in 1890. It is a symmetrical reversible pendulum about a half meter in length and is provided with interchangeable knife-edges and weights.

SECTION 16. *Notes on the Progress of Research in Terrestrial Gravity Measurements.* — To obtain some instrument with which the force of gravity could be more conveniently and simply measured than with the pendulum, has been a problem that has long engaged the attention of physicists, and was considered of sufficient importance for the appointment of a special committee by the British Association for the Advancement of Science a few years ago. Various devices depending principally on the compressibility of gases, and the elasticity of metals, have been proposed from time to time, but nothing has yet been found to give sufficiently reliable results. Pendulums as they have been used in gravimetric research may be divided into three general classes: the ball and wire, the reversible and the invariable. The ideal simple pendulum to which the law $t = \pi \sqrt{\frac{l}{g}}$ applies consists of a weight concentrated at a single point and suspended from its center of oscillation by a weightless thread. The nearest approach to this possible in practice is the ball and wire pendulum, which in early days was much used, but which was an instrument only suited for laboratory experiments, and even then was subject to serious difficulties in eliminating various sources of error. With this instrument the moments of inertia of the various parts must be considered in computing the length of the pendulum. The reversible pendulum, which has been very generally used in modern absolute measurements of the force of gravity, depends on the principle that in any compound or material pendulum swung from a point which may be called the center of suspension, there is a reciprocal point situated on a line passing through the center of gravity, called the center of oscillation, about which the period of the pendulum will be the same if it is reversed; and further, that the period of the compound pendulum will be the same as that of a simple pendulum of length equal to the distance between the center of suspension and the center of oscillation, and known as the equivalent simple pendulum. This principle was first applied by Kater in his convertible pendulum, an unsymmetrical pendulum with movable weights, so that the center of gravity could be shifted until the condition of equal periods about the two knife-edges was obtained. Following Bessel's idea, the reversible pendulum as used in recent years has had a symmetrical form and fixed center of gravity, but with one end heavy and the other light. It is so designed that the periods of oscillation shall be approximately equal about the two knife-edges. When this condition is reached, the period of the equivalent simple pendulum is given by the relation $T^2 = \frac{h t^2 - h' t'^2}{h - h'}$, where t and t' are the times of oscillation about the knife-edges, whose distances from the center of gravity are respectively h and h'; g may be determined from this relation (remembering that $h + h'$ is the length of the equivalent simple pendulum whose period is T) when the periods in the two positions are ascertained, and the distance between knife-edges, and the approximate distance from each knife-edge to the center of gravity. The determination of the absolute force of gravity is an operation of more importance to physics in general than to geodesy. Nevertheless, in order to be able to express results in absolute measure, a number of such determinations have been made in connection with geodetic operations. The following table (M) gives some of the more important determinations made either in this connection or otherwise, with results referred to Washington by means of relative connections that have been made.[1] Some of these results are now principally interesting from an historical point of view. Even the determinations apparently the most reliable do not show a satisfactory accordance.

TABLE M. — ABSOLUTE DETERMINATIONS OF THE FORCE OF GRAVITY, WITH RESULTS REDUCED TO WASHINGTON, C. AND G. S. OFFICE (NOT REDUCED TO SEA LEVEL).

Number.	Observer.	Date.	Place of determination.	Apparatus.	Results reduced to Washington, Coast and Geodetic Survey Office.	
					Length sec. pendulum.	Gravity.
					cm.	Dynes or cm.
1	Borda . .	1792.	Paris . . .	Ball and wire	99.3102	980.153
2	Kater . .	1817.	London . .	Kater convertible pendulum	.3236	.285
3	Bessel . .	1826–27.	Königsberg,	Ball and wire, 2 lengths, differential .	.3021	.072
4	Sabine . .	1829.	Greenwich .	Kater convertible pendulum	.3005	.056
5	Plantamour,	1865–71.	Geneva . .	Bessel reversible pendulum	.3028	.079
6	Peirce . .	1876.	Paris . . .	Bessel reversible pendulum	.3109	.159
7	Von Orff .	1877.	Munich . .	Repsold reversible pendulum	.3088	.138
8	Mendenhall,	1880.	Tokio . .	Ball and wire	.3114	.164
9	Oppolzer .	1884.	Vienna . .	Repsold reversible pendulum	.3085	.135
10	Lorenzoni .	1886.	Padua . .	Repsold reversible pendulum	.3007	.058
11	Defforges .	1893.	Washington,	Two reversible pendulums, differential,	.3115	.165

In the study of the variations of gravity over the earth's surface, with which geodesy and terrestrial physics are principally concerned, the invariable pendulum has been largely used and appears to be the most convenient form on account of its greater simplicity both in its construction and manipulation. The development of this instrument and its various types has already been referred to. Reversible pendulums have also been used to a considerable extent in this connection, and even the ball and wire pendulum was so employed in the earlier work. The first experimental proof of the variations of gravity with latitude was furnished by the famous observation of Richer, who in 1672 measured the length of a seconds pendulum at Cayenne near the equator, and found that it was $1\frac{1}{4}$ line (= 2.8 mm.), or about the $\frac{1}{350}$th part shorter there than at Paris. Many astronomers attributed

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[1] For a more complete list see App. No. 1, Report U. S. C. and G. Survey for 1894, p. 48.

this difference simply to the effect of the warmer climate on the iron standard of length, but its reality was soon confirmed by observations made in other parts of the world under the auspices of the French Academy, as well as by the theories of Newton, published in 1687, as to the flattening of the earth at the poles. In 1743 Clairaut published his famous theorem establishing a relation between the force of gravity and the flattening of the earth, which may be stated as follows: $\frac{a-b}{a} = \frac{5}{2}\frac{c}{g_e} - \frac{g_p - g_e}{g_e}$ where a and b are the equatorial and polar semi-diameters of the earth, g_p and g_e are the polar and equatorial forces of gravity, and c is the centrifugal force at the equator.[1] "In his demonstration, Clairaut makes no assumption of original fluidity; he supposes the strata to be concentric and coaxal spheroidal shells, the density varying from stratum to stratum in any manner whatever; it is assumed however that the superficial stratum has the same form as if it were fluid, and in relative equilibrium when rotating with uniform angular velocity. Professor Stokes in his demonstration of Clairaut's Theorem, in two papers published in 1849, showed that if the surface be a spheroid of equilibrium of small ellipticity, Clairaut's Theorem follows independently of the adoption of the hypothesis of original fluidity or even of that of any internal arrangement in nearly spherical strata of uniform density."[2] In the early part of this century a number of expeditions were sent out partly or wholly for the purpose of making pendulum observations, among the more important of which may be noted those of Kater, 1818–19; Sabine, 1819–24; Foster, 1828–31; Lütke, 1826–29; Freycinct, 1817–20; Duperrey, 1822–25, and Biot and Mathieu, 1808–24. With the methods then in use, however, but a comparatively small number of points could be determined, and these were almost entirely confined to the sea coast. The subject was then almost entirely neglected until 1864, when, in connection with the Great Trigonometrical Survey of India, an extensive series of pendulum observations, without precedent up to that time, was undertaken and carried out, yielding most interesting results. Since that time this subject has been taken up by various countries engaged in geodetic operations, and has been included in the scope of the investigations of the International Geodetic Association. In the reports of this Association the results are systematic-

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[1] A more rigid expression for this formula is given by Helmert, Geodäsie, Vol. II, p. 83.

[2] Clarke's Geodesy, p. 82.

ally collected and published from time to time. Professor Helmert's elaborate report on the subject at the meeting of the Association in Berlin, in 1895, included 968 such measurements, more than a third of which, however, were in a single country (Austria).

The flattening of the earth cannot be computed from Clairaut's Theorem directly, because thus far it has been impracticable to measure the force of gravity at the poles. But it has been demonstrated that the increase of gravity from the equator to the poles will be as the square of the sine of the latitude, or $g_0 = g_e \left(1 + \frac{g_e - g_p}{g_e} \sin^2 \phi_0 \right)$ where g_0 is gravity at any latitude ϕ_0, g_e at the equator and g_p at the poles. With this expression g_e and g_p may be derived from determinations of g made at two or more different latitudes. Substituting in Clairaut's Theorem, the amount of the flattening can then be computed. As material has accumulated from time to time, a number of such deductions have been made by combining all available pendulum observations. Some of these are as follows:

From a table by Professor Harkness, Report C. and G. Survey for 1893, Part II, p. 250.

Date.	Authority.	Flattening $= \frac{a-b}{a}$.
1799.	Laplace.	335.8
1825.	Sabine.	289.1
1830.	Airy.	282.8
1834.	Baily.	285.3
1880.	Clarke.	292.2
1884.	Helmert.	299.3

The two most important values of the flattening of the earth derived from the entirely independent method of arc measurements, are those of Bessel (1841) $\frac{1}{299.2}$, and Clarke (1880) $\frac{1}{293.5}$. The pendulum observations, of course, furnish information only as to the ratio of the axes and not as to their absolute lengths, which are furnished by arc measurements. The flattening as deduced by either method is subject to uncertainties because of the irregularities in the earth's surface, both in density and shape and the necessary confinement of measurements to land areas, but the pendulum observations have the advantage of the possibility of extension to regions that can never be reached by triangulation.

Early in the discussion of pendulum observations it became apparent that the force of gravity over the earth's surface did not always follow Clairaut's law when the reduction to sea level was made by Bouguer's formula, or the attraction of the mass above sea level was subtracted. As early as 1830 Airy pointed out the fact that gravity seemed to be greater on oceanic islands than on continents in corresponding latitudes, and the accumulation of later data has clearly brought out the fact that with Bouguer's reduction there is apparently an excess of gravity of about $\frac{1}{1000}$th part on oceanic islands as compared with continental coasts, and a defect of similar amount beneath elevated continental masses. Two causes might lead to such a condition : first, the sea level may be distorted, raised above the mean figure of the earth under continents, and lowered below in ocean centers, and thus points at sea level under continents would be at a greater distance from the earth's center than at oceanic islands ; or second, the earth's crust may be less dense below continents than under the oceans. On the theory that the crust of the earth is in a condition analogous to hydrostatic equilibrium, which was first proposed by Airy in 1855, it has been computed that the distortion of the sea level would not be over about 10 feet (3 meters). This theory appears to be the favorite one, and based on it the differences between normal and observed gravity, using Bouguer's reduction, have been taken as a measure of the excess or deficiency in density beneath the sea level. In discussions of the figure of the earth from pendulum observations various methods have been proposed of eliminating these local peculiarities. Thus it has been proposed in the reduction to sea level to omit the correction for the attraction of the mass above sea level, for the reason that on the equilibrium theory that mass must be compensated by a deficiency of density beneath. This would not help matters much in the case of oceanic island observations, however, where the stations are often close to sea level. Faye in 1880 suggested that while in general the equilibrium condition might be true, it could scarcely apply to limited areas on the earth's surface ; as, for instance, that a large plateau might be supported in a condition of equilibrium, whereas a mountain on that plateau would be supported by the partial rigidity of the crust, and he therefore proposed that in the reduction of pendulum observations to sea level the attraction of average areas should be considered as probably compensated by deficiency or excess of density beneath, but that the local departures from that average area should be allowed for. A rough application of this idea to a number of observations made in this country in 1894, and in other parts of the world previously, showed that the results gave far greater accordance on this supposition than on any other. A striking illustration of this was Pike's Peak, which is a comparatively isolated mountain rising about 2,450 meters above a plateau whose elevation is about 1,840 meters above sea level. When the attraction of the entire mass above sea level was subtracted, the observed force of gravity appeared to be about $\frac{1}{4000}$th part below normal, but when no correction for this attraction was applied, gravity appeared about the same amount above normal. When, however, only the attraction of the peak itself as it stood above the average elevation of the country was allowed for, the result appears quite normal. The result obtained at the celebrated station Moré in the Indian series, at an elevation of 15,408 feet (4,696 meters) in the Himalayan mountains, is not discordant with this idea. Here it was found that the defect of gravity with Bouguer's reduction to sea level was closely equal to the correction for the attraction of the mass above sea level, but Moré is situated in a valley and is shown to have been nearly at the average elevation of the surrounding region.

The connection between variations in the force of gravity and deflections of the plumb line was brought out in an interesting manner in the Indian series. As the triangulation approached the Himalayas the deflection towards this mountain mass was found to be less than had been estimated, a fact that was explained when the pendulum observations indicated a deficiency of density beneath. Quite recently such a relation has been brought out in a striking manner by a series of gravity measurements made along a meridian line in Germany, at points where the plumb line deflections had been obtained by a comparison of astronomical latitude observations with geodetically determined positions. In Professor Helmert's discussion of this work, he shows that plumb line deflections, in a region where they would not be accounted for by the apparent surface conditions, have a distinct relation to irregularities in density beneath, as developed by the pendulum.[1]

Another application of pendulum gravity measurements has been in the determination of the mean density of the earth. By comparing the measured force of gravity at the ordinary surface with that at the summit of a mountain or the bottom of a mine, it is possible to compute the ratio of the mean density of the earth to the density of the

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[1] "Ergebnisse von Messungen der Intensität der Schwerkraft auf der Linie Kolberg-Schneekoppe, von F. R. Helmert." Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin. XVIII. 1896.

mountain or the mass between the bottom and top of the mine, which latter may be estimated from determinations of the specific gravity of surface specimens. Because of various practical difficulties this method cannot compete with refined laboratory methods of recent times, and is likely to prove more valuable when reversed, that is, in the investigation of the mean densities of mountains. Some of the determinations made by pendulum observations are as follows:

Date.	Observer.	Place.	Mean density of the earth.
1821.	Carlini.	Mount Cenis, Alps.	4.95
1854.	Airy.	Harton Pit (mine), England.	6.56
1880.	Mendenhall.	Fujiyama, Japan.	5.77
1883.	Von Sterneck.	Pribram (mine), Bohemia.	5.77
1892.	Preston.	Mauna Kea, Hawaiian Islands.	5.13
1894.	Putnam.	Pike's Peak, United States.	5.63

PART IV. EXAMPLES OF OBSERVATIONS.

SECTION 17. *Latitude Observations at Umanak, Greenland.*— These observations were made by Talcott's method[1] with meridian telescope No. 13, used as a zenith telescope. The method depends on the micrometric measurement of the difference of zenith distance of two stars crossing the meridian at nearly equal distances, one north and one south of the zenith, and at a short interval of time. It is evident that the mean of the declinations of two stars which crossed the meridian at exactly equal zenith distances north and south, would be the latitude of the place, and with this method it is only necessary to determine a correction to the mean declinations to allow for the fact that the zenith distances are not exactly equal. The strong point of the method lies in the fact that it is free from circle readings, depending only on the micrometer, a delicate level, and the computed declinations of the stars.

For this latitude only three pairs of stars (as given below) were observed on two nights. The right ascensions and declinations given are the mean places for 1896.0, computed from the Greenwich (1880), Safford's, and the Pulkowa catalogues. The second star in each of these pairs was observed at lower culmination.

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[1] For explanations of this method and of the instruments used, see Report U. S. C. and G. Survey for 1880, App. 14; also Chauvenet's Astronomy, Vol. II, p. 340; also Doolittle's Practical Astronomy, p. 478.

STAR NUMBER. B. A. C. catalogue.	Magnitude.	Right ascension.			Declination.			Approximate zenith distance for setting telescope.	
		h.	m.	s.	°	′	″	°	′
7143	5.1	20	34	00.03	+23	45	03.47	46	55 S.
2982	5.6	8	44	48.35	+62	21	03.52	46	58 N.
7258	6.5	20	50	41.29	+13	19	29.48	57	21 S.
3106	4.4	9	01	32.17	+52	01	26.91	57	18 N.
7402	5.6	21	14	34.37	+43	30	29.28	27	10 S.
3199	4.6	9	22	15.38	+81	47	09.14	27	32 N.

The apparent declinations of the stars for the date of observation were computed by the independent star numbers, by the formula (see American Ephemeris, Part II), $\delta = \delta_0 + \tau \mu' + g \cos (G + a_0) + h \cos (H + a_0) \sin \delta_0 + i \cos \delta_0$, where a_0, δ_0 are the star's mean right ascension and declination at the beginning of the year, τ is the fraction of a year from January 1, μ' is the annual proper motion in declination, and g, G, h, H, and i are factors given in the Ephemeris for each day in the year.

The formula for the latitude, when the observations are made in the meridian, is: $\phi = \frac{1}{2} (\delta + \delta') + \frac{1}{2} (M - M') R + \frac{b}{4} [(n + n') - (s + s')] + \frac{1}{2} (r - r')$ where δ and δ' are the declinations and M and M' the micrometer readings of the south and north stars respectively, R the value in arc of one division of the micrometer, n and s the north and south readings of the level for the south star, and n' and s' the same for the north star, b the value in arc of one division of the level, and r and r' the refraction corrections for the south and north stars. The value of one division of the latitude level was 2″.23 ($= b$). The value of one turn (100 divisions) of the micrometer was determined at Umanak on August 12, 1896, by observing Polaris near eastern elongation, setting the micrometer thread at each even turn, and noting the time of transit of Polaris;[1] giving the result 1 turn = 79″.647. Table N gives a summary of the observations and reductions. The resulting value for the latitude of the meridian telescope is 70° 40′ 29″.2 N., from which the latitude of the magnetic station (12 meters south) is 70° 40′ 28″.8 N., and of the flagstaff (50 meters south) is 70° 40′ 27″.6 N.

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[1] For explanation and example, see Report C. and G. Survey for 1880, App. 14, pages 51 and 58.

TABLE N.—LATITUDE OBSERVATIONS AT UMANAK.

Date.	CATALOGUE. B. A. C.		MICROMETER.		LEVEL.			Declination.	Sum and Half Sum.	CORRECTIONS.			Latitude.
	Star No.	N. S.	Reading.	Diff. Z. D.	N.	S.	Diff. N—S.			Microm.	Level.	Refr.	
			t. d.	t. d.				° ′ ″	° ′ ″	′ ″	″	″	° ″
Aug. 11, 1896.	7143 2982	S N	20 90.5 23 36.5	— 2 46.0	5.0 8.6	7.9 4.5	+1.2	23 45 14.72 117 39 00.64	141 24 15.36 70 42 07.68	— 1 37.97	+0.67	—.06	70 40 30.32
Aug. 12, 1896.	7143 2982	S N	20 60.5 23 06.5	— 2 46.0	4.9 8.4	8.4 4.9	0.0	23 45 14 95 117 39 00.89	141 24 15.84 70 42 07.92	— 1 37.97	0.00	—.06	29.89
Aug. 11, 1896.	7258 3106	S N	21 22.3 19 16.4	+ 2 05.9	3.4 9.1	9.8 4.1	—1.4	13 19 41.54 127 58 36.28	141 18 17 82 70 39 08.91	+ 1 22.00	—0.78	+.08	30.21
Aug. 12, 1896.	7258 3106	S N	21 81.0 19 76.8	+ 2 04.2	4.3 7.1	9.0 6.1	—3.7	13 19 41.72 127 58 36.50	141 18 18.22 70 39 09.11	+ 1 21.32	—2.07	+.08	28.44
Aug. 11, 1896.	7402 3199	S N	12 38.0 29 44.8	—17 06.8	2.9 10.9	10.5 2.5	+0.8	43 30 40.92 98 12 56.91	141 43 37.83 70 51 48.92	—11 19.72	+0.45	—.25	29.40
Aug. 12, 1896.	7402 3199	S N	12 83.5 29 94.3	—17 10.8	4.3 8.7	9.1 4.8	—0.9	43 30 41.23 98 12 57.25	141 43 38.48 70 51 49.24	—11 21.31	—0 50	—.25	27.18
												Mean.	70 40 29.24

SECTION 18. *Example of Computation of Longitudes from Chronometer 1823 (sidereal).*

Station.	Date. (Civil local.)	Epoch Greenwich sidereal time.	Observed corrections on local sidereal time.	Corrections on Greenwich sidereal time.	Average rate per day on sidereal time. (+ losing.)	Corrections on Greenwich sidereal time computed from traveling rate.	Longitude west of Greenwich.
	1896.	h. m.	h. m. s.	s.	s.	m. s.	h. m. s.
Sydney †	July 10.	22 36	—4 00 52.30	—05.23	....	....	......
Sydney	July 11.	21 08	—4 00 50.81	—03.74	+1.62	....	......
Sydney	July 12.	21 08	—4 00 49.15	—02.08	....	....	......
Sydney	July 16.*	12 00	....	[+03.78]	....	....	......
Turnavik	July 20.	13 43	—3 57 08.20	......	....	+0 14.0	3 57 22.2
Ashe Inlet	July 25.	24 01	—4 41 54.90	......	....	+0 27.6	4 42 22.5
Godhavn	Aug. 3.	8 08	—3 33 16.20	......	....	+0 48.6	3 34 04.8
Umanak	Aug. 5.*	12 00	[—3 27 40.04]	......	....	+0 54.0	3 28 34.0
Umanak	Aug. 7.	24 48	—3 27 34.25	......	....	....	......
Umanak	Aug. 8.	24 31	—3 27 31.64	......	....	....	......
Umanak	Aug. 11.	23 23	—3 27 25.65	......	+2.29	....	......
Umanak	Aug. 12.	23 23	—3 27 23.30	......	....	....	......
Umanak	Aug. 20.	23 16	—3 27 04.65	......	....	....	......
Umanak	Sept. 9.*	24 00	[—3 26 18.78]	......	....	+2 15.3	3 28 34.1
Niantilik	Sept. 18.	16 40	—4 22 40.5	......	....	+2 37.1	4 25 17.6
Sydney	Sept. 26.	4 36	—3 57 46.8	......	....	+2 56.0	4 00 42.8
Washington (C. and G. S.),†	Oct. 3.*	12 00	....	[+3 14.28]	....	....	......
Washington	Oct. 6.	1 40	—5 04 41.04	+3 21.10	....	....	......
Washington	Oct. 15.	4 45	—5 04 23.19	+3 38.95	+1.91	....	. ....
Washington	Oct. 16.	5 22	—5 04 21.40	+3 40.74		....	......
Washington	Oct. 17.	2 14	—5 04 20.01	+3 42.13	....	....	......

The traveling rate used in the above is deduced as follows:

		h.	m. s.
Correction at Washington on Greenwich sidereal time . .	October 3, at	12.0	+3 14.28
Correction at Sydney on Greenwich sidereal time	July 16, at	12.0	+0 03.78
Loss in	79.0 days		+3 10.50
Loss at Umanak in	35.5 days		+1 21.26
Traveling on ship,	43.5 days		+1 49.24
Traveling rate per day			+ 2.51

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* These are dates of arrival and departure (on which no time observations were made), and the chronometer correction is carried out to these dates for each station by using the average rate at that station.

† The adopted longitude of the transit at Sydney was 4 h. 00 m. 47.07 s., and at Washington 5 h. 08 m. 02.14 s.

SECTION 19. *Example of Observations of Sun for Azimuth of Mark and for Time, with Computations.* — Niantilik, Cumberland Sound, September 18, 1896, P.M. Instrument, Theodolite Magnetometer, No. 19.

Object.	Position of instrument.	Time. Chronometer, 1842.	Horizontal Circle.			Vertical Circle.		
			A.	B.	Mean.	A.	B.	Mean.
		h. m. s.	° ′	′	′	° ′	′	′
Azimuth mark	D	......	53 58	59	58.5	....	..	....
	R	......	233 55	55	55.0	....	..	....
Means	....	......	53	..	56.8	....	..	...
Sun's first and upper limb . . .	R	7 39 20	229 46	44	45.0	17 17	18	17.5
	....	40 40	230 05	03	04.0	11	13	12.0
	....	41 34	19	16	17.5	06	09	07.5
Sun's second and lower limb . .	D	42 58	51 16	17	16.5	73 33	33	33.0
	....	44 04	33	33	33.0	39	39	39.0
	....	45 33	54	55	54.5	46	47	46.5
Means	....	7 42 21.5	50	..	48.4	16	..	46.4
Sun's second and lower limb . .	D	7 46 34	52 09	09	09.0	73 50	51	50.5
	....	47 33	23	24	23.5	55	57	56.0
	....	48 31	38	38	38.0	74 02	03	02.5
Sun's first and upper limb . . .	R	51 04	232 38	36	37.0	16 16	17	16.5
	....	52 05	52	50	51.0	11	13	12.0
	....	53 21	233 12	09	10.5	03	07	05.0
Means	....	7 49 51.3	52	..	38.2	16	..	07.4
Azimuth mark	R	......	233 56	55	55.5	....	..	...
	D	......	53 58	58	58.0	....	..	...
Means	....	......	53	..	56.8	....	..	...

Computation of Azimuth of Mark.

Formula, $\tan^2 \frac{1}{2} A = \frac{\sin (s-\phi) \sin (s-h)}{\cos s \cos (s-p)}$

where A = azimuth from north.
ϕ = latitude.
h = corrected altitude.
p = polar distance.
$s = \frac{1}{2}(\phi + h + p)$.

Date, 1896.	Sept. 18. P. M.	Sept. 18. P. M.
	h. m. s.	h. m. s.
Chronometer time	7 42 21.5	7 49 51.3
Correction to 1842 on G. M. T.	+2 09.8	+2 09.8
Greenwich mean time	7 44 31.3	7 52 01.1
Sun's apparent declination	1° 26′.9	1° 26′.8
Sun's north polar dist. = p	88° 33′.1	88° 33′.2
h observed	16° 46′.4	16° 07′.4
Correction for parallax	+0′.1	+0′.1
Correction for refraction	—3.1	—3.3
h corrected	16 43.4	16 04.2
p	88 33.1	88 33.2
ϕ	64 53.5	64 53.5
$\frac{1}{2}(h + p + \phi) = s$	85 05.0	84 45.4
$s - \phi$	20 11.5	19 51.9
$s - h$	68 21.6	68 41.2
$s - p$	—3 28.1	—3 47.8
Log sin $(s - \phi)$	9.53802	9.53124
Log sin $(s - h)$	9.96826	9.96923
Log numerator	9.50628	9.50047
Log cos s	8.93301	8.96090
Log cos $(s - p)$	9.99920	9.99904
Log denominator	8.93221	8.95994
Log $\tan^2 \frac{1}{2} A$	0.57407	0.54053
Log tan $\frac{1}{2} A$	0.28704	0.27026
$\frac{1}{2} A$	62° 41.4′	61° 46.6′
A	125 22.8	123 33.2
Horiontal circle reads	50 48.4	52 38.2
True meridian reads	176 11.2	176 11.4
Azimuth mark reads	53 56.8	53 56.8
Mark west of north	122 14.4	122 14.6

Computation of Chronometer Correction.

Formula, $\tan \frac{1}{2} t = \cot \frac{1}{2} A \frac{\sin (s-h)}{\cos (s-p)}$

where t = hour angle of sun.

Date, 1896.	Sept. 18. P. M.	Sept. 18. P. M.
Log cot $\frac{1}{2} A$	9.71296	9.72974
Log sin $(s - h)$	9.96826	9.96923
Log numerator	9.68122	9.69897
Log cos $(s - p)$	9.99920	9.99904
Log tan $\frac{1}{2} t$	9.68202	9.69993
$\frac{1}{2} t$	25° 40′.9	26° 37′.0
t	51° 21′.8	53° 14′.0
	h. m. s.	h. m. s.
t in time	3 25 27.2	3 32 56.0
Equation of time	—6 14.7	—6 14.8
Local mean time	3 19 12.5	3 26 41.2
1842 reads	7 42 21.5	7 49 51.3
Correction on local $m. t.$	—4 23 09.0	—4 23 10.1

SECTION 20. *Example of Observations of Magnetic Declination.* Station, Sydney, Nova Scotia. Date, July 11, 1896. Instrument, Magnetometer 19. Magnet 19L suspended, scale erect. Line of detorsion, 330°.

Local time. A. M.	SCALE READINGS. Left.	SCALE READINGS. Right.	Mean.	
				Azimuth circle, A. 11° 04′. B. 191° 04′.5.
h. m.	d.	d.	d.	
7 10	38.8	49.1	43.95	
15	42.2	45.9	44.05	
40	42.3	46.9	44.60	East elongation.
57	39.0	47.5	43.25	
8 17	39.0	46.3	42.65	
56	35.2	48.4	41.80	
P. M.	Line of detorsion, 280°.			Azimuth circle, A. 10° 58′. B. 190° 59′.
12 35	32.4	41.0	36.70	
12 45	30.6	40.1	35.35	
1 25	24.8	44.1	34.45	West elongation.
35	28.3	41.7	35.00	
48	28.1	43.8	35.95	

READINGS OF AZIMUTH MARK.

At beginning of A. M. observations . . .	262°	47′
At end of A.M. observations	262	47.5
At beginning of P.M. observations . . .	262	41
At end of P.M. observations	262	41.2
Mean	262°	44′.2

DETERMINATION OF AXIS OF MAGNET.
(Magnet observed alternately erect and inverted.)

Scale.	Scale Readings.		Mean.	Alternate Mean.	Axis.
	d.	d.	d.	d.	d.
E	40.3	45.1	42.70	....	....
I	35.2	23.0	29.10	42.70	35.90
E	33.5	51.9	42.70	29.00	35.85
I	38.8	19.0	28.90	42.52	35.71
E	34.7	50.0	42.35	28.72	35.54
I	29.8	27.3	28.55	42.12	35.34
E	35.8	48.0	41.90	....	....
				Mean	35.67

Mean scale reading of east and west magnetic elongation				39.52
Reduction to axis	°	+07′.7	= difference =	3.85
Azimuth circle reads	11	01.4		
Magnetic south meridian reads	11	09.1		
Magnetic north meridian reads	191	09.1		
Mean reading of mark	262	44.2		
Azimuth of mark E. of N.	46	43.7		
True meridian reads	216	00.5		
Magnetic declination	24	51.4	W. of N.	

SECTION 21. *Example of Observations of Magnetic Dip.* Station, Sydney, Nova Scotia. Date, July 11, 1896. Dip Circle, No. 4,655. Needle No. 2.

POLARITY OF MARKED END B NORTH.

CIRCLE EAST.				CIRCLE WEST.			
Face East.		Face West.		Face East.		Face West.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
73 59 61	73 61 60	74 02 01	74 04 04	75 35 31	75 29 24	75 31 29	75 28 26
73 60.0	73 60.5	74 01.5	74 04.0	75 33.0	75 26.5	75 30.0	75 27.0
73 60.2		74 02.8		75 29.8		75 28.5	
	74 01.5				75 29.2		

Mean, 74° 45′.4.

POLARITY OF MARKED END B SOUTH.

CIRCLE WEST.				CIRCLE EAST.			
Face West.		Face East.		Face West.		Face East.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
74 57 58	74 52 50	75 34 33	75 31 31	73 41 40	73 38 39	74 10 18	74 09 15
74 57.5	74 51.0	75 33.5	75 31.0	73 40.5	73 38.5	74 14.0	74 12.0
74 54.2		75 32.2		73 39.5		74 13.0	
	75 13.2				73 56.2		

Mean, 74° 34′.7.

Resulting Dip, 74° 40′.0.

	h. m.
Local time of beginning	11 28 A.M.
Local time of ending	11 55 A.M.
Magnetic meridian reads	61° 16′

DETERMINATION OF MAGNETIC MERIDIAN.
Circle in magnetic prime vertical.

	° ′
Circle N, Needle N.	57 43
Circle N, Needle S.	58 12
Circle S, Needle N.	64 47
Circle S, Needle S.	64 23
Mean	61 16

The above scheme of observation comprises a complete system of reversals of the position of the needle, the position of the circle, and the polarity of the ends of the needle, with the idea of eliminating all sources of error due to the form and magnetism of the needle, etc.

SECTION 22. *Example of Observations and Computation of Horizontal Intensity of Earth's Magnetism.* — The method used depends on the determination of two relations between the horizontal intensity (H) and the magnetic moment (m) of the principal magnet used. By using this magnet to deflect another magnet suspended in the earth's field, the relation $\frac{m}{H}$ is obtained, and by oscillating the principal magnet the product $m\,H$ is determined, and by combining these two results m and H are found. The observations and reductions required are shown in the following forms, together with the formulas used.

DEFLECTIONS WITH THEODOLITE MAGNETOMETER.

Date, July 11, 1896. Station, Sydney, Nova Scotia. Instrument, Magnetometer 19. Magnet 19L, deflecting at right angles to Magnet 19*s* suspended. Deflecting distance $r = 49$ cm.

Magnet.	North end.	Circle Readings.				Circle Readings.			
		No.	A	B	Mean.	No.	A	B	Mean.
			° ′	′	′		° ′	′	′
East.	E.	1	193 35.5	34	34.75	....	....	....	....
	W.		....	....	....	2	188 17	16	16.50
	E.	3	37	35	36.00	....	....	....	....
	Mean.		193		35.38		188		16.50
West.	W.	...	....	..	....	6	188 23.5	22	22.75
	E.	7	193 30	28	29.00	..	....	..	....
	W.	...	....	..	....	8	23.5	21	22.25
	Mean.		193		29.00		188		22.50

Computation : $\frac{m}{H} = \frac{1}{2}\, r^3 \sin u \left(1 - \frac{P}{r^2} \ldots . \right)$

	°	′
Magnet East, $2u$ =	5	18.88
Magnet West, $2u$ =	5	06.50
Mean	5	12.69
u =	2	36.34

	h.	m. A.M.		°C.
Time of beginning . .	10	30	Temperature . . .	17.2
Time of ending . . .	10	43	Temperature . . .	23.5
Mean	10	36	t = ...	20.4

	Logarithms.
$\frac{1}{2}$	9.69897
r^3	5.07112
Sin u	8.65763
$1 - \frac{P}{r^2}$	0.00076
$1 + \frac{2\,km}{r^3}$	0.00004
$\frac{m}{H}$	3.42852

P is the so-called distribution coefficient.

$1 + \frac{2\,km}{r^3}$ is the induction correction.

OBSERVATIONS OF OSCILLATIONS.

Date, July 11, 1896. Station, Sydney, Nova Scotia. Instrument, Magnometer 19. Magnet, 19L. Chronometer, 1823 (sidereal) daily rate $235\overset{s}{.}0$ gaining on mean time.

Number of oscillations.		Chronometer time.			Temperature t'.	Extreme scale readings.		Time of 100 oscillations.	
		h.	m.	s.	°C.			m.	s.
Right . . .	0	9	28	52.3	23.7	22.9	37.2	....	
	10		29	44.6	....	....	....	....	
	20		30	37.2	....	....	....	....	
Left	31		31	34.7	....	....	....	....	
	41		32	27.0	....	....	....	....	
	51		33	19.4	....	....	....	....	
Right . . .	100	9	37	36.6	....	....	....	8	44.3
	110		38	29.0	....	....	....		44.4
	120		39	21.1	....	....	....		43.9
Left	131		40	19.0	....	....	....		44.3
	141		41	11.5	....	....	....		44.5
	151		42	03.7	18.2	24.9	34.1		44.3
(10 h. 14 m. A.M.) Means.					21.0	24.	36.	8	44.28

Determination of coefficient of torsion. Value of one scale div'n = 2'.0.

Torsion circle.	Scale.		Mean.	Differences.		Logarithms.
330	24.9	34.1	29.50		$v = 3'.4$	
				1.50	$5400' + v'$	3.73267
60	24.0	38.0	31.00			
				3.50	5400 (ar. co.)	6.26761
240	23.0	32.0	27.50			
				1.75	$1 + \frac{h'}{f}$	0.00028
330	22.5	36.0	29.25			
			Mean v =	1.69		

COMPUTATION.

$$T^2 = T'^2 \left(1 + \frac{k'}{f}\right) \left(1 - (t' - t)\,q\right) (1 + k\,H)$$

where the quantities in the parentheses are respectively the torsion, temperature, and induction corrections, and T is the corrected time of oscillation.

		s.
Observed time of 100 oscillations	=	524.28
Time of one oscillation	=	5.2428
Correction for rate	= —	.0143
Correction for arc	=	.0000
	$T' =$	5.2285

q	.00049
$t' - t$	$21.0 - 20.4 = + 0.6$
$(t' - t)\,q$	$+ .00029$
$1 - (t' - t)\,q$	0.99971

$$m\,H = \frac{\pi^2 M}{T^2}$$

where m = magnetic moment of magnet

H = horizontal force of earth's magnetism

M = moment of inertia of magnet

T = time of oscillation.

$m = 415.2$ (at 22.2 °C.)

$H = 0.1548$

	Logarithms.
T'	0.71838
T'^2	1.43676
$1 + \frac{k'}{f}$	0.00028
$1 - (t' - t)\,q$	9.99987
$1 + k\,H$	0.00084
T^2	1.43775
(ar. co.) T^2	8.56225
π^2	0.99430
M	2.25145
$m\,H$	1.80800
m	2.61826
H	9.18974

Observations of deflections, { Date, July 11. Hour, 10 h. 36 m. A.M.
Temperature $t = 22°.2$C.

	$\frac{m}{H}$	3.42852
	$m\,H$	1.80800
	m^2	5.23652
	m	2.61826

SECTION 23. *Example of Time Observations in Connection with Pendulum Work.* — In Table P is given an example of one night's time observations at Umanak, using the star list given in Table O. The transits of eight stars (four in each position of the telescope) across the meridian were observed by the eye and ear method, noting the time of passage across each of five lines. The value of one division of the striding level of meridian telescope No. 13 (used in these observations) was $1''.68 = 0^s.112$. To obtain the level error (b) of the instrument, one-fourth this amount (or $0^s.028$) is to be multiplied into the sum of the readings west end of level minus sum of readings of east end. In this form the means of the times are taken for each star, and the diurnal aberration (K) and level (Bb) corrections are applied, and compared with the apparent right ascensions of the stars as taken from the Berliner Jahrbuch or the American Ephemeris. The resulting values, $a - t$, are the chronometer corrections not yet free from the collimation (c) and azimuth (a) errors of the instrument. In Table Q is shown the computation of these errors and the derivation of the final chronometer correction by the field method of time computation.[1] The three stars of small declination (time stars) of each group are combined and treated as one star by taking the means of their $a - t$, C and A respectively. A first approximation to c is found by dividing the difference between the $a - t$ for the two groups of time stars (positions E and W) by the difference of the mean C. Applying then the collimation correction ($-Cc$), the quantities $a - t - Cc$ result. The azimuth errors (a_e and a_w) are next derived by dividing the difference between $a - t - Cc$ for time stars, and azimuth stars by the difference in A, treating each position of the instrument separately. The azimuth corrections (Aa) are next applied, and if the resulting values $a - t - Cc - Aa$ differ for the two positions it indicates that the first value of c may be improved. The difference may be regarded as the effect of collimation error, and treated as before to obtain a correction to c. With improved values of c, a_e and a_w this method may be continued until the chronometer corrections in the two positions of the instrument agree. In general where the stars for observation are conveniently chosen, the first approximation will be sufficient, as it would be in this example. When satisfactory val-

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[1] **This field method of reducing time observations is more fully explained in App. No. 9, Report C. and G. Survey for 1896 (not yet published).**

ues of c, a_e and a_w are obtained, the corrections Cc and Aa are applied to each star separately, and the chronometer corrections ($\triangle T$) and residuals (ν) derived. The mean of the former is taken as the final chronometer correction at the epoch of the mean of the right ascensions.

TABLE O. — STAR LIST FOR OBSERVING, AND STAR FACTORS FOR COMPUTATION, FOR UMANAK, GREENLAND. Latitude, (ϕ) = 70° 40′ N.

Star.	Magnitude.	Right ascension α.	Declination δ.	Zenith distance $\zeta = \phi - \delta$.	STAR FACTORS.			Correction for diurnal aberration $.0206 \cos \phi \sec \delta = K$.
					Azimuth $\sin(\phi - \delta) \sec \delta = A$.	Collimation $\sec \delta = C$.	Level $\cos(\phi - \delta) \sec \delta = B$.	
		h. m. s.	° ′	° ′				s.
ε Cygni	2.6	20 42 04	33 35	+37 05	+ .72	1.20	.95	−.01
76 Draco.	6.0	50 11	82 09	−11 29	−1.46	7.32	7.17	−.05
υ Cygni	4.0	53 21	40 46	+29 54	+ .66	1.32	1.15	−.01
61 Cygni pr.	5.7	21 02 17	38 14	+32 26	+ .68	1.28	1.07	−.01
ζ Cygni	3.0	08 34	29 48	+40 52	+ .76	1.15	.87	−.01
τ Cygni	4.0	10 42	37 36	+33 04	+ .69	1.27	1.06	−.01
α Cephei	2.6	16 09	62 09	+ 8 31	+ .32	2.14	2.12	−.01
1 H. Draco. (Sub-polar).	4.5	22 16	98 13	−27 33	+3.24	−7.00	−6.20	+.05

TABLE P. — STAR OBSERVATIONS FOR TIME AT UMANAK, August 8, 1896.

Star.	ε Cygni.	76 Draco.	ν Cygni.	61 Cygni pr.	ζ Cygni.	τ Cygni.	α Cephei.	1 H. Draco.
Position of instrument.	E.	E.	E.	E.	W.	W.	W.	W.
Level readings. Direction of objective.	N. W. end. E. end.	S. W. end. E. end.	N. W. end. E. end.	Mean N. +1.25	S. W. end. E. end.	S. W. end. E. end.	N. W. end. E. end.	Mean N. +0.30
Level in first position.	Div. 8.3 Div. 16.0	Div. 16.9 Div. 7.7	Div. 8.1 Div. 16.1	Mean S. +0.90 Mean +1.08	Div. 7.8 Div. 16.9	Div. 8.3 Div. 16.0	Div. 16.4 Div. 7.9	Mean S. +0.35 Mean +0.32
Level reversed . . .	16.9 7.9	8.0 16.3	16.9 7.7	s. +1.08 × 0.28	16.5 8.0	16.8 7.8	8.0 16 2	
Sums	25.2 23.9	24.9 24.0	25.0 23.8		24.3 24.9	25.1 23.8	24.4 24.1	s. +0.32 × 0.28
Σ W − Σ E . . .	+1.3	+0.9	+1.2	s. = +.030 = b_e	−0.6	+1.3	+0.3	= +.009 b_w
Transit observations . .	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.
Line 5	0 09 01.6	0 16 51.0	0 20 15.7	0 29 13.6	0 35 33.2	0 37 37.8	0 42 41.5	0 48 57.0
Line 4	18.0	17 17.5	33.7	31.0	49.3	55.6	43 11.0	49 21.5
Line 3	34.5	42.0	52.1	48.6	36 05.0	38 13.0	40.8	44.5
Line 2	51.4	18 07.0	21 10.5	30 06.5	21.2	30.5	44 10.5	50 09.5
Line 1	10 07.9	33.0	28.6	24.3	37.1	48.0	40.4	34.0
Means	0 09 34.68	0 17 42.10	2 20 52.12	0 29 48.80	0 36 05.16	0 38 12.98	0 43 40.84	0 49 45.30
Diur. aber. corr. = K . .	−.01	−.05	−.01	−.01	−.01	−.01	−.01	+.05
Level correction = Bb . .	+.03	+.22	+.03	+.03	+.01	+.01	+.02	−.06
Time partly corrected = t	0 09 34.70	0 17 42.27	0 20 52.14	0 29 48.82	0 36 05.16	0 38 12.98	0 43 40.85	0 49 45.29
Right ascension = a	20 42 03.53	20 50 10.54	20 53 21.01	21 02 17.45	21 08 33.95	21 10 41.71	21 16 09.10	21 22 16.12
$a - t$	− 3 27 31.17	− 3 27 31.73	− 3 27 31.13	− 3 27 31.37	− 3 27 31.21	− 3 27 31.27	− 3 27 31.75	− 3 27 29.17

TABLE Q.—COMPUTATION OF CHRONOMETER CORRECTION FROM STAR OBSERVATIONS AT UMANAK, August 8, 1896.

Star.	Position.	$a-t$	C	A	Cc	Aa	ΔT	v	
		h. m. s.			s.	s.	s.	s.	
ϵ Cygni	E.	−3 27 31.17	−1.20	+ .72	+.09	+ .33	−31.59	− .05	Final chronometer correction at 21 h. 03 m. (local sidereal time). h. m. s. ΔT = − 3 27 31.64
76 Draco.	E.	31.73	−7.32	−1.46	+.58	− .67	−31.64	.00	
ν Cygni	E.	31.13	−1.32	+ .66	+.10	+ .30	−31.53	− .11	
61 Cygni pr.	E.	31.37	−1.28	+ .68	+.10	+ .31	−31.78	+ .14	
ζ Cygni	W.	31.21	+1.15	+ .76	−.09	+ .45	−31.57	− .07	
τ Cygni	W.	31.27	+1.27	+ .69	−.10	+ .41	−31.58	− .06	
α Cephei	W.	31.75	+2.14	+ .32	−.17	+ .19	−31.77	+ .13	
1 H. Draco	W.	29.17	−7.00	+3.24	+.55	+ 1.92	−31.64	.00	
First approximation		$a-t$	C	A	Cc	$a-t-Cc$	Aa'	$a-t-Cc-Aa$	
Mean of time stars	E.	− 31.22	−1.27	+ .69	+.09	−31.31	+ .30	−31.61	s. $c = -.068$ $a_E = +.428$ $a_W = +.627$
Azimuth star	E.	− 31.73	−7.32	−1.46	+.50	−32.23	− .62	−31.61	
Mean of time stars	W.	− 31.41	+1.52	+ .59	−.10	−31.31	+ .37	−31.68	
Azimuth star	W.	− 29.17	−7.00	+3.24	+.48	−29.65	+ 2.03	−31.68	
Final approximation									
Mean of time stars	E.	− 31.22	−1.27	+ .69	+.10	−31.32	+ .32	−31.64	s. $c = -.079$. $a_E = +.460$ $a_W = +.593$
Azimuth star	E.	− 31.73	−7.32	−1.46	+.58	−32.31	− .67	−31.64	
Mean of time stars	W.	− 31.41	+1.52	+ .59	−.12	−31.29	+ .35	−31.64	
Azimuth star	W.	− 29.17	−7.00	+3.24	+.55	−29.72	+ 1.92	−31.64	

SECTION 24. *Example of Pendulum Observations.*—Umanak, Greenland, August 10, 1896. Swing No. 5. Pendulum *A* 6, reversed on knife-edge I.

	COINCIDENCES OBSERVED.		Arc.	Pressure.	Dummy thermometer.	Air thermometer.
	Chronometer 1,842.	Chronometer 177.				
	h. m. s.	h. m. s.		mm.	°C.	°C.
	Up 1 01 17	Down 12 59 35	4.5 mm. = 52′	67.3	11.05	10.55
	Down 1 04 18	Up 1 02 33				
	Up 1 07 17	Down 1 05 31				
	Down 1 10 16	Up 1 08 28				
	Down 8 30 41	Up 8 28 50				
	Up 8 33 39	Down 8 31 44				
	Down 8 36 37	Up 8 34 42				
	Up 8 39 35	Down 8 37 38	1.6 mm. = 19′	68.7	10.6	10.6
Interval from down coincidences	7 32 19	7 32 07	Means . . .	68.0	10.82	
Interval from up coincidences	7 32 18	7 32 09	Reduction to 0°C. . . .	—2.5	—0.12	Thermo correction.
Mean interval	7 32 18 = 27138 s.	7 32 08 = 27128 s.		65.5	10.70	
Approximate time of two coincidence intervals .	s. 357.5	s. 354.2				
Number of coincidence intervals	152	154				
Time in one coincidence interval	s. 178.54	s. 176.16				

The balance of the computation is summarized in the tables of results (H).

AN ANALYTICAL INVESTIGATION OF THE HYDROLYSIS OF STARCH BY ACIDS.[1]

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FEW problems of commercial analysis have been so complicated and so discouraging as that of the determination of the components of starch conversion products. The well-known schemes of commercial analysis of worts and similar products of the action of diastase are based on the assumption that but two simple compounds are formed from the starch — maltose and dextrin. In the case of glucose syrups and starch sugars, which are the results of acid hydrolysis, it is known that the reaction proceeds farther, as dextrose is formed from the maltose and dextrin.

Musculus and Gruber[2] decided that these reactions went on together, so that, except at the very beginning or final stage of hydrolysis, all of these compounds must be present in solution.

The analysis of acid-converted starch products must, therefore, take into consideration the presence of the third compound, dextrose.

Much doubt, however, has been thrown on the accuracy of such analyses, as during the past twenty years the researches of O'Sullivan,

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NOTE. — Among the numerous errors incident to compilation, the authors have had their attention drawn to an important clerical error which had been carried through the calculation of Tables C and E. These tables have therefore been recalculated in this reprint. While these corrections have changed the carbohydrate values of Table C somewhat and the constants of Table E, the values of *K* remain unchanged, and the tabulated results in Tables I, II, and III are not materially affected. Of the plate, Figure 3 is the only one affected by these corrections, and as the character of the curves remains unchanged it was not thought worth the trouble to prepare a new plate drawn exactly to scale, especially as the correction on a plot of this size is hardly noticeable. In short, the main results of the investigation remain as originally set forth.

[1] Reprinted from the Journal of the American Chemical Society, 18, No. 10, October, 1896. (Received July 3, 1896.)

[2] Bull. Soc. Chim., 2, 30.

Brown, Heron, Morris, Bondonneau, Herzfeld, Musculus, Bruckner, Fischer, and other distinguished investigators, have shown that not only the simple compounds referred to can be isolated from starch products, but also many others of quite distinct optical and chemical properties. Space will not permit a review of this work, which is in many points conflicting. The recent conclusion of Lintner and Düll is that the following compounds result from hydrolysis:[1]

Hydrolysis with oxalic acid.	With diastase.
Amylodextrin.	Amylodextrin.
Erythrodextrin I.	Erythrodextrin I.
Erythrodextrin IIα.	....
Erythrodextrin IIβ,	....
Achroodextrin I.	Achroodextrin I.
Achroodextrin II.	Achroodextrin II.
Isomaltose.	Isomaltose.
Dextrose.	Maltose.

Others, as Brown and Morris,[2] deny the existence of the isomaltose of Fischer, Lintner, and Düll, and mention another compound, maltodextrin, as intermediate between dextrin and maltose.[3]

In 1885, Brown and Morris[4] discovered the remarkable law that at any stage of the conversion of starch by diastase, the total product, in its optical properties and relation to Fehling solution, behaved exactly as if made up of two components only, maltose and dextrin, so that it was possible by taking the rotatory power to calculate at once the cupric reducing power if the total carbohydrates were known. This law indicated that, however complicated the bodies isolated, they could be considered as existing in solution as two simple compounds, and did much to establish the validity of the principles of the usual commercial analyses of beer worts and similar products.

The method of analysis of glucose syrups and starch sugars implies the assumption of a similar law, but the proof that this law actually exists under varying conditions of hydrolysis apparently has not been worked out.

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[1] Ber. d. chem. Ges., 28, 1522–1531.

[2] J. Chem. Soc., No. 393 (August, 1895).

[3] A very complete bibliography of the original publications on the carbohydrates is in Tollen's Handbuch der Kohlenhydrate, 1, 331–360 (1888); 2, 368–398 (1895).

[4] Ann. Chem. (Liebig), 231, 131.

Our investigations have been made, first, to determine whether there was any simple constant relation between the optical rotation and the cupric reducing powers of starch products hydrolyzed under different conditions; and, secondly, whether any laws could be found affecting the three simple bodies assumed to be formed and determined by the usual methods of analysis.

Incidentally we have collected some data as to the speed of hydrolysis, influence of carbohydrates on specific gravity of solutions, and some looking to the adoption of a more rapid and accurate method of determining cupric reducing power by Fehling solution. The latter data are included in a separate paper. The work on specific gravities is not yet sufficiently complete for publication.

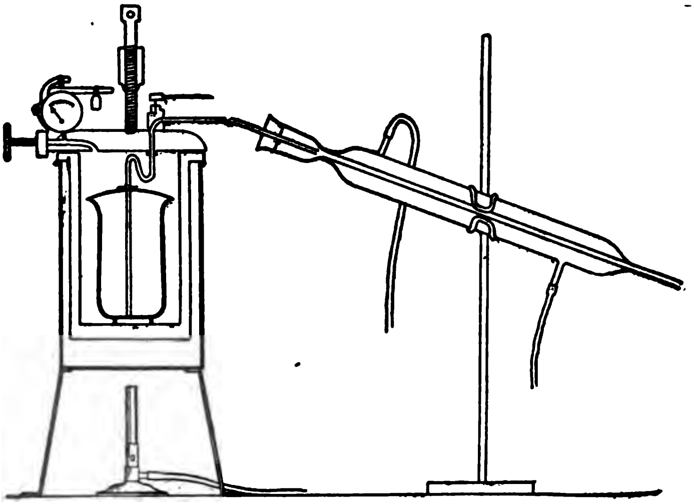

FIG. 1.

An autoclave of the usual construction was modified in the following manner: The thermometer tube was taken out and in its place was attached a specially constructed valve, by means of which liquor cooking in a beaker in the interior could be removed at any time during the progress of the experiment. This superheated liquor was prevented from vaporizing by passing through a condenser. Excessive condensation into the beaker was prevented in large part by a well-fitting lead cap. The illustration sufficiently explains the apparatus.

In most of the work, about 100 grams of a good quality of commercial corn starch[1] was mixed with a liter of water containing the hydrolyzing acid. Samples of from 50 cc. to 75 cc. of the liquor were removed at different stages of the conversion, and immediately shaken up with a few grams of marble dust. Two drops of tenth normal sodium hydroxide solution were then added to the sample, which was cooled and filtered. This method of neutralization, except in cases of very low converted samples, gave an absolutely clear filtrate, the filtration being exceedingly rapid, and the removal of the albuminoids being practically complete. Low converted products often required to be heated with aluminum hydroxide before filtering.

The samples were tested as follows:

(1) For specific gravity by Westphal balance, corrected to a temperature of 15.5° C.

(2) Specific rotatory power ($[\alpha]_D$) by a Schmidt and Haensch half-shade saccharimeter.

(3) Cupric reducing power by means of Fehling solution.

Total Solids. — Total solids were calculated from the specific gravity of the solution by the factor 0.00386, which was taken to represent the influence of 1 gram of the mixed carbohydrates in 100 cc. of solution. Corrections were made when necessary for the influence of other substances in solution, not carbohydrates. This factor 386 is practically that of Balling and Brix, and has been found exact for approximately 10 per cent. solutions of cane sugar, and the balance of evidence seems to be that it is correct for starch products.[2]

We have made several determinations of this factor by drying 10 cc. of solution on rolls of dried paper at a temperature of 100–105° C. Our results point to the constancy of this factor 386, even in solutions of low rotatory power, but are not yet complete enough to establish the value for all rotations.

Therefore, in this work we have adopted the expedient used by Brown and Morris, and others, and calculated all optical and copper

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[1] An analysis of this starch by the usual commercial methods gave:

	Per cent.
Starch	89.15
Oil	0.14
Ash	0.12
Albuminoids	0.42
Water	10.21
	100.04

[2] Recent results have modified our views on this point, but as used in our *calculations* the factor 386 is correct.

reduction constants on the assumption that all three carbohydrates in solution affect the specific gravity like cane sugar when the concentration is approximately 10 per cent. Even if subsequent investigations show that this view is not exactly correct, the relative values of the constants will not be appreciably affected nor the truth of the laws as set forth.

To illustrate this method of calculation of constants we give the following from our own determinations:

10 grams of dextrose dissolved in 100 cc. of water gave a rotation of 30.70° on the Schmidt and Haensch saccharimeter. This gives $[\alpha]_D$ as 52.8.[1] As the increase in specific gravity per gram of crystallized dextrose in 100 cc. is 0.00381, $[\alpha]_{D386}$ is 53.5.

9.751 grams of crystallized maltose anhydride in 100 cc. of water gave a rotation of 77.40. This gives an absolute specific rotatory power of 136.6. The specific gravity factor of maltose being 0.00390, $[\alpha]_{D386}$ is 135.2°. No exact figure is known for the influence of crystallized dextrin on the specific gravity of its solution. O'Sullivan gives 0.00385, and the balance of evidence seems to favor this. Hence 195 is probably correct for $[\alpha]_{D386}$.[2]

In like manner the values for *K* have been reduced to a dextrose with the factor 386.

Specific Rotatory Power. — All readings were made as nearly as possible at a temperature of 20° C. in 200 mm. tubes, the mean of several readings being taken. Corrections for zero error were made frequently, and the instrument was carefully screened by glass plates from the heat of the lamps. Comparisons were made with a Laurent polariscope to determine the value of the division in terms of angular degrees for sodium light, the accuracy of the quartz wedges having been verified previously. With standard quartz plates the usual factor 0.346 was obtained, but solutions of commercial glucose of approximately 10 per cent. gave the figure 0.344, which agrees with the recent work of Rimbach[3] and other investigators. We have taken, therefore, the latter factor in our calculation.

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[1] Precautions against bi-rotation were taken in both examples cited.

[2] Brown and Heron. Ann. Chem. (Liebig), 199, 190–243.

[3] Ber. d. Chem. Ges., 27, 2282.

TABLE A.

COMPARISON OF SCHMIDT AND HAENSCH HALF-SHADE SACCHARIMETER WITH THAT OF LAURENT POLARISCOPE READING IN ANGULAR DEGREES.

	S. AND H. SACCHARIMETER. (Using bat-wing burner and lens.)			LAURENT POLARISCOPE. (Sodium flame.)			
Test.	Reading.	Zero error.	Corrected reading.	Reading.	Zero error.	Corrected reading.	Factor.
$t = 20-22$)							
Quartz A . . .	62.965	0.300	62.665	21° 40′	0	21.666°	0.3457
Quartz A . . .	62.800	0.150	62 650	21° 40′	0	21.666°	0.3458
Quartz A . . .	62.970	0.290	62.680	21° 40.2′	0 6′	21.660°	0.3458
Quartz A . . .	62.836	0.130	62.706	21° 40.7′	0.6′	21.666°	0.3455
Glucose A . . .	77.510	0.277	77.233	26° 35′	0	26 582°	0.3442
Glucose B . . .	76.355	0.150	76.205	26° 15.3′	0	26.254°	0.3445
Glucose B . . .	76.355	0.150	76.205	26° 14′	0	26.233°	0.3442
Glucose C . . .	76.535	0.150	76.385	26° 18′	0	26.300°	0.3443
Glucose D . . .	76.110	0.130	75.980	26° 10.3′	0.6′	26.162°	0.3443
($t = 25$)							
Hydrolyzed starch products . . .	E. 92.73[1]	00	92.73	31° 56′	—1′	31.95°	0.3445
	F. 24.84	00	24.84	8° 32′	—1′	8.55°	0.3442

Cupric Reducing Power. — Our method is practically that of O'Sullivan, first published in 1876. The copper is weighed as the oxide. We have found this method exact and rapid. An analytical investigation of this process has been made by one of us, and given in detail in a separate paper.

Plotted Results. — To show the relationship of the copper-reducing power, and the specific rotatory power of the products formed during the progress of the hydrolysis of the starch, we have plotted our results, taking as abscissæ the decreasing values of the rotatory power, from the amylodextrin stage (195°) to that of dextrose ($[a]_{D386} = 53.5°$), and as ordinates the cupric reducing power (K_{386}) taking that of an equivalent weight of dextrose as 100.[2] (See Figure 2.)

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[1] Using Welsbach burner.

[2] Data given in Table B.

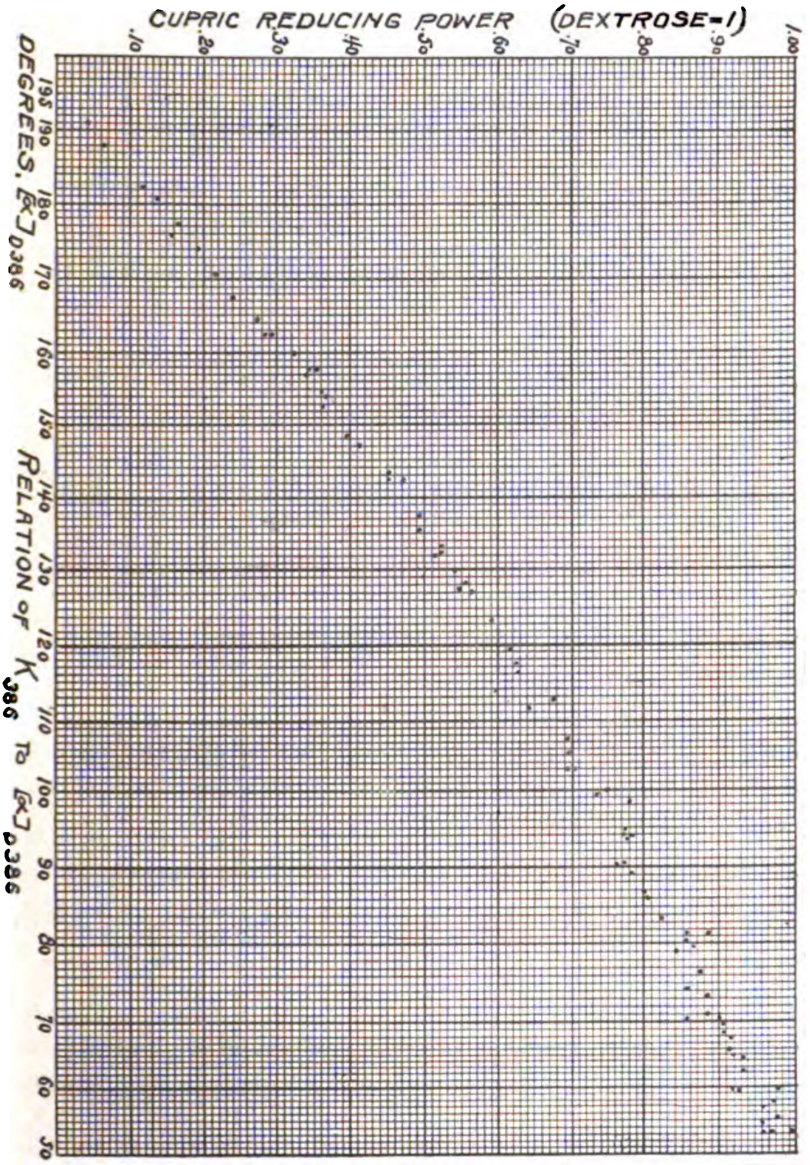
CUPRIC REDUCING POWER (DEXTROSE=1)
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
195
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
DEGREES. [α]D386
RELATION OF K386 TO [α]D386

FIG. 2.

TABLE B.[1]

HYDROLYSIS OF STARCH. EXPERIMENTAL DATA.

Run.	Number of sample.	Minutes cooking.	Grams starch.	Atmospheres pressure.	Acid.		Amount cc.	Water cc.	Specific gravity 15.5.	Saccharimeter reading.	Copper oxide.	$[\alpha]_D$ 386.	K 386.
					Kind.	Concent.							
8*a*	2	30	110	2	HCl	$\frac{n}{10}$	10	990	1.0456	98.0	0.1552[2]	142.7	0.4747
	3	45	...	..	....	..	...	...	1.0394	59.3	0.2103	99.95	0.7480
	4	75	...	..	....	..	...	...	1.0374	41.5	0.2275	73.67	0.8537
	5	135	...	..	....	..	...	...	1.0367	32.9	0.2480	59.53	0.9283
10	1	15	110	2	HCl	$\frac{n}{10}$	10	990	1.0199	57.3	0.0060	191.30	0.0412
	2	45	...	..	....	..	...	...	1.0320	84.8	0.0366	176.0	0.1567
	3	75	...	..	....	..	...	...	1.0348	80.7	0.0923	154.0	0.3652
	4	100	...	..	....	..	...	...	1.0315	67.6	0.1026	142.5	0.4523
	5	130	...	..	....	..	...	...	1.0315	60.8	0.1258	128.1	0.5584
	6	160	...	..	....	..	...	...	1.0318	54.6	0.1368	114.0	0.5993
	7	190	...	..	....	..	...	...	1.0318	49.4	0.1594	103.1	0.6995
	8	220	...	..	....	..	...	...	1.0318	44.7	0.1781	93.95	0.7827
	9	250	...	..	....	..	...	...	1.0323	42.2	0.1848	86.66	0.8000
	10	280	...	..	....	..	...	...	1.0323	38.4	0.1940	78.94	0.8407
11	1	15	110	2	HCl	$\frac{n}{10}$	100	900	1.0414	89.55	0.1290	143.6	0.4434
	2	30	...	..	....	..	...	...	1.0417	55.95	0.2320	89.10	0.7825
	3	45	...	..	....	..	...	...	1.0419	41.0	0.2747	64.98	0.9230
	4	60	...	..	....	..	...	...	1.0414	36.0	0.2837	57.75	0.9663
	5	75	...	..	....	..	...	...	1.0412	33.0	0.2830	53.19	0.9685
	6	90	...	..	....	..	...	...	1.0406	32.5	0.2763	53.16	0.9590
13	1	15	110	2	HCl	$\frac{n}{10}$	100	900	1.0394	103.2	0.0056	174.0	0.1958
	2	45	...	..	....	..	...	...	1.0384	75.7	0.1500	129.9	0.5405
	3	60	...	..	....	..	...	...	1.0380	61.1	0.1898	105.7	0.6988
	4	90	...	..	....	..	...	...	1.0380	45.5	0.2339	79.50	0.8646
	5	120	...	..	....	..	...	...	1.0375	38.25	0.2448	67.75	0.9175
14	2	22½	110	2	HCl	$\frac{n}{10}$	100	900	1.0379	97.8	0.0661	167.4	0.2415
	3	35	...	..	....	..	...	...	1.0384	85.9	0.1095	148.6	0.3964
	4	52½	...	..	....	..	...	...	1.0370	64.75	0.1664	116.2	0.6279
	5	75	...	..	....	..	...	...	1.0374	50.80	0.2040	90.20	0.7640

[1] This table does not include all the data of Table E. Samples on which were made determinations of optical constants only have been omitted for lack of space.

[2] Obtained from a solution $\frac{1}{10}$ of the original concentration.

TABLE B. — *Continued.*

HYDROLYSIS OF STARCH. EXPERIMENTAL DATA.

Run.	Number of sample.	Minutes cooking.	Grams starch.	Atmospheres pressure.	Acid.		Amount cc.	Water cc.	Specific gravity 15.5.	Saccharimeter reading.	Copper oxide.	$[\alpha]_D$ 386.	K 386.
					Kind.	Concent.							
	6	105	...	..	....	..	....	....	1.0374	39.60	0.2281	70.31	0.8561
	7	135	...	..	....	..	....	....	1.0374	34.95	0.2493	62 34	0.9367
15	2	30	110	2	HCl	$\frac{n}{10}$	1000	....	1.0371	88.1	0.0890	157.7	0.3329
	3	60	...	..	....	..	....	....	1.0337	67.05	0.1247	132.1	0.5146
	4	90	...	..	....	..	....	....	1.0337	56 50	0.1551	111 4	0.6421
	5	120	...	..	....	..	....	....	1.0337	46.00	0.1863	90.65	0.7727
16	1	25	110	2	HCl	$\frac{n}{10}$	1000	....	1.0327	79.90	0.0679	162 3	0.2877
	2	40	...	..	....	..	....	....	1.0393	81.40	0.1395	137.5	0.4946
	3	50	...	.	....	..	....	....	1.0380	70.60	0.1617	123.4	0.5936
	4	75	...	..	....	..	....	....	1.0380	57.00	0.1994	99.61	0.7348
17	1	15	55	2	HCl	$\frac{n}{10}$	25	475	1.0360	105.5	0.0173	188.5	0.0643
	2	23	...	..	....	..	....	....	1.0341	92.9	0.0344	180.9	0.1393
	3	33	...	..	....	..	....	....	1.0343	88.1	0.0539	170 6	0.2173
	4	42	...	..	....	..	....	....	1.0352	86.2	0 0751	162.7	0.2963
	5	50	...	..	....	..	....	....	1.0308	79.5	0.0828	157.0	0.3396
18	1	75	60	2	HCl	$\frac{n}{10}$	50	450	1.0422	74.7	0.1892	117.6	0.6273
	2	90	...	..	....	..	....	....	1.0423	68.0	0.2100	106.8	0.6958
	3	110	...	..	....	..	....	....	1.0428	60.3	0.2369	93 56	0.7796
	4	120	...	..	....	..	....	....	1.0428	52.6	0.2587	81.62	0.8507
	5	135	...	..	....	..	....	....	1.0429	49.2	0.2676	76.05	0.8720
19	1	15	60	2	HCl	$\frac{n}{10}$	50	450	1.0383	105.0	0.0329	182.1	0.1186
	2	30	...	..	....	..	....	....	1.0374	87.0	0.0975	154.5	0.3619
	3	40	...	..	....	..	....	....	1.0374	66.2	0.1337	117.6	0.6255
	4	130	...	..	....	..	....	....	1.0359	39.8	0.2272	73.62	0.8882
	5	150	...	..	....	..	....	....	1.0326	34.8	0.2093	70.89	0.8997
20	1	45	60	2	$H_2C_2O_4$	$\frac{n}{10}$	50	450	1.0327	87.2	0.0396	177.1	0.1673
	2	90	...	..	....	..	....	....	1.0301	71.2	0.0766	157.7	0.3526
	3	120	...	..	....	..	....	....	1.0318	65.8	0.1125	135.5	0.4917
21	2	60	60	2	$H_2C_2O_4$	$\frac{n}{10}$	100	400	1.0352	75.9	0.1145	143.2	0.4523

TABLE B. — *Concluded.*

HYDROLYSIS OF STARCH. EXPERIMENTAL DATA.

Run.	Number of sample.	Minutes cooking.	Grams starch.	Atmospheres pressure.	Acid.		Amount cc.	Water cc.	Specific gravity 15.5.	Saccharimeter reading.	Copper oxide.	$[\alpha]_D$ 386.	K 386.
					Kind.	Concent.							
	3	75	..	..	....	..	...	...	1.0359	71.6	0.1350	132.4	0.5237
	4	105	..	..	....	..	...	...	1.0355	64.0	0.1577	119.8	0.6200
24	1	30	65	2	HCl	$\frac{n}{10}$	100	400	1.0440	88.2	0.1651	133.1	0.5236
	3	60	..	..	....	..	...	...	1.0371	38.1	2×(0.1211)	68.19	0.9080
	4	75	..	..	....	..	...	...	1.0376	33.95	2×(0.1319)	59.95	0.9745
	5	90	..	..	....	..	...	...	1.0406	34.7	2×(0.1388)	56.75	0.9526
25	1	45	65	2	$H_2C_2O_4$	$\frac{n}{10}$	200	300	1.0414	99.7	0.0966	159.9	0.3240
	2	90	..	..	....	..	...	...	1.0448	85.6	0.1799	126.9	0.5611
	3	135	..	..	....	..	...	...	1.0452	67.0	2×(0.1265)	98.42	0.7791
	4	180	..	..	....	..	...	...	1.0458	55.3	2×(0.1401)	80.17	0.8525
	5	225	..	..	....	..	...	...	1.0455	47.7	2×(0.1483)	69.61	0.9088
26	1	30	65	2	H_2SO_4	$\frac{n}{10}$	100	400	1.0447	110.9	0.0869	164.7	0.2760
	2	62	..	..	....	..	...	...	1.0466	89.3	2×(0.0821)	127.3	0.5480
	3	90	..	..	....	..	...	...	1.0478	74.2	2×(0.1227)	103.6	0.7144
	4	120	..	..	....	..	...	...	1.0500	63.1	2×(0.1475)	83.79	0.8206
	5	150	..	..	....	..	...	...	1.0525	56.4	2×(0.1614)	70.96	0.8848
27	1	10	60	4	HCl	$\frac{n}{10}$	50	450	1.0430	95.2	0.1281	147.0	0.4144
	2	20	..	..	....	..	...	...	1.0430	60.85	2×(0.1196)	93.97	0.7738
	3	30	..	..	....	..	...	...	1.0430	42.7	2×(0.1414)	65.94	0.9162
	4	45	..	..	....	..	...	...	1.0430	35.3	2×(0.1466)	54.51	0.9506
	5	60	..	..	....	..	...	...	1.0430	34.8	2×(0.1533)	53.70	0.9968
33	1	10	60	4	HCl	$\frac{n}{10}$	100	400	1.0426	60.8	0.2351	94.77	0.7754
	2	15	..	..	....	..	...	...	1.0426	41.4	0.2833	64.54	0.9378
	3	20	..	..	....	..	...	...	1.0423	35.4	0.2919	55.58	0.9736
34	1	10	60	3	HCl	$\frac{n}{10}$	200	300	1.0435	56.4	0.2532	86.10	0.8143
35	1	90	60	1	HCl	$\frac{n}{10}$	100	400	1.0381	87.6	0.0992	152.7	0.3616
	2	180	..	..	....	..	...	...	1.0391	66.5	0.1887	112.9	0.6751
	3	225	..	..	....	..	...	...	1.0403	49.5	0.2525	81.56	0.8831
39	2	90	60	4	HCl	$\frac{n}{10}$	50	450	1.0384	39.7	0.2621	53.01	0.9607
	3	120	..	..					1.0378	30.4	0.2628	53.49	0.9779

The results point to the remarkable fact that the cupric reducing power of the total product bears a constant relation to the specific rotatory power, even when the starch is hydrolyzed under widely varying conditions. Hence, given the one, the value of the other can be calculated. To a rotation of about 90°, the plotted results outline with extraordinary exactness the arc of a circle, the equation of which is very nearly

$$x^2 + y^2 - 758x + 772.4y = 0,$$

which exactly intercepts the "zero" and "hundred" points at 195 and 53.5, respectively. The upper part of the curve is not so well defined, the results showing more discrepancy at the high conversion stages. This may be due to some decomposition, and the formation of "reversion" products as stated by Wohl,[1] Maercker, Ost, and others. Wohl's figures show the maximum amount of dextrose possible to be 92.7 per cent. of the theoretical quantity. Others give 96 to 97 per cent., the missing dextrose being supposed to be converted into dextrin-like bodies identical with those variously described as "gallisin," "isomaltose," etc. We have experimented but little along this line, having made but one hydrolysis with this special object, using $\frac{N}{100}$ hydrochloric acid at four atmospheres pressure, with the following results:

Time of cooking.	$[\alpha]_D$.
60 minutes	55.24
90 minutes	53.09
120 minutes	53.40
150 minutes	54.42

While several of our own results at the low rotations show a cupric reducing power of only about 96 per cent. of that of pure dextrose, we do not think that we are justified in arriving at any definite conclusion with the data at hand.

That the solutions begin to color considerably at rotations beyond 90° is, moreover, a strong indication of such decomposition. On the other hand, this accounts for much of the discrepancy of the plot at this part of the curve, as it is exceedingly difficult to get accurate readings on the saccharimeter of these highly colored solutions. Obviously, too, slight errors in the readings affect the calculations of the rotatory power the most at these lowest rotations.

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[1] Ber. der chem. Ges., 23, 2101.

Quite as noteworthy are the curves[1] plotted by taking the values of maltose, dextrin, and dextrose as computed for every five degrees of rotation from the values of K, as given by this curve.

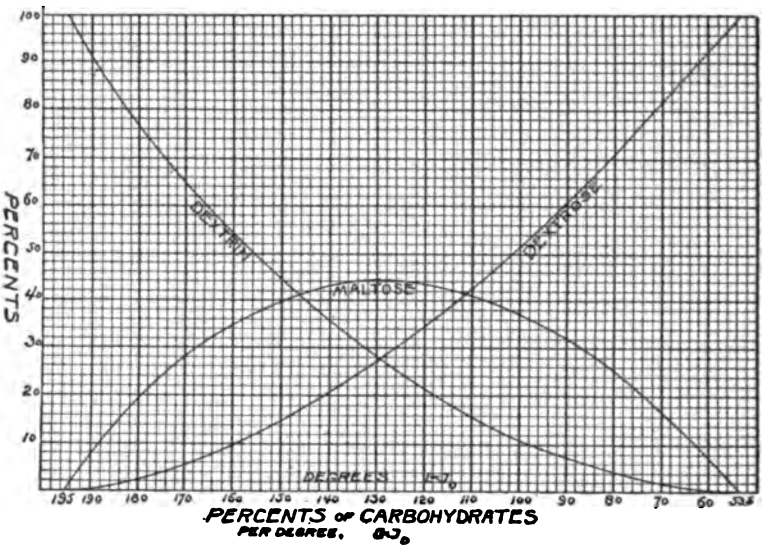

FIG. 3.

In this work we have figured constants for solids estimated from the specific gravities of solutions by the factor 386, and calculated percentages by the well-known equations:

$$g + m + d = 1.00$$
$$g + 0.61m = K$$
$$195d + 135.2m + 53.5g = a$$

Where g is per cent. dextrose,
m is per cent. maltose,
and d is per cent. dextrin.

$$\text{Hence } m = \frac{a + 141.5K - 195}{26.52}.$$

Examining these curves we see that the dextrin starting from the maximum of 100 per cent. gradually falls to zero near the rotation

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[1] See Figure 3.

corresponding to dextrose, while the maltose gradually rises, reaches a maximum percentage of 46.2 at about 129° rotation, corresponding to the usual state of conversion of commercial glucose, and then falls, disappearing at 53.5°. The dextrose, on the contrary, steadily mounts to 100 per cent. It will be noted, too, that at the point of maximum maltose the dextrin and dextrose, as shown by the intersection of the curves, are present in equal quantity.

Tests with phenylhydrazin acetate show the presence of the dextrose distinctly at about 185°, and we had hoped to prove the gradual rise of the dextrose percentage by means of the dextrosazon. While copious precipitates of this beautiful compound were obtained, any attempt of ours to isolate it in anything like quantitative amounts proved a failure, even in solutions containing a known amount of pure dextrose. We hope to take this up more fully in a later investigation.

We have also calculated a table (Table C) from the curves, giving the value of maltose, dextrose, and dextrin within .1 per cent. for successive stages of acid hydrolysis represented by each degree of rotation between 195 and 53.5. This table, calculated for the factor 386, makes no allowance for possible decomposition of high-converted products.

TABLE C.

CALCULATED VALUES OF CUPRIC REDUCING POWERS AND PARTS OF MALTOSE, DEXTROSE, AND DEXTRIN PER UNIT OF CARBOHYDRATE FOR EACH DEGREE OF ROTATION OF A NORMALLY HYDROLYZED STARCH SOLUTION.

$[\alpha]^{20}_{D\,386}$.	K_{386}.	m_{386}.	g_{386}.	d_{386}.
195	0.000	0.000	0.000	1.000
194	0.011	0.017	0.001	0.982
193	0.022	0.038	0.001	0.966
192	0.032	0.052	0.001	0.947
191	0.041	0.068	0.002	0.930
190	0.051	0.084	0.002	0.914
189	0.061	0.098	0.002	0.900
188	0.071	0.114	0.003	0.883
187	0.081	0.128	0.003	0.869
186	0.090	0.143	0.005	0.852
185	0.100	0.157	0.005	0.838
184	0.109	0.170	0.008	0.822
183	0.118	0.183	0.010	0.807
182	0.127	0.195	0.012	0.793
181	0.137	0.207	0.014	0.779
180	0.146	0.219	0.016	0.765
179	0.155	0.227	0.019	0.754
178	0.164	0.237	0.022	0.741
177	0.173	0.247	0.024	0.729
176	0.182	0.257	0.027	0.716
175	0.191	0.266	0.031	0.708
174	0.199	0.274	0.034	0.692
173	0.207	0.282	0.038	0.680
172	0.216	0.290	0.042	0.668
171	0.224	0.298	0.046	0.656
170	0.233	0.305	0.050	0.645
169	0.242	0.312	0.053	0.635
168	0.251	0.318	0.056	0.625
167	0.259	0.325	0.060	0.615
166	0.267	0.331	0.064	0.605
165	0.275	0.337	0.068	0.595
164	0.283	0.343	0.073	0.584
163	0.292	0.350	0.076	0.572
162	0.300	0.356	0.083	0.561
161	0.308	0.362	0.088	0.550
160	0.316	0.367	0.093	0.540
159	0.324	0.374	0.098	0.528
158	0.332	0.381	0.102	0.517
157	0.340	0.387	0.106	0.507
156	0.348	0.392	0.110	0.498
155	0.356	0.397	0.115	0.488
154	0.365	0.402	0.120	0.478
153	0.373	0.407	0.125	0.468
152	0.381	0.412	0.130	0.458
151	0.389	0.414	0.135	0.451
150	0.397	0.421	0.140	0.439
149	0.404	0.425	0.146	0.429
148	0.412	0.429	0.152	0.419
147	0.419	0.432	0.158	0.410
146	0.427	0.434	0.163	0.403
145	0.435	0.436	0.169	0.395
144	0.442	0.439	0.175	0.386
143	0.450	0.442	0.183	0.375

TABLE C. — *Continued.*

$[\alpha]^{20}_{D\,386}$.	K_{386}.	m_{386}.	g_{386}.	d_{386}.
142	0.458	0.445	0.188	0.367
141	0.465	0.448	0.193	0.359
140	0.473	0.450	0.199	0.351
139	0.481	0.452	0.206	0.342
138	0.488	0.454	0.212	0.334
137	0.496	0.456	0.219	0.325
136	0.503	0.458	0.224	0.318
135	0.510	0.459	0.230	0.311
134	0.517	0.459	0.237	0.304
133	0.524	0.460	0.244	0.296
132	0.531	0.460	0.250	0.290
131	0.538	0.461	0.257	0.282
130	0.546	0.462	0.264	0.274
129	0.553	0.462	0.272	0.266
128	0.560	0.462	0.279	0.258
127	0.567	0.461	0.284	0.253
126	0.574	0.460	0.294	0.246
125	0.580	0.460	0.301	0.239
124	0.588	0.459	0.308	0.233
123	0.595	0.458	0.315	0.227
122	0.602	0.456	0.323	0.221
121	0.608	0.455	0.331	0.214
120	0.614	0.453	0.338	0.209
119	0.621	0.451	0.346	0.203
118	0.628	0.450	0.354	0.196
117	0.635	0.448	0.361	0.191
116	0.642	0.446	0.369	0.185
115	0.649	0.444	0.377	0.178
114	0.656	0.442	0.387	0.171
113	0.663	0.439	0.395	0.166
112	0.669	0.436	0.403	0.161
111	0.675	0.433	0.411	0.156
110	0.681	0.429	0.420	0.152
109	0.687	0.425	0.428	0.147
108	0.694	0.421	0.436	0.143
107	0.700	0.418	0.445	0.137
106	0.707	0.414	0.453	0.133
105	0.713	0.411	0.462	0.127
104	0.719	0.407	0.471	0.122
103	0.725	0.402	0.480	0.118
102	0.732	0.398	0.489	0.113
101	0.738	0.393	0.498	0.109
100	0.744	0.389	0.508	0.103
99	0.750	0.384	0.518	0.098
98	0.757	0.380	0.527	0.093
97	0.763	0.374	0.536	0.090
96	0.769	0.368	0.545	0.087
95	0.775	0.362	0.554	0.084
94	0.781	0.357	0.563	0.080
93	0.787	0.352	0.572	0.076
92	0.793	0.347	0.581	0.072
91	0.799	0.342	0.591	0.068
90	0.805	0.336	0.600	0.064
89	0.810	0.329	0.610	0.061
88	0.816	0.322	0.620	0.058
87	0.822	0.315	0.630	0.055
86	0.828	0.308	0.640	0.052

TABLE C. — *Concluded.*

$[a]^{20}_{D386}$.	K_{386}.	m_{386}.	g_{386}.	d_{386}.
85	0.834	0.302	0.650	0.048
84	0.839	0.294	0.660	0.044
83	0.844	0.287	0.670	0.043
82	0.850	0.279	0.680	0.041
81	0.856	0.272	0.690	0.038
80	0.862	0.264	0.701	0.035
79	0.867	0.256	0.712	0.032
78	0.872	0.247	0.722	0.031
77	0.878	0.237	0.733	0.030
76	0.884	0.228	0.744	0.028
75	0.889	0.219	0.755	0.026
74	0.895	0.210	0.766	0.024
73	0.901	0.199	0.778	0.023
72	0.906	0.189	0.789	0.022
71	0.911	0.179	0.791	0.020
70	0.916	0.170	0.811	0.018
69	0.921	0.159	0.824	0.017
68	0.926	0.149	0.835	0.016
67	0.932	0 139	0.846	0.015
66	0.937	0.130	0.856	0.014
65	0.942	0.121	0.867	0.012
64	0.947	0.110	0.879	0.011
63	0.952	0.099	0.880	0.011
62	0.957	0.088	0.902	0.010
61	0.962	0.078	0.914	0.008
60	0.967	0.068	0.926	0.006
59	0.972	0.057	0.937	0.006
58	0.977	0.047	0.948	0.005
57	0.982	0.036	0.960	0.004
56	0.987	0.025	0.971	0.004
55	0.992	0.015	0.982	0.003
54	0.997	0.005	0.993	0.002
53.5	1.000	0.000	1.000	0.000

It would seem obvious that we are now prepared to determine whether a sample of glucose is a product of one hydrolysis or is a mixture of two separately converted products, by comparison of the actual analytical results with those calculated from the rotatory power.

For testing this method we have made a few analyses of commercial glucoses obtained in open market.

In the manufacture of glucose syrup all the starch is not hydrolyzed under strictly the same conditions, as the factory practice is to pump the starch into the converter which is under steam pressure and already contains the hydrolyzing acid. As the filling of a converter takes about one-third of the total time of cooking, it is clear that there is a radical difference in the time of hydrolysis of different portions of starch. Nevertheless, we have found that samples known to have been made under these conditions conform to the laws of our curve, and the evidence seems strong that those which depart widely from these conditions are mechanical mixtures.

The following determinations of four samples of commercial glucose, giving the cupric reducing power as found and as calculated for the corresponding rotation, will illustrate the method:

Sample.	a_{D386}.	K_{386} (obtained.)	K_{386} (calculated.)
I. C. Pope Co. (J)	131.7	0.520	0.537
II. C. Pope Co. (M)	125.4	0.578	0.578
III. Rockford Co.	141.9	0.454	0.457
IV. Chicago Co.	137.2	0.505	0.495

Evidently II and III are normally hydrolyzed. IV is possibly a mixture, while I is undoubtedly so. As this latter is a sample of jelly goods which in factory practice are often made by mixing two lots, our conclusion is strengthened.

From the results as a whole we have concluded that the evidence is strong: (1) That in any homogeneous acid-converted starch product, irrespective of the conditions of hydrolysis, the specific rotatory power always represents the same chemical composition.

(2) That but three simple carbohydrates,[1] possibly in molecular aggregates, exist in the solution of a starch product hydrolyzed by acids.

DETERMINATION OF THE CONVERSION OF COMMERCIAL GLUCOSE.

In the manufacture of glucose it is obviously essential to have a rapid means of determining the degree of conversion of the starch during the cooking process. The usual factory practice is to control the conversion by means of iodine color tests. These tests are usually made by adding a definite number of drops of standard iodine solution to a test-tube of the cooled glucose liquor. The tint at which

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[1] Leaving out of consideration the possible small amounts of products formed by reversion.

the conversion is considered complete varies in general practice from that corresponding to $[\alpha]_D = 128$ to $[\alpha]_D = 135$, the variation being even greater in some cases, depending on the ideas of the manufacturer, and the grade of goods desired.

By daily practice workmen become quite expert in making these iodine tints, which are usually carried out by crude methods and read off without comparison with any standard. Nevertheless, the product, when examined by more refined laboratory processes, shows wide variations from day to day, which does not appear surprising when we examine into the errors of such color tests.

Assuming that the test is carried out under uniform conditions of concentration and proportion of reagent to liquor to be tested, which is by no means always the case, the other conditions affecting the color are (1) temperature, (2) turbidity, and (3) illumination.

Uniform temperature can be obtained easily by some simple cooling device, as a stream of running water.

The acid converter liquors are always turbid when tested, as filtration in this rapid testing is impracticable. The turbidity, however, is fairly constant. It is the third condition, that of illumination, which is constantly variable, and which gives rise to the greatest error. This source of error can be largely eliminated by the use of a comparison standard, prepared of the same volume as that used in the color test, and hermetically sealed in a glass tube of the standard size used in testing. Mixtures of solutions of iron salts with finely pulverized glass, giving the requisite turbidity when shaken, can be easily made to exactly match the iodine tint, and will preserve their intensity indefinitely. When properly adjusted by means of polariscopic tests, such standards have served well to fix the point of conversion within narrow limits, and have done much to insure a uniform product.

It is of course important that there should be in the hands of the chemist or superintendent of the works a much more exact means of testing the degree of conversion. This is most naturally accomplished by determining the specific rotatory power.

We have arranged a table for quickly calculating specific rotatory power, and found it so useful that we venture to publish it. The following simple calculation will sufficiently explain the principles on which the table has been worked out:

TABLE D.

Table for Determining Specific Rotatory Power of Solutions of 7.50°–10° Brix by Reading of Ventzke Saccharimeter.

Brix.	Specific gravity.	W = gram per 100 cc.	Log $\frac{17.20}{W}$.	Brix.	Specific gravity.	W = gram per 100 cc.	Log $\frac{17.20}{W}$.
7.50	1.0298	7.724	0.3477	8.80	1.0352	9.110	0.2760
7.55	1.0300	7.777	0.3447	8.85	1.0354	9.163	0.2735
7.60	1.0302	7.829	0.3418	8.90	1.0356	9.217	0.2709
7.65	1.0304	7.883	0.3388	8.95	1.0358	9.270	0.2684
7.70	1.0306	7.936	0.3359	9.00	1.0360	9.324	0.2657
7.75	1.0308	7.989	0.3330	9.05	1.0362	9.378	0.2634
7.80	1.0310	8.042	0.3301	9.10	1.0364	9.430	0.2610
7.85	1.0312	8.096	0.3272	9.15	1.0366	9.484	0.2585
7.90	1.0315	8.149	0.3244	9.20	1.0368	9.538	0.2560
7.95	1.0317	8.202	0.3216	9.25	1.0370	9.592	0.2536
8.00	1.0319	8.255	0.3187	9.30	1.0372	9.646	0.2510
8.05	1.0321	8.308	0.3160	9.35	1.0374	9.690	0.2488
8.10	1.0323	8.361	0.3132	9.40	1.0376	9.753	0.2464
8.15	1.0325	8.415	0.3104	9.45	1.0378	9.807	0.2440
8.20	1.0327	8.468	0.3077	9.50	1.0381	9.862	0.2415
8.25	1.0329	8.522	0.3050	9.55	1.0383	9.916	0.2391
8.30	1.0331	8.575	0.3022	9.60	1.0385	9.970	0.2368
8.35	1.0333	8.629	0.2995	9.65	1.0387.	10.023	0.2346
8.40	1.0335	8.682	0.2969	9.70	1.0389	10.077	0.2323
8.45	1.0337	8.735	0.2943	9.75	1.0391	10.130	0.2300
8.50	1.0339	8.788	0.2916	9.80	1.0393	10.185	0.2277
8.55	1.0341	8.842	0.2889	9.85	1.0395	10.239	0.2252
8.60	1.0343	8.895	0.2864	9.90	1.0397	10.293	0.2231
8.65	1.0345	8.949	0.2838	9.95	1.0399	10.347	0.2207
8.70	1.0347	9.002	0.2812	10.00	1.0401	10.401	0.2185
8.75	1.0350	9.056	0.2786	....	....	....	....

Taking the usual formula for the specific rotatory power, $a = \frac{av}{lw}$, where a is the angle of rotation of w grams of the active substance in v cc. of solution observed through a column l decimeters long. If we make $a = a$, it is plain w is the weight of substance under standard conditions which will give a direct reading of the specific rotatory power without calculation. In an instrument reading in angular degrees under the usual conditions of $v = 100$ and $l = 2$, w is therefore 50 *g*.

If a is the reading of a saccharimeter with the Ventzke scale, $w = 50 \times 0.344 = 17.20$, and the specific rotatory power of any solution of known concentration of an optically active substance will be

$\frac{17.2a}{w}$. The easiest way of finding the concentration of glucose solutions with sufficient exactness for this work is by the Brix (or Balling) hydrometer, as this instrument is now made of great accuracy.

Brix hydrometers are carried in regular stock of the larger houses dealing in chemical apparatus for brewers and sugar manufacturers, with scales having a range of about five degrees and easily read to 0.05 per cent. Thermometers are attached having corrections for temperature marked on the scale. Concentrations of about 10 per cent. are most convenient for polarizing; hence a spindle will be needed reading from 5 to 10 per cent.

The method of determining rotatory powers is as follows: The glucose is diluted to an approximately 10 per cent. solution. An exact Brix (or Balling) reading is taken, corrected for standard temperature, and the solution polarized in a 200 mm. tube in any saccharimeter with the Ventzke scale. The logarithm of the factor $\frac{17.20}{w}$ corresponding to the Brix reading is then found in the table. Therefore, the calculation which is, $\log [a]_D = \log \frac{17.20}{w} + \log a$, simply requires finding the logarithm of the saccharimeter reading, and the number corresponding to the sum of this, and the logarithm given in the table. This number is the required specific rotatory power.[1]

Thus a solution of 7.85 Brix having a reading of 51.7°, Ventzke, has the rotatory power of its anhydrous carbohydrates determined as follows:

By the table, the corresponding logarithmic factor is 0.3272.

$$\begin{array}{ll} \text{Log } 51.7 = & 1.7135 \\ \text{Factor} & \underline{0.3272} \\ & 2.0407 = \log 109.8, \end{array}$$

which is the required rotatory power.

In this calculation no correction is made for ash, which, as a rule, does not affect the results appreciably.

The errors due to the slight variations in the concentration of the solutions used and changes in the temperature of the laboratory are

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[1] Obviously a table made on the scheme of the well-known Schmitz table for cane-sugar syrups would do away with all calculation. Such a table is, however, rather bulky for insertion here.

too small to be taken into consideration in factory work or in general commercial analysis. The method in practice is quite as rapid as the "quotient of purity" determination of cane-sugar syrups. We suggest that this, or some similar scheme, be uniformly used for expressing the results of all polarimetric investigations of honeys, syrups, and similar indeterminate mixtures of carbohydrates met with in commercial analysis, instead of merely giving the polarizations, or the specific rotatory powers referred to the weights of the samples. The advantages are obvious. Such analytical results would be close approximations to the exact specific rotatory powers of the mixed anhydrous carbohydrates, and would be convenient of interpretation by inspection as being directly comparable on what is, for all practical purposes, an absolute standard, and the one used in all strictly scientific work of the kind.

THE SPEED OF THE HYDROLYSIS OF STARCH BY ACIDS.[1]

The laws of the speed of hydrolysis of the carbohydrates with the exception of that of cane-sugar have been but little studied. Solomon[2] has collected some data on the action of various acids at boiling temperature. Welhelmy[3] showed in the case of the catalytic action of hydrochloric acid on cane-sugar, that if the amount of acid and the temperature remained constant the rate of the inversion at any specified moment is proportional to the amount of unchanged sugar present at that moment.

That is, if A_0 represent the amount of sugar originally present, x the amount of this sugar changed over in any period of time t, and c the reaction-constant, we have $\frac{dx}{dt} = c\,(A_0 - x)$.

The relative values of the constant c, of the various acids in their action on cane-sugar, have been determined by several observers, notably Ostwald,[4] who has compared, by means of their constants, the relative effect of chemically equivalent quantities of a large number of acids, taking the constant of hydrochloric acid as a standard with the arbitrary value of 100.

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[1] We are greatly indebted to Professor A. A. Noyes, of this department, for valuable aid in calculating the results of this work on speed of hydrolysis.

[2] J. prakt. Chem. (2), 28.

[3] Ber. d. Chem. Ges., 18, 2211.

[4] J. prakt. Chem., 401 (1884).

Recent work shows that acids act on salicin,[1] one of the glucosides, in a manner analogous to that of cane-sugar, the speed of hydrolysis of this body by the different acids bearing the same relation to hydrochloric acid.

The observations noted above suggested the possibility that in the hydrolysis of starch the acids would show the same proportional speed of reaction. This is an especially interesting problem, because the starch molecule is exceedingly complicated, the molecular weight being undoubtedly very high. Starch hydrolysis, however, must be considered as somewhat different from that of cane-sugar or salicin. While these are easily soluble in cold water, starch is totally insoluble at ordinary room temperature. On the other hand, amylodextrin, the product of decomposition of starch by boiling water, is somewhat soluble in cold water, its solubility increasing with rise of temperature.

As by the customary procedure in determining speed of hydrolysis, it would be necessary to ascertain the exact moment when all the starch has been converted into the soluble form, a point not conveniently determined, we have adopted a method of measurement based on the following principles:

The conversion products of starch, with the possible exception of those of very high rotatory power, are easily soluble in water, and can be looked upon as mixtures of maltose, dextrose, and dextrin.

The starch first changes to amylodextrin. The hydrolysis then proceeds by successive stages through the so-called maltodextrin, maltose, and dextrose. "Reversion," so-called, may take place to some extent, a small amount of the dextrose forming dextrin-like bodies, "gallisin," "isomaltose," etc., but this point is not considered in this work. The dextrin may, therefore, be looked upon as the original substance hydrolyzed, and maltose and dextrose as successive products of the reaction.

Further, we have shown that, whatever the condition of hydrolysis by acids, the specific rotatory power of any conversion product corresponds to a definite chemical composition, tables for determining which we have constructed.

Thus, for instance, a conversion product of 160° has been proved to contain 54.0 per cent. dextrin, the remainder being maltose and dextrose.

Hence, the time of taking any sample after the contents of the

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[1] Noyes and Hall; Ztschr. phys. Chem., 240 (1895).

autoclave have acquired constant temperature, which requires about ten minutes, can be taken as the initial point for determining speed of hydrolysis, and all subsequent samples referred to this, as it is obvious that in any sample we can ascertain the dextrin unacted upon at that stage of the hydrolysis. The same holds true of maltose.

We have to deal with two reactions, the first being the hydrolysis of dextrin to maltose.

If A_0 is the amount of dextrin at the initial point taken, $A_0 - x$, the amount remaining at any time, t, and c the constant depending on conditions of hydrolysis, we get, $\frac{dx}{dt} = c\,(A_0 - x)$.

This, on integrating, gives nat. log $\frac{A_0}{A - x} = ct$, or $\frac{1}{t}$ nat. log $\frac{A_0}{A_0 - x} = c$, which is the general equation of a first-order reaction. The second decomposition is that in which maltose is hydrolyzed to dextrose, and is peculiar in so far as it proceeds simultaneously with that by which the maltose is formed. As a result of the hydrolysis of the dextrin, the maltose increases rapidly to a maximum of 46.2 per cent. at a rotation of 129°. It then gradually diminishes, while the dextrose percentage always increases.

Consequently, the equation expressing accurately the rate of change in the total amount of maltose present is quite complicated, and we have, therefore, used an approximate formula, which is sufficiently exact for the work in hand. The formula is derived from the exact differential equation

$$\frac{dD}{dt} = c_2\,M,$$

which states that the amount of dextrose formed at each moment is proportional to the amount of maltose present by replacing the differential quantities by finite differences, which in applications of the formula must of course be taken small. In the place of M the average amount of maltose present during the interval of time considered is also substituted. That is, if M_1 and M_2 are the amounts of maltose present at the time, t_1 and t_2, and D_1 and D_2 the amounts of dextrose present at these same times, and c_2 is the reaction constant, we get as a result of the above-mentioned substitutions:

$$D_2 - D_1 = c_2 \frac{M_1 + M_2}{2} (t_2 - t_1),$$

or,

$$\left(\frac{1}{t_2 - t_1}\right) \left(\frac{D_2 - D_1}{\frac{M_1 + M_2}{2}}\right) = c_2.$$

The results are contained in the following tables:

TABLE E.

SPEED OF HYDROLYSIS OF STARCH.

Hydrochloric acid 0.02 normal at 2 $A\ t = 135°$ C.

$t_0 = 20$; $[a]^{20}_{D\,386} = 161$; $A_0 = 55.0$.

Time t. (Minutes.)	$[a]^{20}_{D\,386}$.	$A_0 - x$.	$\log^1 \frac{A_0}{A_0 - x}$.	C_1.	$\frac{D_2 - D_1}{\frac{m_1 + m_2}{2}}$	C_2.
10	137	32.5	.2285	.0219	.3286	.0329
20	118	19.6	.4481	.0224	.3225	.0333
30	101	10.9	.7130	.0237	.3417	.0342
40	87	5.5	1.0000	.0225	.3816	.0382
50	76	2.8	1.2932	.0258	.4296	.0430
60	69	1.7	1.5100	.0252	.4134	.0413
70	64	1.1	1.7090	.0271	.4833	.0483

$C_1 = 0.0242$. $C_2 = 0.0387$.

Sulphuric acid 0.02 normal at 2 $A\ t = 135°$ C.

$t_0 = 20$; $[a]^{20}_{D\,386} = 177°$; $A_0 = 72.9$.

10	163	57.2	.1053	.0105	.1809	.0181
20	152	45.8	.2018	.0109	.1365	.0136
30	140	35.1	.3174	.0105	.1601	.0160
40	129	26.6	.4378	.0109	.1601	.0160
60	109	14.7	.7954	.0132	.3518	.0171
80	90	6.4	1.0565	.0132	.4581	.0229
100	77	3.0	1.3856	.0138	.4641	.0232
120	66	1.4	1.7166	.0143	.6524	.0326

$C_1 = .0121$. $C_2 = .0199$.

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[1] As is customary, common logarithms are used in these calculations.

TABLE E. — *Continued.*

Oxalic acid 0.04 normal at 2 $A\,t = 135°$ C.

$t_0 = 20$; $[\alpha]^{20}_{D\,386} = 180°$; $A_0 = 76.5$.

Time *t.* (Minutes.)	$[\alpha]^{20}_{D\,386}$.	$A_0 - x$.	$\log \frac{A_0}{A_0 - x}$.	C_1.	$\frac{D_2 - D_1}{\frac{m_1 + m_2}{2}}$	C_2.
20	157	50.7	.1787	.00894	.2970	.0148
40	137	32.5	.3718	.00929	.2684	.0134
60	120	20.9	.5636	.00939	.2617	.0138
80	106	13.3	.7598	.00949	.2653	.0137
100	93	7.6	1.0029	.01003	.3099	.0158
120	82	4.1	1.2709	.01059	.3423	.0171
140	73	2.3	1.5220	.01087	.4101	.0205

$C_1 = .00980$. $C_2 = .00156$.

Sulphuric acid 0.02 normal at 2 $A\,t = 135°$.

$t_0 = 50$; $[\alpha]^{20}_{D\,386} = 187°$; $A_0 = 86.9$.

50	179	75.4	.0616	.00123	.0901	.00180
100	172	66.8	.1142	.00114	.0889	.00177
150	165	59.5	.1645	.00109	.0829	.00165
200	159	52.8	.2164	.00108	.0843	.00168
250	151	45.1	.2848	.00113	.0939	.00187
300	144	38.6	.3524	.00117	.0938	.00187
350	137	32.5	.4271	.00122	.0983	.00196
400	131	28.2	.4888	.00122	.0828	.00185

$C_1 = .00116$. $C_2 = .00181$.

Acetic acid 0.5 normal at 2 $A\,t = 135°$ C.

$t_0 = 50$; $[\alpha]^{20}_{D\,386} = 170°$; $A_0 = 64.5$.

50	143	37.5	.2356	.00470	.3561	.00712
100	121	21.4	.4792	.00479	.3225	.00645
150	103	11.8	.7377	.00491	.3058	.00611
200	86	5.2	1.1936	.00597	.4404	.00881
250	74	2.4	1.4294	.00571	.4623	.00924

$C_1 = .00522$. $C_2 = .00755$.

TABLE E. — *Continued.*

Hydrochloric acid 0.01 normal at 1 A $t = 121^\circ$ C.
$t_0 = 40$; $[\alpha]^{20}_{D\,386} = 183^\circ$; $A_0 = 80.7$.

Time t. (Minutes.)	$[\alpha]^{20}_{D\,386}$.	$A_0 - x$.	$\log \frac{A_0}{A_0 - x}$	C_1.	$\frac{D_2 - D_1}{\frac{m_1 + m_2}{2}}$	C_2.
40	168	62.5	.1110	.00277	.1837	.00459
70	158	51.7	.1934	.00276	.1314	.00438
100	149	42.9	.2744	.00274	.1091	.00364
140	137	32.5	.3950	.00282	.1657	.00414
180	126	24.6	.5160	.00287	.1637	.00409
200	120	20.9	.5860	.00293	.0984	.00492
250	107	13.7	.7702	.00308	.2457	.00491

$C_1 = .00285$. $C_2 = .00438$.

Hydrochloric acid 0.01 normal at 2 A $t = 135^\circ$ C.
$t_0 = 20$; $[\alpha]^{20}_{D\,386} = 176^\circ$; $A_0 = 71.6$.

10	162	56.1	.1059	.0106	.1827	.0183
20	148	41.9	.2327	.0116	.1758	.0176
40	128	25.8	.4433	.0111	.2850	.0143
60	110	15.2	.6731	.0110	.2845	.0142
80	93	7.6	.9741	.0127	.3530	.0172
100	81	3.8	1.2751	.0127	.3782	.0184
120	70	1.8	1.6996	.0142	.5475	.0294

$C_1 = .0120$. $C_2 = .0182$.

Hydrochloric acid 0.01 normal at 3 A $t = 145^\circ$ C.
$t_0 = 10$; $[\alpha]^{20}_{D\,386} = 174^\circ$; $A_0 = 69.2$

5	158	51.7	.1265	.0253	.2076	.0425
10	140	35.1	.2948	.0295	.1855	.0590
15	125	23.9	.4617	.0308	.2242	.0616
20	110	15.2	.6583	.0329	.2677	.0658
30	88	5.8	1.0766	.0359	.5353	.0535
40	74	2.4	1.4599	.0365	.5489	.0549
50	65	1.2	1.7609	.0352	.6116	.0611

$C_1 = .0323$. $C_2 = .0569$.

TABLE E. — *Continued.*

Hydrochloric acid 0.01 normal at 4 At — 153° C.

$t_0 = 10$; $[a]^{20}_{D\,386} = 147°$; $A_0 = 41.0$.

Time t. (Minutes.)	$[a]^{20}_{D\,386}$.	$A_0 - x$.	$\log \frac{A_0}{A_0 - x}$.	C_1.	$\frac{D_2 - D_1}{\frac{m_1 + m}{2}}$	C_2.
5	117	19.1	.3318	.0664	.4613	.0923
10	96	8.7	.6733	.0673	.4509	.0902
15	79	3.2	1.1077	.0738	.5351	.1072
20	68	1.6	1.4087	.0704	.5580	.1160
25	61	0.8	1.7097	.0684	.6960	.1392
30	57	0.4	2.0107	.0670	.8847	.1769

$C_1 = .0688.$ $C_2 = .1203.$

Hydrochloric acid 0.04 normal at 3 At = 145° C.

$t_0 = 5$; $[a]^{20}_{D\,386} = 150°$; $A_0 = 43.9$.

3	115	17.8	0.3921	.1307	.5479	.1826
5	95	8.4	0.7182	.1436	.4329	.2165
7	80	3.5	1.0984	.1569	.5017	.2509
10	66	1.4	1.4964	.1496	.7866	.2622
13	58	0.5	1.9435	.1495	1.0400	.3467
15	56	0.4	2.0404	.1360	.6389	.3195

$C_1 = .1444.$ $C_2 = .2631.$

Hydrochloric acid 0.02 normal at 3 At = 145° C.

$t_0 = 10$; $[a]^{20}_{D\,386} = 148°$; $A_0 = 41.9$.

5	116	18.5	0.3550	.0710	.4961	.0992
10	96	8.7	0.6827	.0683	.4903	.0981
15	80	3.5	1.0781	.0672	.4937	.0987
20	69	1.7	1.3918	.0696	.5343	.1069
25	61	0.8	1.7291	.0692	.7003	.1400
30	56	0.4	2.0201	.0673	1.1070	.2214

$C_1 = .0688.$ $C_2 = .1274.$

TABLE E. — *Concluded.*

Hydrochloric acid 0.01 normal at 3 A $t = 145°$ C.

$t_0 = 5$; $[a]^{20}_{D\,386} = 174°$; $A_0 = 69.2$.

Time t. (Minutes.)	$[a]^{20}_{D\,386}$.	$A_0 - x$.	$\log \frac{A_0}{A_0 - x}$.	C_1	$\frac{\frac{D_2 - D_1}{m_1 + m_2}}{2}$	C_2.
5	158	51.7	0.1265	.0253	.2076	.0415
10	140	35.1	0.2948	.0295	.2328	.0465
15	125	23.9	0.4617	.0307	.2294	.0459
20	110	15.2	0.6583	.0329	.2677	.0535
30	88	5.8	1.0767	.0359	.5326	.0533
40	74	2.4	1.4599	.0365	.5489	.0549
50	65	1.2	1.7609	.0332	.6102	.0610

$C_1 = .0320$. $C_2 = .0424$.

Hydrochloric acid 0.005 normal at 3 A $t = 145°$ C.

$t_0 = 20$; $[a]^{20}_{D\,386} = 172°$; $A_0 = 66.8$.

20	142	36.7	0.2601	.00130	.3973	.00189
40	113	16.6	0.6047	.00151	.2418	.00121
60	91	6.7	1.0087	.00168	.5020	.00251
80	77	3.0	1.3577	.00169	.4559	.00223
100	66	1.4	1.6787	.00168	.6701	.00335
120	59	0.6	2.0466	.00171	.7595	.00380

$C_1 = .0159$. $C_2 \doteq .02497$.

At the head of each table are given data as to the concentration and nature of the acid, the temperature corresponding to the steam pressure given in atmospheres, and $[a]^{20}_{D\,386}$ at the initial time period t_0 with the corresponding value of A_0. Time values are expressed in minutes, and the constants c_1 for the hydrolysis of dextrin, c_2 for that of maltose, are calculated according to the formulas given above.

The results show that the constants in general are satisfactory, and that, therefore, the reaction like the sucrose inversion follows the law of the first order. It will also be seen that the values c_1 are much more uniform than those of c_2, which is to be expected since c_1 is absolute, and c_2 only approximate. Deviations of c_1 may be fairly ascribed to variations in temperature, which, though slight, are significant, owing to the high temperature coefficient of the reaction.

The dextrin values in Table C are consequently correct within the limits of error of analysis. It will be seen that the values of c_2 are much more constant in those determinations in which t is larger, and the values of $[a]_D$ decrease slowly. This was to be expected from the conditions of the approximate formula given above for the decomposition of maltose, these requiring that the amount of substance changed in a period of time must be small. The question of reversion may possibly have some influence on the values of c_2, but as yet we are not prepared to express ourselves definitely on this subject.

The relative effects are shown in the following table. Table I shows the influence on the speed of hydrolysis of various acids at the same temperature, 135° C.

Table II shows the influence of temperature on the speed of hydrolysis when the same amount of acid is used.

Table III gives the influence of varying amounts of acid.

The mean value of constants is given in column II. Column III gives the relative value of the constants referred to, that of $\frac{1}{50}N$ hydrochloric acid at 135° taken as 100. Column IV gives the velocity constants determined by Ostwald[1] for cane-sugar inversion by the same acids at half-normal concentration.

TABLE I.

Acid.	Concentration.	II.	III.	IV.
Hydrochloric	0.02 N	0.0242	100	100
Sulphuric	0.02 N	0.0110	50.0	53.6
Oxalic	0.04 N	0.00980	40.8	. . . .
(Oxalic)	(0.02 N)	(0.00249)	(20.4)	18.6
Sulphurous	0.02 N	0.00126	4.79	. . . .
Acetic	0.5 N	0.00522	21.5	. . . .
(Acetic)	(0.02 N)	0.00021	0.8	0.4

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[1] Loc. cit.

TABLE II.

Acid.	Concentration.	Temperature.	I.	II.
Hydrochloric	0.01 N	121	0.00283	11.5
Hydrochloric	0.01 N	134	0.0120	49.7
Hydrochloric	0.01 N	145	0.0323	133.4
Hydrochloric	0.01 N	153	0.0688	284.2

TABLE III.

Acid.	Concentration.	II.	III.
Hydrochloric	0.04 N	0.1413	596.7
Hydrochloric	0.02 N	0.0678	284.3
Hydrochloric	0.01 N	0.0314	132.2
Hydrochloric	0.005 N	0.0155	65.7

It is seen that the corresponding numbers of columns III and IV agree fairly well. The relative influence of the various acids upon the hydrolysis of starch, sucrose, and salicin are, therefore, nearly identical. It should be noted, however, that the chemical activity of hydrochloric acid on starch, as in the case of salicin and cane-sugar, increases in a greater ratio than the concentration, while the electrical conductivity increases more slowly.

The influence of temperature can be explained graphically by a curve approximating a parabola. (Figure 4.)[1]

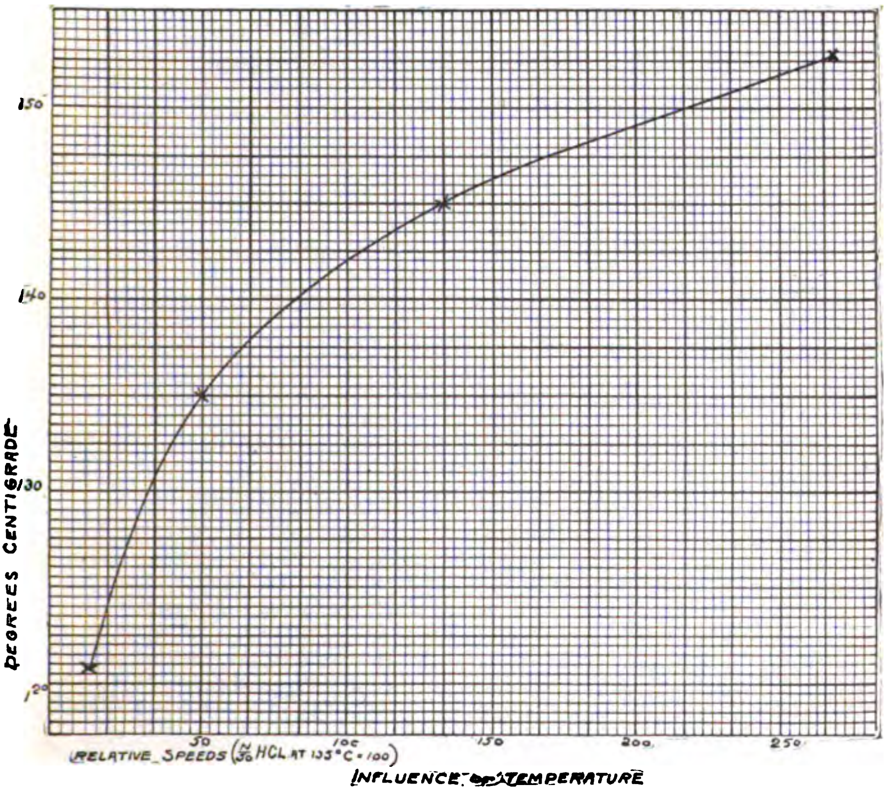

FIG. 4.

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[1] Note that the last plot is accidentally displaced five divisions to the left.

Figure 5 shows the influence of the various acids.

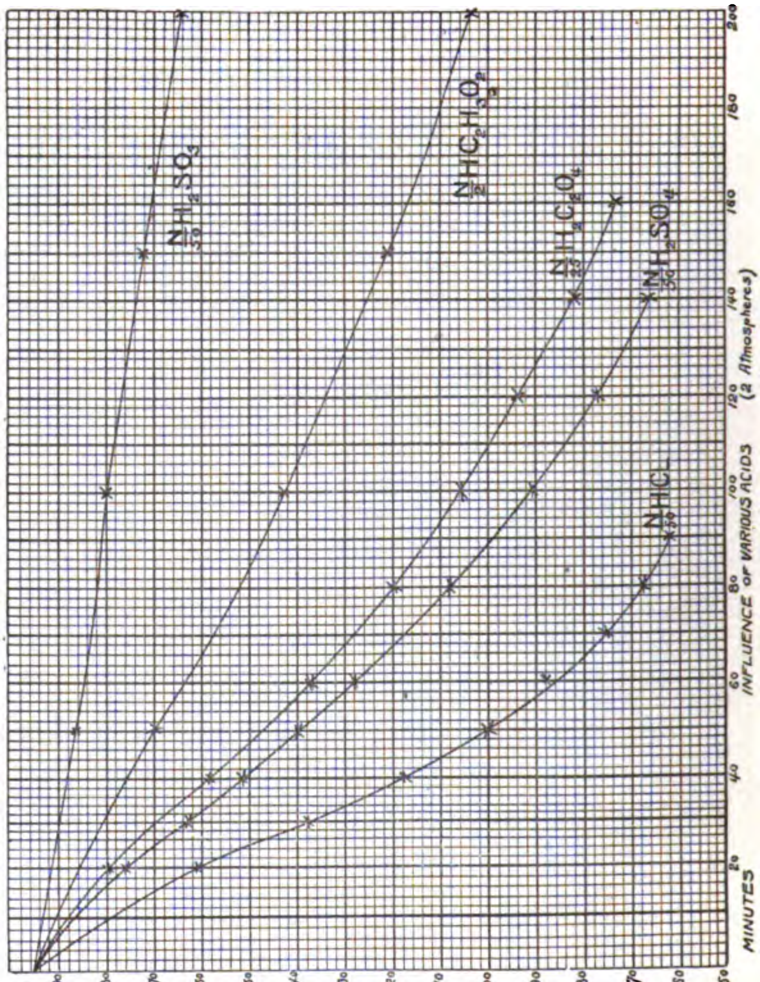

FIG. 5.

Figure 6 shows the influence of the concentration, or amount of acid used.

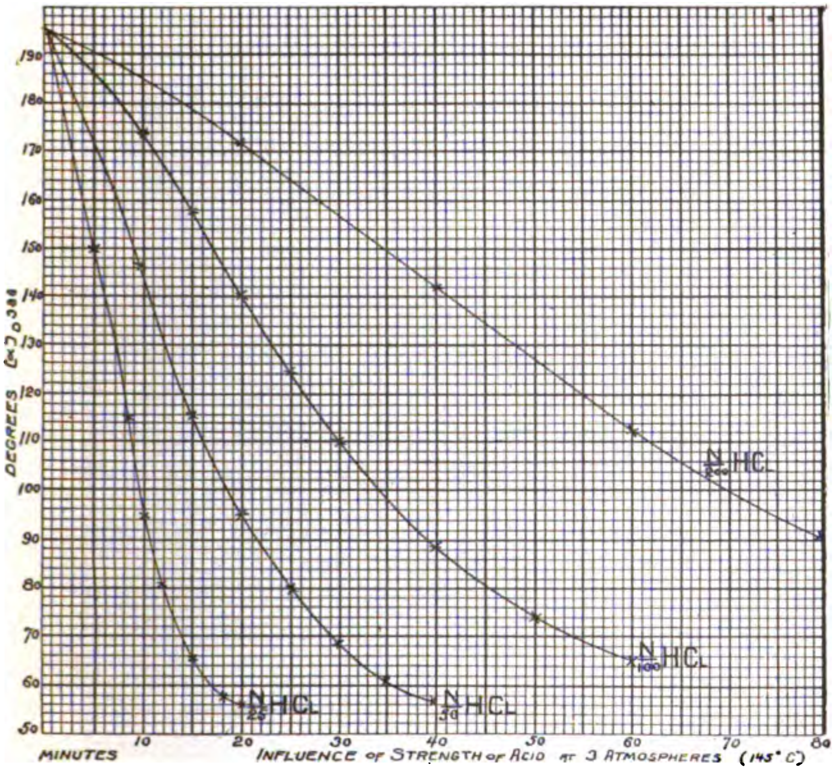

FIG. 6.

Figure 7 shows the relative curves due to temperature.

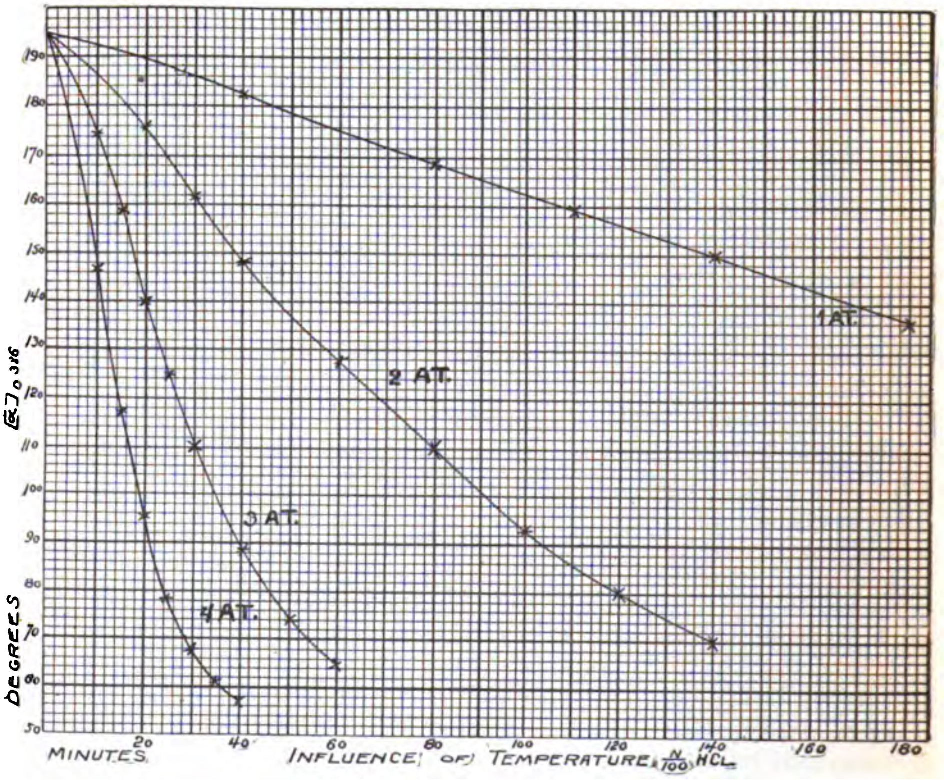

Fig. 7.

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THE DETERMINATION OF REDUCING SUGARS IN TERMS OF CUPRIC OXIDE.[1]

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IT is now approximately fifty years since alkaline metallic solutions were first used in determining quantitatively the various reducing sugars. During this period of time many investigators have worked on the subject, and much has been done towards perfecting the method of analysis, so that to-day there are several admirable processes in use for the exact estimation of these carbohydrates.

The quantitative methods of determining reducing sugars may be divided into two main classes — those based upon the volumetric plan, and those which depend on a gravimetric estimation of the precipitated cuprous oxide.

Of the first class, many processes have been suggested which have met with more or less success. The volumetric methods are mainly used for factory control work, where the progress of some processes requires a rapid and fairly accurate idea of the stage of manufacture. In expert hands the volumetric methods are capable of giving excellent and concordant results, and are, therefore, used in the laboratories of many consulting chemists, and even in scientific institutions.

The main objections to the use of the volumetric methods are that each freshly prepared quantity of Fehling solution requires accurate standardization against pure sugar of the same kind as that which is undergoing analysis. Different dilutions and the time of boiling affect the results materially. The exact determination of the "end-point" also requires considerable practice and skill.

On the other hand, the Fehling liquor used in the gravimetric

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[1] Reprinted from the Journal of the American Chemical Society, 18, No. 9, September, 1896.

processes need not be made up as accurately as is required for volumetric work. The gravimetric methods, however, ordinarily require more time. A possible loss of cuprous oxide by filtration and an incomplete oxidation to the higher oxide are also potent factors, though where the requisite degree of care is exercised these need not cause anxiety. The same statement regarding dilution and time of boiling holds true with as much force in gravimetric as in volumetric work.

The gravimetric methods are generally employed for scientific and accurate analytical work. Here the processes are comparatively few, all depending upon the oxidation of the total sugar present in an excess of the alkaline copper solution.

The tables in use for the determination of reducing sugars are mainly constructed in terms of metallic copper. As the amount of metal precipitated per gram of carbohydrate is not a constant for all dilutions of any sugar, specially constructed tables are generally employed. Several such tables have been prepared, as, for instance, Allihn's table of reduced copper for dextrose, Wein's table for maltose, and Soxhlet's table for lactose, etc.

Various modifications of the alkaline copper solutions are used for the determination of the different sugars, each requiring special treatment. Therefore a chemist in determining the amount of malt sugar in, say beer, must, if he uses Wein's table for maltose, follow exactly Wein's method for the estimation of that sugar.

Where a variety of work is carried on in a laboratory it is therefore necessary to have several different Fehling solutions on hand for each special kind of determination. If all the tables for the estimation of the different carbohydrates could have been prepared for use under uniform conditions, the existing state of affairs would be much simplified.

In order to supply this need, I have constructed such tables, using a method which I have employed for some time in determining reducing sugars. This method, proposed by O'Sullivan[1] in 1876, is used to some extent in England, but as it seems to be not generally known, I here give the procedure in detail:

To 15 cc. of the copper sulphate solution, prepared as given below, are added 15 cc. of the alkaline tartrate solution, in an Erlenmeyer flask having a capacity of from 250–300 cc. The mixture is diluted

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[1] J. Chem. Soc., 2, 130 (1876).

with 50 cc. of freshly boiled distilled water and placed in a boiling water bath for five minutes. 20 to 25 cc. accurately measured from a calibrated burette of an approximately one-half per cent. solution of the sugar to be analyzed are then run into the hot Fehling liquor, and the whole kept in the boiling water bath for from twelve to fifteen minutes. The flask is then removed from the bath, and the precipitated cuprous oxide is filtered as rapidly as possible, either through filter paper or asbestos in a Soxhlet's tube or porcelain Gooch crucible, and washed with boiling distilled water until the wash-water no longer reacts alkaline. It is ignited and weighed as cupric oxide, as described below. The corresponding amounts of dextrose, maltose, or lactose are ascertained by reference to the tables at the end of this article. It should be noted that the above directions must be closely followed. The volume of the Fehling liquor and the added sugar solution should be from 100–105 cc.

The Fehling solution used is made up according to Soxhlet's formula, with a very slight modification. 69.278 grams of pure crystallized copper sulphate, pulverized and dried between filter paper, are dissolved in distilled water. It is advantageous to add 1 cc. of strong sulphuric acid to this, as recommended by Sutton.[1] The whole is then made up to one liter with distilled water and kept in a separate bottle. The alkaline tartrate solution is made by dissolving 346 grams of crystalline Rochelle salt and 100 grams of sodium hydroxide in distilled water and making up to one liter. This is also kept in a separate bottle.

Two methods of filtration of the precipitated cuprous oxide and further treatment are generally adopted. In the first, double "washed" filter paper is used; in the other the precipitate is retained by a layer of asbestos. After washing the precipitate on the filter paper as above described, it is dried in the usual manner and ignited in a previously weighed porcelain crucible, taking care to burn the filter paper cautiously, heating for fifteen minutes to a red heat, cooling the crucible over sulphuric acid in a desiccator, and weighing as cupric oxide. Additional treatment with nitric acid has been found of no practical advantage, the results by direct ignition being very exact, providing the filter paper is slowly burned. The chief objection to the employment of filter paper to retain the precipitated cuprous oxide is that

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[1] Sutton: Vol. Anal., fourth edition, 256 (1882).

some of the finely divided particles are liable to go through, thus causing low results.

As a substitute for paper, carefully selected asbestos is often used for filtering purposes. To insure a layer of asbestos which shall be kept at constant weight under the action of hot Fehling liquor, it is advantageous to boil the mineral with nitric acid (1.05–1.10 sp. gr.) for a short time, washing the acid out with hot water, and then boiling with a 25 per cent. solution of sodium hydroxide. This is also washed out with hot water. Reboiling with the above reagents as before diminishes the liability of leaving any soluble portions. As thus prepared the filtering material may be kept indefinitely under water in a wide-mouthed bottle ready for use.

The objections of some chemists[1] to the employment of asbestos, on the ground that it loses weight on using, does not seem to hold when it is prepared as above. A sample boiled as stated with acid and alkali three times lost only two-tenths milligram when two "blanks" of hot dilute Fehling solution, as used in the process above described, were passed through the mineral in a porcelain Gooch crucible.

For use, a layer of asbestos, about 1 cm. in thickness, is placed in a porcelain Gooch crucible to retain the finely divided precipitate, which is filtered by means of suction in the usual manner. The crucible containing the cuprous oxide is then dropped into a triangular frame made of platinum wire, suspended within an iron radiator, or shell, heated to redness. This quickly and thoroughly dries the asbestos without cracking the crucible. After about five minutes the crucible is transferred by means of a pair of nippers to a red-hot platinum crucible, and heated for about fifteen minutes. It is then quickly transferred to a desiccator near at hand to prevent cracking, allowed to cool, and weighed. As cupric oxide is somewhat hygroscopic, it is advantageous to weigh quickly and to keep the balance case as dry as possible. Prolonged heating in the iron radiator would have changed the cuprous oxide to the cupric state. The advantage of transferring the porcelain crucible to a red-hot platinum crucible is that the oxidation is quickly completed, as a much higher temperature is available.

If pressed for time, another determination can be made in the same crucible without cleaning it. As a rule, it is, however, advisable

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[1] Killing: Ztschr. angew. Chem., 431 (1894); Praeger: Ztschr. angew. Chem., 520 (1894).

to wash out the cupric oxide by means of hot nitric acid (1.05–1.10 sp. gr.) and then with hot water. The crucible is then heated, cooled, and weighed as before. It must necessarily be weighed, because this treatment with hot nitric acid dissolves some of the asbestos.

If preferred, a Soxhlet's tube may be used to retain the precipitated cuprous oxide. As a porcelain Gooch crucible possessed obvious advantages over this apparatus, I have used it in all my determinations with success.

The cupric reducing powers of dextrose, maltose, and lactose were determined by the method given above. A table for invert sugar was not constructed, because most invert sugar determinations are made by double polarization in a saccharimeter.

DEXTROSE.

The "cupric reducing power" of dextrose was first determined. This is defined as "the amount of cupric oxide which 100 parts reduce."[1] This may be represented by $\frac{100\ W}{D}$, in which W is the weight of cupric oxide obtained by the given weight of any sugar, and D the weight of cupric oxide formed by an equal weight of dextrose.[2] Hence, if the amount of cupric oxide formed by 1 gram of dextrose be known, the amount of cupric oxide reduced by 1 gram of any other substance, calculated upon this number as a percentage, will represent the cupric oxide reducing power of the substance, which we denote by the symbol K.

The amount of cupric oxide has been determined by O'Sullivan[3] to be 2.205 grams per gram dextrose. The factor for dextrose in terms of cupric oxide is, therefore, the reciprocal of 2.205 or 0.4535. This value, 0.4535, was assumed to be a constant for all amounts of dextrose when used with Fehling's solution in the manner indicated. As such, it was a very convenient quantity, it being only necessary to obtain the weight of cupric oxide formed by the action of a dextrose solution, multiply this by 0.4535, and the amount of dextrose corresponding was obtained. No tables are needed if this assumption be true. Consequently, the determination of dextrose was indeed a very simple one.

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[1] J. Chem. Soc., 2, 130 (1876).

[2] J. Chem. Soc., Trans., 606 (1879).

[3] Loc. cit.

On an extended investigation of this subject, using various amounts of dextrose on the same volume of Fehling liquor in each determination, I find that the value of 2.205, above given as representing the quantity of cupric oxide obtained by the action of 1 gram of dextrose, is not, as was heretofore assumed, a constant for all weights of dextrose taken, the amount varying from 2.27 grams cupric oxide per gram dextrose for small quantities of sugar to 2.22 grams cupric oxide for the largest amount of dextrose permissible. Allihn,[1] boiling his sugar solutions with the Fehling liquor and reducing the cuprous oxide to copper, obtained analogous varying results.

The purity of the dextrose used was first determined, dextrose anhydride being employed. 10.008 grams of anhydrous dextrose were dissolved in distilled water, and the solution boiled to prevent birotation. It was then transferred to a flask, the capacity of which at 15.5° C. was 100.08 cc., thus giving a solution which contained 0.100 gram dextrose anhydride per cubic centimeter.

The specific gravity of the above solution at 15.5° was determined in the usual manner by means of a picnometer, with thermometer attached.

Capacity picnometer (at 15.5°) = 55.2055 cc.
Dextrose solution (at 15.5°) = 57.3083 grams.

On calculating from these values, we find the specific gravity of a dextrose solution containing 10 grams dextrose in 100 cc. to be 1.03809 at 15.5°.

The specific rotatory power was determined by the usual method, a Schmidt and Haensch saccharimeter being used in polarizing the dextrose solution. The polarizations were carried out in a 200 mm. tube at 20°. To change from the readings of a saccharimeter to the rotary degrees, it is necessary to multiply the reading observed by 0.344, as shown by Rimbach.[2] I have verified this value with concordant results, a Laurent polariscope being used for comparison. The rotation of the above solution was 30.7 divisions. This gives by means of the usual formula — $[\alpha]^{20}_{D} = \frac{av}{lw}$ — a specific rotatory power of 52.8°, which is in accordance with that obtained by other observers.[3] The dextrose used was consequently pure.

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[1] J. prakt. Chem. (2), **22**, 63.

[2] Ber. d. chem. Ges., **27**, 2282.

[3] Pribram: Monat. f. Chem., **9**, 399; Landolt: Ber. d. chem. Ges., **21**, 191.

For the determination with Fehling liquor, 25 cc. of the dextrose solution at 15.5° were accurately measured from a calibrated burette and made up to 500 cc. with distilled water at the same temperature. This consequently gave a solution each cubic centimeter of which contained 5 mg. dextrose. Various quantities of this were then taken to ascertain the cupric reducing power of dextrose. The results in detail are given below. In each case the combined volumes of the Fehling liquor and the sugar solution were made up to 105 cc., as described above.

Milligrams dextrose.	Cupric oxide obtained.	Cupric oxide per gram dextrose.	Dextrose equivalent.	Mean dextrose equivalent.
12½	0.0283	2.264	0.4416	0.4401
12½	0.0285	2.280	0.4386	
25	0.0569	2.276	0.4393	0.4419
25	0.0565	2.260	0.4425	
50	0.1129	2.258	0.4429	0.4440
50	0.1123	2.246	0.4452	
62½	0.1407	2.251	0.4443	0.4449
62½	0.1403	2.245	0.4454	
75	0.1683	2.244	0.4457	0.4462
75	0.1679	2.239	0.4467	
100	0.2233	2.233	0.4478	0.4483
100	0.2227	2.227	0.4489	
125	0.2776	2.221	0.4503	0.4503
125	0.2782	2.225	0.4493	
125	0.2770	2.216	0.4512	
125	0.2774	2.219	0.4506	
125	0.2777	2.222	0.4500	
140	0.3105	2.218	0.4508	0.4511
140	0.3100	2.215	0.4515	

The foregoing values of the amounts of cupric oxide per gram dextrose are given graphically in curve *A*, Figure 1, and the dextrose equivalents of this in *A*, Figure 2.

From this we get the amount of dextrose corresponding to a given weight of copper oxide by means of the formula:

$$D = (0.4400 + 0.000037\,W)\,W,$$

in which D is the amount of dextrose, and W the weight of cupric oxide.

The dextrose table given in this article is based on this formula, the values of W varying from 30 to 320.

MALTOSE.

The cupric reducing power of dextrose is given as 100. Using this as a basis, the reducing force of maltose, as given by O'Sullivan,[1] is 65. Brown and Heron[2] place the value somewhat lower, claiming that 61 is more exact. The results which I have obtained agree very well with this latter number.

In the case of maltose, as with dextrose, it was found that the amount of cupric oxide obtained per gram of sugar was not a constant. The cupric reducing power of various amounts of maltose was, however, found to be almost exactly a constant when referred to the cupric oxide from equal weights of dextrose. That is, calling the reducing power of dextrose 100 for different aliquot parts of that sugar, the cupric reducing power of maltose referred to this standard was always 61.

The specific gravity of .maltose was determined in the usual manner. 9.7558 grams maltose anhydride were dissolved in distilled water to 100.08 cc. at 15.5°.

Maltose solution at 15.5° = 57.3049 grams.

On calculating this we find the specific gravity of the above solution to be 1.03803. For a solution containing 10 grams maltose anhydride in 100 cc. it would consequently be 1.03900 at 15.5°.

The specific rotatory power was determined as usual. The rotation of the above solution at 20° in a 200 mm. tube was 77.4 divisions on the saccharimeter scale. This gives $[\alpha]_D^{20} = 136.6^\circ$.

As maltose anhydride is somewhat difficult to prepare, the solutions used to determine the cupric reducing powers were made up to approximately 10 per cent. from the maltose hydrate. The specific gravity of the solutions was then determined. Subtracting from this value 1.00000 — the specific gravity of water — and dividing the remainder by 0.00390, we get the amount of maltose anhydride in 100 cc. of solution.

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[1] Loc. cit.

[2] J. Chem. Soc., Trans., 619 (1879).

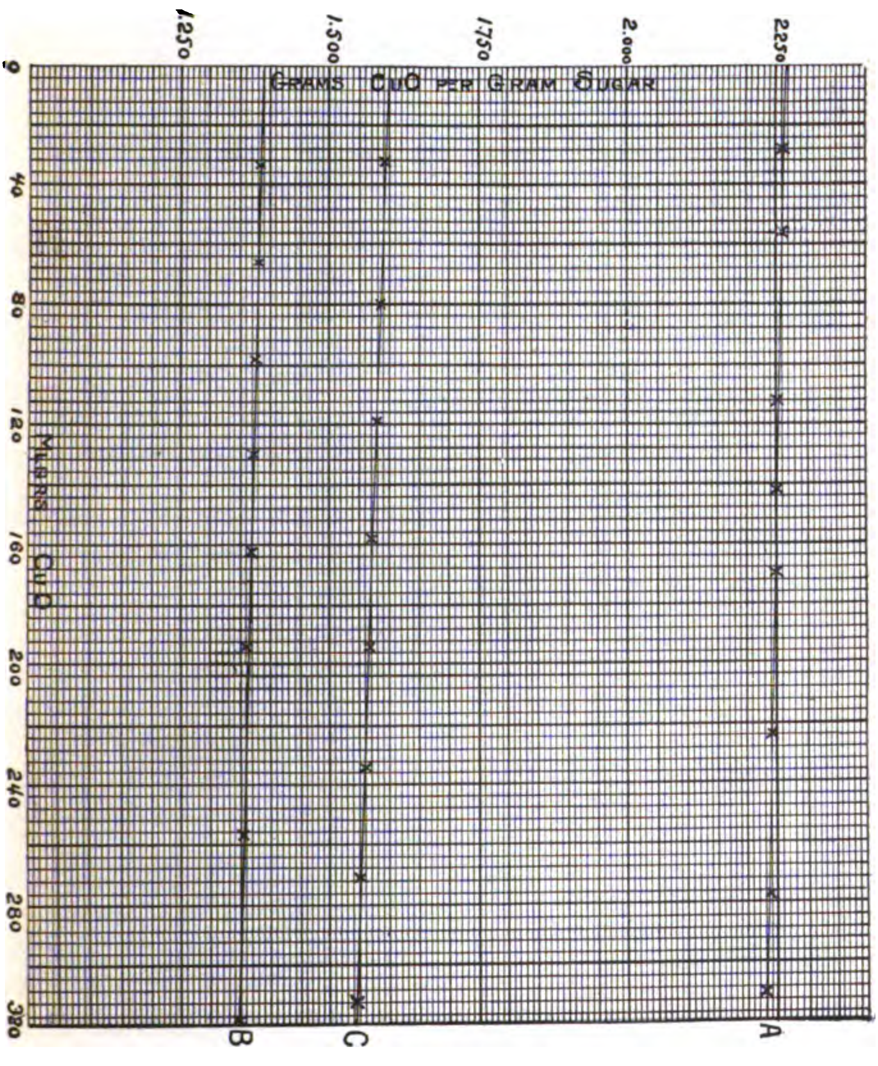

FIG. 1. GRAMS OF CUPRIC OXIDE PER GRAM OF SUGAR AT VARIOUS DEGREES OF DILUTION. *A*, DEXTROSE. *B*, MALTOSE. *C*, LACTOSE.

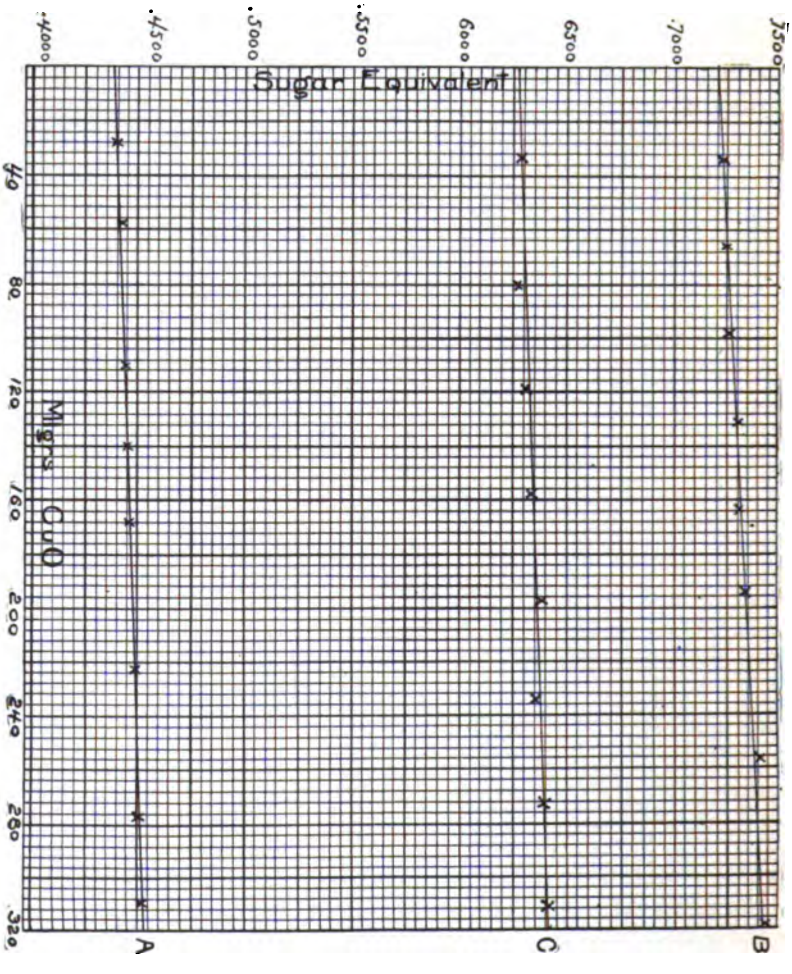

Fig. 2. Sugar Equivalent Corresponding to Amount of Cupric Oxide Obtained. *A*, Dextrose. *B*, Maltose. *C*, Lactose.

Maltose solution at 15.5° = 57.2511 grams,

which gives a specific gravity of 1.037054, or 9.501 grams maltose anhydride in 100 cc.

The solution for Fehling determinations was made in the same manner as the dextrose solutions above. Each cubic centimeter of the diluted maltose solution therefore contained 4.75 mg. maltose anhydride.

Milligrams maltose.	Cupric oxide obtained.	Cupric oxide per gram maltose.	Maltose equivalent.	Mean maltose equivalent.
23.75	0.0329	1.386	0.7218	0.7240
23.75	0.0327	1.377	0.7263	
47.5	0.0656	1.381	0.7243	0.7253
47.5	0.0654	1.377	0.7263	
71.25	0.0983	1.380	0.7247	0.7263
71.25	0.0979	1.374	0.7278	
95.0	0.1304	1.373	0.7286	0.7297
95.0	0.1300	1.369	0.7308	
118.75	0.1623	1.370	0.7302	0.7319
118.75	0.1619	1.367	0.7336	
142.5	0.1940	1.361	0.7345	0.7354
142.5	0.1934	1.357	0.7369	
190.0	0.2572	1.353	0.7284	0.7395
190.0	0.2566	1.350	0.7406	
237.5	0.3198	1.347	0.7429	0.7433
237.5	0.3193	1.345	0.7437	

The maltose equivalent in terms of copper oxide is shown in *B*, Figure 2. From this we get the amount of maltose corresponding to a given weight of cupric oxide by the formula:

$$M = (0.7215 + 0.000061\ W)\ W,$$

in which M is the weight of maltose, and W the amount of cupric oxide obtained. It will be seen that these values make the cupric reducing power of maltose 0.61 that of dextrose.

LACTOSE.

Lactose was investigated in the same manner as the preceding. 10.008 grams lactose anhydride were dissolved in distilled water, boiled, and made up to 100.08 cc. at 15.5°.

The above solution, polarized in a 200 mm. tube at 20°, gave a rotation of 30.7 divisions. This gives the specific rotatory power of lactose of 52.8°.

The amounts of cupric oxide found by the reduction of known weights of lactose were determined as in the previous cases, with the following results:

Milligrams lactose.	Cupric oxide obtained.	Cupric oxide per gram lactose.	Lactose equivalents.	Mean lactose equivalents.
20	0.0319	1.595	0.6269	0.6289
20	0.0317	1.585	0.6308	
50	0.0798	1.596	0.6266	0.6274
50	0.0796	1.592	0.6282	
75	0.1188	1.584	0.6313	0.6323
75	0.1184	1.579	0.6334	
100	0.1577	1.577	0.6340	0.6355
100	0.1570	1.570	0.6369	
125	0.1955	1.564	0.6395	0.6379
125	0.1964	1.561	0.6363	
150	0.2345	1.563	0.6397	0.6404
150	0.2340	1.560	0.6410	
175	0.2729	1.560	0.6412	0.6418
175	0.2724	1.557	0.6424	
200	0.3112	1.556	0.6425	0.6430
200	0.3107	1.553	0.6436	

The cupric oxide values per gram lactose are presented graphically in curve *C*, Figure 1, while the reciprocals of these quantities are shown in *C*, Figure 2. For this latter the amount of lactose corresponding to the weight of cupric oxide obtained is determined by the following:

$$L = (0.6270 + 0.000053\ W)\ W,$$

in which L is the lactose, and W the amount of copper oxide. The accompanying table for lactose is constructed on this basis.

* * * * * * *

It will be seen from the above results that the amount of cupric oxide produced by the action of 1 gram of reducing carbohydrate on Fehling liquor, in the manner described, is not a constant for all dilutions.

The cupric reducing power of maltose is 0.61 that of dextrose.

The following tables for the determination of the reducing sugars in terms of cupric oxide are based on the analytical results presented above, and can be used in the process outlined in the same manner as any other table for the same purpose:

Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.
30	13.2	21.7	18.8	89	39.4	64.7	56.2
31	13.7	22.4	19.5	90	39.9	65.5	56.8
32	14.1	23.1	20.1	91	40.3	66.2	57.4
33	14.6	23.9	20.7	92	40.8	66.9	58.1
34	15.0	24.6	21.4	93	41.2	67.7	58.7
35	15.4	25.3	22.0	94	41.7	68.4	59.3
36	15.9	26.1	22.6	95	42.1	69.1	60.0
37	16.3	26.8	23.3	96	42.5	69.9	60.6
38	16.8	27.5	23.9	97	43.0	70.6	61.2
39	17.2	28.3	24.5	98	43.4	71.3	61.9
40	17.6	29.0	25.2	99	43.9	72.1	62.5
41	18.1	29.7	25.8	100	44.4	72.8	63.2
42	18.5	30.5	26.4	101	44.8	73.5	63.8
43	19.0	31.2	27.1	102	45.3	74.3	64.4
44	19.4	31.9	27.7	103	45.7	75.0	65.1
45	19.9	32.7	28.3	104	46.2	75.7	65.7
46	20.3	33.4	29.0	105	46.6	76.5	66.3
47	20.7	34.1	29.6	106	47.0	77.2	67.0
48	21.2	34.8	30.2	107	47.5	77.9	67.6
49	21.6	35.5	30.8	108	48.0	78.7	68.2
50	22.1	36.2	31.5	109	48.4	79.4	68.9
51	22.5	37.0	32.1	110	48.9	80.1	69.5
52	23.0	37.7	32.7	111	49.3	80.9	70.1
53	23.4	38.4	33.3	112	49.8	81.6	70.8
54	23.8	39.2	34.0	113	50.2	82.3	71.4
55	24.2	39.9	34.6	114	50.7	83.1	72.0
56	24.7	40.5	35.2	115	51.1	83.8	72.7
57	25.1	41.3	35.9	116	51.6	84.5	73.3
58	25.5	42.1	36.5	117	52.0	85.2	74.0
59	26.0	42.8	37.1	118	52.4	85.9	74.6
60	26.4	43.5	37.8	119	52.9	86.6	75.2
61	26.9	44.3	38.4	120	53.3	87.4	75.9
62	27.3	45.0	39.0	121	53.8	88.1	76.6
63	27.8	45.7	39.7	122	54.2	88.9	77.2
64	28.2	46.5	40.3	123	54.7	89.6	77.9
65	28.7	47.2	40.9	124	55.1	90.3	78.5
66	29.1	47.9	41.6	125	55.6	91.1	79.1
67	29.5	48.6	42 2	126	56.0	91.8	79.8
68	30.0	49.4	42.8	127	56.5	92.5	80.4
69	30.4	50.1	43.5	128	56.9	93.3	81.1
70	30.9	50.8	44.1	129	57.3	94.0	81.7
71	31.3	51.6	44.7	130	57.8	94.8	82.4
72	31.8	52.3	45.4	131	58.2	95.5	83.0
73	32.2	53.0	46.0	132	58.7	96.2	83.6
74	32.6	53.8	46.6	133	59.1	97.0	84.2
75	33.1	54.5	47 3	134	59.6	97.7	84.9
76	33.5	55.2	47.9	135	60.0	98.4	85.5
77	34.0	56.0	48.5	136	60.5	99.2	86.1
78	34.4	56.7	49.2	137	60.9	99.9	86.8
79	34.9	57.4	49.8	138	61.3	100.7	87.4
80	35.4	58.1	50.5	139	61.8	101.4	88.1
81	35.9	58.9	51.1	140	62.2	102.1	88.7
82	36 3	59.6	51.7	141	62.7	102.8	89.3
83	36.8	60.3	52.4	142	63.1	103.5	90.0
84	37.2	61.1	53.0	143	63.6	104.3	90.6
85	37.7	61.8	53.6	144	64.0	105.0	91.3
86	38.1	62.5	54.3	145	64.5	105.8	91.9
87	38.5	63.3	54.9	146	64.9	106.5	92.6
88	39.0	64.0	55.5	147	65.4	107.2	93.2

Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.
148	65.8	108.0	93.9	207	92.6	151.8	132.1
149	66.3	108.7	94.5	208	93.1	152.5	132.8
150	66.8	109.5	95.2	209	93.5	153.3	133.4
151	67.3	100.2	95.8	210	94.0	154.1	134.1
152	67.7	111.0	96.5	211	94.4	154.8	134.7
153	68.3	111.7	97.1	212	94.9	155.6	135.4
154	68.7	112.4	97.8	213	95.3	156.3	136.0
155	69.2	113.2	98.4	214	95.8	157.1	136.7
156	69.6	113.9	99.1	215	96.3	157.8	137.3
157	70.0	114.7	99.7	216	96.7	158.6	138.0
158	70.5	115.4	100.4	217	97.2	159.3	138.6
159	70.9	116.1	101.0	218	97.6	160.0	139.3
160	71.3	116.9	101.7	219	98.1	160.8	139.9
161	71.8	117.6	102.3	220	98.6	161.5	140.6
162	72.3	118.4	103.0	221	99.0	162.3	141.2
163	72.7	119.1	103.6	222	99.5	163.0	141.9
164	73.2	119.9	104.3	223	99.9	163.7	142.5
165	73.6	120.6	104.9	224	100.4	164.5	143.2
166	74.1	121.4	105.6	225	100.9	165.3	143.8
167	74.5	122.1	106.2	226	101.3	166.0	144.5
168	74.9	122.9	106.9	227	101.8	166.8	145.1
169	75.4	123.6	107.5	228	102.2	167.5	145.8
170	75.8	124.4	108.2	229	102.7	168.3	146.4
171	76.3	125.1	108.8	230	103.1	169.1	147.0
172	76.8	125.8	109.5	231	103.6	169.8	147.7
173	77.3	126.6	110.1	232	104.0	170.6	148.3
174	77.7	127.3	110.8	233	104.5	171.3	149.0
175	78.2	128.1	111.4	234	105.0	172.1	149.6
176	78.6	128.8	112.0	235	105.4	172.8	150.3
177	79.1	129.5	112.6	236	105.9	173.6	150.9
178	79.5	130.3	113.3	237	106.3	174.3	151.6
179	80.0	131.0	113.9	238	106.8	175.1	152.2
180	80.4	131.8	114.6	239	107.2	175.8	152.9
181	80.8	132.5	115.2	240	107.7	176.6	153.5
182	81.3	133.2	115.8	241	108.1	177.3	154.2
183	81.8	134.0	116.5	242	108.6	178.1	154.8
184	82.2	134.7	117.1	243	109.0	178.8	155.5
185	82.7	135.5	117.8	244	109.5	179.6	156.1
186	83.1	136.2	118.4	245	109.9	180.3	156.8
187	83.5	136.9	119.1	246	110.4	181.1	157.4
188	84.0	137.7	119.7	247	110.9	181.8	158.1
189	84.4	138.4	120.4	248	111.3	182.6	158.7
190	84.9	139.1	121.0	249	111.8	183.3	159.4
191	85.4	139.9	121.7	250	112.3	184.1	160.0
192	85.9	140.6	122.3	251	112.7	184.8	160.7
193	86.3	141.4	123.0	252	113.2	185.5	161.3
194	86.8	142.1	123.6	253	113.7	186.3	162.0
195	87.2	142.8	124.3	254	114.1	187.1	162.6
196	87.7	143.6	124.9	255	114.6	187.8	163.3
197	88.1	144.3	125.6	256	115.0	188.6	163.9
198	88.6	145.1	126.2	257	115.5	189.3	164.6
199	89.0	145.8	126.9	258	116.0	190.1	165.2
200	89.5	146.6	127.5	259	116.4	190.8	165.9
201	89.9	147.3	128.2	260	116.9	191.6	166.5
202	90.4	148.1	128.8	261	117.3	192.4	167.2
203	90.8	148.8	129.5	262	117.8	193.1	167.8
204	91.3	149.6	130.1	263	118.3	193.9	168.1
205	91.7	150.3	130.8	264	118.7	194.6	169.5
206	92.2	151.1	131.5	265	119.2	195.4	169.8

Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.	Parts copper oxide.	Parts dextrose.	Parts maltose.	Parts lactose.
266	119.6	196.1	170.4	294	132.5	217.4	188.9
267	120.1	196.9	171.1	295	133.0	218.2	189.5
268	120.6	197.7	171.7	296	133.4	218.9	190.2
269	121.0	198.4	172.4	297	133.9	219.7	190.8
270	121.4	199.2	173.0	298	134.3	220.4	191.5
271	121.9	199.9	173.7	299	134.8	221.2	192.1
272	122.4	200.7	174.4	300	135.3	221.9	192.8
273	122.8	201.5	175.0	301	135.7	222.7	193.4
274	123.3	202.2	175.7	302	136.2	223.5	194.1
275	123.7	203.0	176.3	303	136.6	224.2	194.7
276	124.2	203.7	177.0	304	137.1	225.0	195.3
277	124.6	204.5	177.6	305	137.6	225.8	196.0
278	125.1	205.2	178.3	306	138.0	226.5	196.6
279	125.6	206.0	178.9	307	138.5	227.3	197.3
280	126.1	206.8	179.6	308	138.9	228.1	197.9
281	126.5	207.5	180.2	309	139.4	228.8	198.6
282	127.0	208.3	180.9	310	139.9	229.6	199.3
283	127.4	209.0	181.5	311	140.3	230.4	199.9
284	127.9	209.8	182.2	312	140.8	231.1	200.6
285	128.3	210.5	182.9	313	141.2	231.9	201.3
286	128.8	211.3	183.6	314	141.7	232.7	202.0
287	129.3	212.1	184.2	315	142.2	233.4	202.6
288	129.7	212.8	184.9	316	142.6	234.2	203.3
289	130.2	213.6	185.6	317	143.1	234.9	203.9
290	130.6	214.3	186.2	318	143.6	235.7	204.6
291	131.1	215.1	186.9	319	144.0	236.5	205.3
292	131.5	215.9	187.6	320	144.5	237.2	205.9
293	132.0	216.6	188.2				

SUPPLEMENTARY TABLE FOR GLUCOSE ANALYSIS.

The amounts of cupric oxide given above are those obtained by the use of absolute weights of sugar. The tables are constructed on this basis. In the case of a mixed product, like commercial glucose, which may be considered made up of the simple bodies dextrin, maltose, and dextrose, it is far more convenient to determine the total carbohydrates present in solution by means of the specific gravity than by drying the glucose, and obtaining in this way the total solids. For this purpose an arbitrary value is taken which shall represent the influence of 1 gram of a mixture of the three substances above mentioned, on the specific gravity if dissolved to 100 cc. in distilled water. Brown and Heron[1] claim that this influence on the specific gravity of 1 gram starch conversion product in 100 cc. is 0.00386. This value has been determined to be correct for solutions of cane sugar, and is much used for glucose work

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[1] Loc. cit.

As above mentioned, the specific gravity of a dextrose solution containing 10 grams dextrose anhydride in 100 cc. is 1.03809 at 15.5°. To determine the cupric reducing power of a substance, using the value 3.86 as a divisor, it therefore becomes necessary to change the figures given in the tables to conform to this new factor; that is, the dextrose equivalents must be multiplied by $\frac{386}{381}$, which has been done for convenience of reference in the following table:

Copper oxide obtained.	Dextrose equivalent.	Copper oxide obtained.	Dextrose equivalent.	Copper oxide obtained.	Dextrose equivalent.
5	0.4461	115	0.4502	225	0.4543
10	0.4463	120	0.4504	230	0.4545
15	0.4465	125	0.4506	235	0.4547
20	0.4467	130	0.4508	240	0.4549
25	0.4468	135	0.4510	245	0.4551
30	0.4470	140	0.4512	250	0.4553
35	0.4472	145	0.4513	255	0.4555
40	0.4474	150	0.4515	260	0.4557
45	0.4476	155	0.4517	265	0.4558
50	0.4478	160	0.4519	270	0.4560
55	0.4480	165	0.4521	275	0.4562
60	0.4482	170	0.4523	280	0.4564
65	0.4484	175	0.4525	285	0.4566
70	0.4485	180	0.4527	290	0.4568
75	0.4487	185	0.4528	295	0.4570
80	0.4489	190	0.4530	300	0.4572
85	0.4491	195	0.4532	305	0.4574
90	0.4493	200	0.4534	310	0.4576
95	0.4495	205	0.4536	315	0.4578
100	0.4497	210	0.4538	320	0.4580
105	0.4498	215	0.4540		
110	0.4500	220	0.4542		

Thus a solution containing 100 mg. of mixed carbohydrates, using the factor 0.00386, if it formed 200 mg. cupric oxide by reduction of the Fehling solution in the manner above described, would have a cupric reducing power, or K_{886}, of 90.68.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
BOSTON, MASS.

MICRO-ORGANISMS AND STERILIZING PROCESSES IN THE CANNING INDUSTRY.

BY SAMUEL C. PRESCOTT AND W. LYMAN UNDERWOOD.

Read October 8, 1896.

THE process of hermetically sealing food materials in jars or cans and their subsequent sterilization by heat has become an enormous and most important industry. From a sanitary point of view, canned foods are of the highest value, because if properly prepared they are free from all bacteria. The enormous use of these goods testifies to the high regard with which they are held, and sanitarians cannot fail to view this fact with satisfaction.

The magnitude of the canning industry at present may be indicated by figures showing the number of cans packed annually, in the United States alone, of some of the larger branches.

Sardines,	80,000,000 cans.	Corn,	72,000,000 cans.
Salmon,	96,000,000 cans.	Tomatoes,	120,000,000 cans.

Oysters (in Baltimore alone), 1,250,000 bushels.

Besides these are packed very extensively, lobsters, clams, meats, soups, peas, beans, and fruits.

It occasionally happens that deterioration and loss of some food materials so prepared may result if the sterilization, or as it is known to the trade, "processing," is not conducted in a thorough and scientific manner. This trouble is not confined to any one class of foods, but may be encountered in vegetables, meats, fish, oysters, clams, and lobsters, although it is a notable fact that spiced goods usually keep indefinitely.

At the suggestion and under the supervision of Professor Sedgwick we have made a careful experimental study of one branch of the industry, viz., the packing of clams and lobsters.

It is generally believed that the canning industry was originated by Nicholas Appert,[1] a Frenchman, who in 1810 preserved fruit by

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[1] Appert: Art of Preserving Animal and Vegetable Substance. (London, 1812.) Bigelow: Elements of Technology, p. 499. (1831.) Edinburgh Review, 23, p. 104.

heating and hermetically sealing in glass jars. Probably the first to adopt these methods in America was William Underwood, an Englishman, who in 1821 began in Boston to preserve foods according to Appert's methods. These methods of Appert were followed until about 1840, when glass jars were largely displaced by tin cans. This substitution, it is believed, originated a year or two before with Charles Mitchell, a Scotchman, who packed corn and lobsters in tin cans near Eastport, Maine.

The advent of tin cans caused the first great stride in the business, as it opened a large field for work in the preservation of meat, vegetables, and fish. Salmon was probably first packed at St. Johns, N. B., in 1839, and shipped directly to the Pacific coast, while at present salmon packing is confined to the Pacific States. About the same time oysters shipped in barrels from Baltimore were packed in Boston. Everything in connection with the process was kept as secret as possible, therefore only a few firms were enabled to engage in the business, but gradually through employees the process became more public. During the war the trade was given a tremendous impetus through the government's requiring canned food supplies for the army, and since the war the growth of the industry has been constant and steady.

With the increased demand for canned goods came also the necessity for better methods. The old method of procedure in packing fish was as follows: After packing and sealing, the cans were heated for an hour in boiling water, then taken out and "tapped" or vented in order to expel air and produce a vacuum, sealed again and boiled for an hour and a half, again tapped and sealed and given a final boiling of three hours. Thus the total time of heating was five and one-half hours, and in many cases even more time was given.

It was formerly believed that the vacuum was the principal factor in keeping the goods, a belief still clung to by many packers. The vacuum, although unnecessary for sterilization, is necessary for inspection. Before the cans are put on the market each one is thoroughly examined to detect any unsoundness, or what is known to the trade as "swells." This examination consists of inspection and sounding the cans after "processing," *i. e.*, sterilization. Sound cans should show a vacuum, as indicated by concavity of the ends, and should emit a peculiar note when struck. On the other hand, unsound cans which have not yet swelled give a characteristic dull tone when struck. By the difference in the quality of the tones a skilled inspector can instantly distinguish between sound and unsound cans. Any cans not showing a vacuum are rejected, the annual loss resulting from this source being very large. After inspection the cans are generally put in stacks, and before leaving the packer are again examined. It sometimes happens, however, that spoiling without swelling occurs. For the detection of such cases, special methods must be employed. Such cases are sometimes found in canned clams, and more frequently in lobster, in the latter case being known to the trade as "black lobster."

Since long continued heating tends to disintegrate and darken the foods which it is desired to preserve as fresh as possible, it has always been the aim of packers to reduce the bath time as much as possible. Consequently there has been a gradual shortening of the time of heating in the water bath, until at present the average treatment by this method is from two and one-half to three hours, divided into two periods.

In 1863 a "chemical bath," consisting of calcium chloride, was introduced to some extent. Owing to the large amount of the salt in solution and its consequent high boiling point, a temperature of 250° F. could be easily obtained. With this temperature the time of heating could be greatly lessened, and at the same time sterilization was assured. In one form of this process a lozenge of sodium sulphite was fastened on the under side of the cover of each can by means of fusible metal. The object of this was "to decompose the air remaining in the can." This method of procedure was found to be impracticable, owing to the frequent explosions of the cans. This bath was in use but a short time, being followed by a return to the earlier methods.

The introduction of digesters or "retorts," about 1870, was the next and most recent step in the development of sterilizing apparatus. By their use an actual temperature of 250° F. (127° C.) may be easily obtained both inside and outside the can; so explosions are avoided. The corresponding pressure is fourteen pounds. The only precaution required is to reduce the temperature and pressure cautiously. They have not been accepted as entirely satisfactory, however, on account of the darkening of the goods caused by long continued heating. It is probable that retorts are now used less than formerly in some quarters, through ignorance of their effectiveness, yet it is well known that many packers are using them with excellent results.

EXAMINATION OF "SWELLED" CANS, AND DESCRIPTIONS OF THE BACTERIA FOUND.

As has been stated above, all cans before they are put upon the market are carefully tested for imperfections, and any showing leakage or swelling are rejected, and the annual loss from these sources is very heavy. Our investigations began with a careful examination of a large number of cans of spoiled clams and lobsters. The contents of such cans were found to be badly decomposed, in some cases almost entirely liquefied, much darkened in color, and of a very disagreeable odor. Bacterial examination showed that in every case where spoiling had occurred, living bacteria were present in great numbers. In sound cans, on the other hand, no living bacteria could be detected, and the contents proved to be sterile. As would be supposed in the present state of bacteriology, there is no reason to doubt that swelling and decomposition are invariably the result of bacterial action. In some cases a can contained a culture apparently pure, while other cans might contain a mixture of several species.

The ordinary bacteriological methods, with some modifications, served for the separation of these organisms into distinct species, and made possible their cultivation in pure cultures in artificial media. Of the nine species of bacteria obtained, two are micrococci, while the other seven are classed among the bacilli. All of them are noticeably rapid in their development in an incubator at blood heat (98° F., 37½° C.) both in liquid and on solid media, while they grow slowly at a temperature of 70° F. (20° C.). They may be readily stained by the usual staining reagents. In several of the forms endospore formation has been observed, and these forms are likewise noticeable for the rapidity with which such sporulation occurs. The following detailed descriptions will show some of the characteristics of these species:

FIG. 1. BACILLUS NO. 1.
× 650.

FIG. 2. BACILLUS NO. 1, SPORES.
× 650.

BACILLUS NO. 1. (Figures 1 and 2.)

GENERAL CHARACTERS.	*Shape and arrangement:* Long rods with rounded ends occurring singly, and in chains of varying lengths. Often shows a gelatinous sheath when grown in liquid culture. *Size:* 4–7 μ x 1.5 μ. *Motility:* Moves with serpentine motion. *Spore formation:* Large oval centrally located spores. Develop with ease. *Relation to temperature:* Grows at both 20° and 37½°, but better at the latter temperature. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Liquefies readily. *Color:* Creamy white.
GELATIN.	*Stick culture:* Growth extends throughout line of puncture. The gelatin is liquefied, forming a broad trumpet-shaped liquid portion, at the bottom of which is a small amount of flocculent precipitate. Film formed on surface, which breaks up and settles, leaving a layer of clear liquid at top. Entirely liquid after three weeks. *Plate culture:* Surface colonies: First appear as small white dots. Liquefaction sets in at once, first appearing as a clear ring of liquid gelatin surrounding the colony. Under low power there is seen a dark granular center, and an outer ring of paler threads interwoven and forming a thin, irregularly circular zone. Flocculent ppt. at bottom of the saucer-shaped depression caused by each colony.
AGAR.	*Streak culture:* A moist, creamy white, smooth, shiny growth covering nearly the whole surface of the agar. Edges appear granular or "frosty." *Plate culture:* Surface colonies: First develop as circular shiny colonies with sharp outline. An irregular film is soon formed which extends out on all sides, giving an irregular, somewhat branched appearance; dot at center, and faint concentric rings. Submerged colonies small, oval or spherical.
POTATO.	A gray slimy growth, extending over large part of the surface. This later becomes cheesy and rough on surface. Potato darkened.
MILK.	Is coagulated, and later the coagulum is dissolved. Acidity, neutral.
SMITH SOLUTION.	No gas produced. Heavy sediment. Much turbidity, and film on surface. Strongly acid.
NITRATE.	Is reduced to nitrite but slightly.
BOUILLON.	Film on surface. Turbid. Heavy sediment of a flaky nature.

BACILLUS No. 2.

GENERAL CHARACTERS.	*Shape and arrangement:* Short rods, occurring singly and in chains of 3–6 elements. *Size:* 1.5–1.8 μ x .6μ. *Motility:* Motile. *Spore formation:* Not observed. *Relation to temperature:* Develops rapidly at 37½° C., more slowly at 20°. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Does not liquefy. *Color:* Pale yellow.
GELATIN.	*Stick culture:* No growth visible until after second day. On fifth day hazy growth is shown all along the line of inoculation. Mass of small rounded colonies on surface. *Plate culture:* Surface colonies: First appear as circular shining droplets almost transparent. After two weeks colonies are ⅛'' in diameter, elevated, rough, with a dot at center, and irregularly concentric rings. Edge of colony crenated or roughly scalloped. Submerged colonies, small, circular and brownish in color.
AGAR.	*Streak culture:* On second day surface is covered with a thin, rough, pale yellow, shiny layer. *Plate culture:* Surface colonies: Circular grayish white colonies somewhat elevated, and sometimes slightly scalloped at edges. Surface rather dull. Dot at center under microscope appears to be shaped like red blood corpuscles, thinner at center than at rim. Sub. colonies: Very small, circular or oval.
POTATO.	Growth for several days almost invisible. Later a scanty, moist, pale yellow growth, following closely the line of inoculation.
MILK.	Is coagulated, forming a solid mass. Strongly acid.
SMITH SOLUTION.	No gas produced. Turbid throughout. Film on surface. Strongly acid. Considerable sediment.
NITRATE.	Is reduced to nitrite with rapidity.
BOUILLON.	Faintly turbid on second day. Solution becomes turbid throughout. Film on surface, and heavy flocculent precipitate.

BACILLUS NO. 3.

General Characters.	*Shape and arrangement:* Stout rods with rounded ends occurring singly and in chains. *Size:* 2–3 μ x 1.75 μ. *Motility:* Motion serpentine and rapid. *Spore formation:* Oval, centrally located spores 1.8 μ x 1.2 μ. *Relation to temperature:* Growth rapid at 37½°; slower at 20°. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Liquefies. *Color:* White.
Gelatin.	*Stick culture:* Development throughout entire length. Liquefies in trumpet shape. Thick film on surface, and heavy flocculent precipitate. *Plate culture:* Surface colonies. Nearly circular with dot at center, concentric rings. Liquefaction commences at once, and a veil-like mass collects at the bottom of the liquefied portion. Under low power the edges of the colonies appear to be made of bacterial filaments which extend from the central mass. Submerged colonies very small and spherical.
Agar.	*Streak culture:* A white, moist, wrinkled growth extending over the whole surface. *Plate culture:* Granular, moist, shiny colonies, dark at center, irregular in outline; edges thick and rough. Tendency to spread.
Potato.	Dirty white, moist layer spreading over the whole surface. Potato much darkened.
Milk.	Is coagulated; coagulum later dissolved.
Smith Solution.	No gas produced. Heavy film on surface and much sediment. Strongly acid.
Nitrate.	Not reduced. Film on surface.
Bouillon.	Growth at surface, then a clear layer below, and at bottom a heavy flocculent precipitate.

BACILLUS NO. 4.

GENERAL CHARACTERS.	*Shape and arrangement:* Rods with rounded ends, occurring singly or in long threads arranged side by side. *Size:* 3–6 μ x 1 μ. *Motility:* Very motile; darting motion. *Spore formation:* Oval centrally located spores 2 μ x 1 μ are readily formed. *Relation to temperature:* Develop rapidly at 37½° C., but slowly at 20°. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Liquefies readily. *Color:* Pale brownish or grayish.
GELATIN.	*Stick culture:* Development quite rapid. Liquefies, giving a liquefied portion having shape of an inverted cone. Film on surface, and flocculent material in suspension. *Plate culture:* Surface colonies: Small circular white liquefying colonies; under low power appear irregularly circular, sharply defined and granular. A ring of liquefied gelatin surrounds each colony almost as soon as the colonies are visible. Submerged colonies very small; spherical.
AGAR.	*Streak culture:* Smooth, white, thin layer of dull luster extending all over surface of the agar. *Plate culture:* Surface colonies: Yellowish white colonies varying in size from small dots to ¼″ in diameter. Nearly circular, dot at center and concentric rings. Submerged colonies: Irregular in shape; very small.
POTATO.	A white pasty, scanty growth at first develops. This later spreads over the whole surface, forming a dry, much wrinkled brown layer.
MILK.	Casein coagulated; coagulum dissolved almost completely. Alkaline.
SMITH SOLUTION.	No gas produced. Slightly turbid, heavy sediment. Growth at surface, neutral reaction.
NITRATE.	Is reduced to nitrite vigorously.
BOUILLON.	Turbid throughout; stringy; tough film on surface, and heavy precipitate in lower third of tube.

BACILLUS NO. 5.

GENERAL CHARACTERS.	*Shape and arrangement:* Bacilli with rounded ends, occurring singly and in chains. *Size:* 3-5 μ long x 1.2-1.5 μ broad. *Motility:* Motion serpentine. *Spore formation:* Not observed. *Relation to temperature:* Rapid development at 37½° C., slow at 20°. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Liquefies rapidly. *Color:* White.
GELATIN.	*Stick culture:* Growth throughout whole line of inoculation. Liquefaction sets in about third day, forming a trumpet-shaped liquefied portion. Film on surface, and flocculent precipitate at lower part of liquefied portion. *Plate culture:* Surface colonies: White circular colonies which begin to liquefy as soon as they are of the size of a pin head, and form depressions or cavities in the gelatin. Under low power they appear to be made up of long interlacing threads which extend from the edge in hair-like processes. Submerged colonies, small, brown, and granular.
AGAR.	*Streak culture:* A pasty thick white growth, rapidly spreading over the whole surface. *Plate culture:* Surface colonies: Thin spreading colonies often coarsely branched; rather large, granular, and dull in luster.
POTATO.	Watery, white growth, later becoming dry and about the same color as the potato, and extending over a large portion of the surface.
MILK.	Is coagulated, and coagulum dissolved. Acidity, neutral.
SMITH SOLUTION.	No gas produced. Turbid throughout. Film on surface. Much sediment. Strongly acid.
NITRATE.	Is reduced to nitrite.
BOUILLON.	Film on surface which breaks up, forming a heavy flaky sediment.

BACILLUS NO. 6.

GENERAL CHARACTERS.	*Shape and arrangement:* Bacilli, occurring singly and in short chains. *Size:* 1.5-μ x 3.5 μ. *Motility:* Motile. *Spore formation:* Not observed. *Relation to temperature:* Grows readily at 37½° C., less rapidly at 20° C. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Liquefies rapidly. *Color:* Yellow.
GELATIN.	*Stick culture:* Development begins at surface. Liquefaction quickly sets in, and a trumpet-shaped liquefied portion is formed. *Plate culture:* Surface colonies: Yellow, circular, shiny colonies, bluish by transmitted light. Plate is entirely liquefied on fourth or fifth day. The colonies float in the liquefied gelatin, appearing as small yellow spheres.
AGAR.	*Streak culture:* A thick, lustrous, moist layer covering the whole surface. Pale orange yellow in color. *Plate culture:* Small dome-shaped surface colonies with sharply defined edges. Yellow. Submerged colonies, very small brownish spheres.
POTATO.	Growth at first thin and watery, and pale yellow in color, later becoming orange yellow, and spreads over the whole surface. Potato is darkened.
MILK.	Is coagulated. Yellow at surface. Coagulum is later dissolved. Neutral.
SMITH SOLUTION.	No gas produced. Solution turbid throughout. Yellow sediment and yellow growth at surface.
NITRATE.	Not reduced. Turbid.
BOUILLON.	Very turbid. Heavy, pale yellow sediment.

Fig. 3. Bacillus No. 7.
× 650.

Fig. 4. Bacillus No. 7, Spores.
× 650.

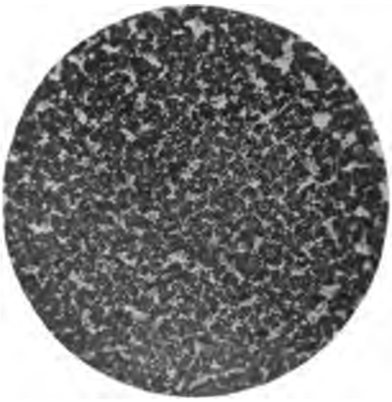

Fig. 5. Micrococcus No. 1.
× 650.

BACILLUS NO. 7. (Figures 3 and 4.)

General Characters.	*Shape and arrangement:* Long slender bacilli with rounded ends, generally occurring singly. *Size:* 3–10 μ x 1.5 μ. *Motility:* Motile. *Spore formation:* Forms drumstick-shaped spores. *Relation to temperature:* Develops rapidly at 37½°, slowly at 20°. *Relation to air:* Anaërobe and facultative aërobe. *Relation to gelatin:* Non-liquefying. *Color:* Yellowish white.
Gelatin.	*Stick culture:* Development is very slight, and growth takes place slowly. *Plate culture:* Surface colonies: Small, circular, whitish colonies, regular in outline, and sharply defined. Submerged colonies appear as small spherical dots.
Agar.	*Streak culture:* Smooth, lustrous layer covering the whole surface of the agar. *Plate culture:* Smooth, circular, rather small white colonies. Outline sharply defined. No characteristic markings. Submerged colonies small, spherical, or oval dots.
Potato.	Development very slow and slight. Lumpy growth after several days.
Milk.	Not coagulated. Acidity, neutral.
Smith Solution.	No gas produced. Slightly turbid.
Nitrate.	Not reduced to nitrite.
Bouillon.	Turbid throughout. Film on surface and sediment.

MICROCOCCUS NO. 1. (Figure 5.)

GENERAL CHARACTERS.	*Shape and arrangement:* Cocci; generally in pairs. *Size:* 1 μ in diameter. *Motility:* Motile; in pairs, sometimes rotation about center. *Spore formation:* Not observed. *Relation to temperature:* Rapid development at 37½°. Slow at 20° *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Non-liquefying. *Color:* Yellow.
GELATIN.	*Stick culture:* Growth first appears at surface. Below surface development is very slow. Yellow growth at surface. *Plate culture:* Surface colonies: Circular with sharply defined edges and yellow color. Under microscope show granular appearance and a deep color at center, surrounded by a paler ring. Submerged colonies show no clear markings, but appear as very small spherical dots.
AGAR.	*Streak culture:* Smooth, lustrous yellow layer covering much of the surface. *Plate culture:* Small, shiny, pale yellow circular colonies, dome-shaped, and smooth in appearance. Submerged colonies generally oval and brownish.
POTATO.	Development slight, a moist, lumpy growth appearing after several days.
MILK.	Not coagulated. Acidity, neutral.
SMITH SOLUTION.	No gas produced. Slight turbidity. Alkaline reaction.
NITRATE.	Not reduced to nitrite.
BOUILLON.	Turbid throughout; film on surface. Considerable sediment.

MICROCOCCUS NO. 2.

GENERAL CHARACTERS.	*Shape and arrangement:* Cocci; occurring sometimes singly, often in groups. *Size:* About .9 μ in diameter. *Motility:* Non-motile. *Spore formation:* Not observed. *Relation to temperature:* Develops quickly at 37½° C., more slowly at 20°. *Relation to air:* Aërobe and facultative anaërobe. *Relation to gelatin:* Liquefies slowly. *Color:* Yellow.
GELATIN.	*Stick culture:* Development chiefly at surface. A yellow film is formed and liquefaction takes place, a cup-shaped depression resulting. *Plate culture:* Small, circular or somewhat irregular colonies, which under low power appear granular; yellow at center, shading into white at the clearly marked edges. They appear bluish by transmitted light. Submerged colonies, spherical or oval, and brownish in color.
AGAR.	*Streak culture:* Bright yellow, thick, sticky growth, branching and extending over the whole surface. *Plate culture:* Pale yellow, raised, circular, shiny, smooth colonies, generally very small. Submerged colonies, pale, oval, or spherical.
POTATO.	Thin, branching, spreading growth of citron yellow, covering much of the surface of the potato. Later, becomes dry, ridged, and roughened.
MILK.	Not coagulated. Neutral reaction.
SMITH SOLUTION.	No gas produced. Slight amount of sediment and some turbidity. Alkaline reaction.
NITRATE.	Not reduced to nitrite.
BOUILLON.	Very turbid throughout. Sediment heavy and viscous.

It is not to be inferred that these include all the species of bacteria which occur in swelled cans even of clams and lobsters. Of those which produce the spoiling of fruits and vegetables, we have as yet slight knowledge.[1]

INOCULATION EXPERIMENTS.

If the organisms isolated from decomposing material are the agents by means of which the decomposition is effected, it should be possible to reproduce this spoiling at will by inoculation of sterile material with cultures of the organisms in question, external conditions being the same in both cases. To determine this point experimentally, sterile cans have been seeded with pure cultures of bacteria obtained from spoiled cans.

For these experiments cans were tested by incubation at blood heat until it was demonstrated beyond doubt that no swelling would result. The outside of these cans was then sterilized either by passing through a flame or by washing in mercuric chloride. A small hole was then made in the top of the can with a hot awl, the can either being held directly in the flame of a Bunsen burner or the operation being carried on in a previously sterilized glass chamber. The bacteria were introduced by means of a platinum needle, and the strictest precautions against contamination were observed. As soon as inoculated the cans were sealed with solder, and, after shaking, were replaced in an incubator at a temperature of 37½° C. (98° F.). A number of similar cans were similarly treated in every way, except that no germs were introduced, the object of this treatment being to show that puncturing the can, thus allowing air to enter, will not cause spoiling if the operation is carried on with due precautions. To illustrate these points more fully a few results are here given:

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[1] A bacterial study of the spoiling of corn, known to the trade as "sour corn," has already been begun, and a number of experiments are now in progress.

No. of cans.	Treatment.	Incubated.	Results.
7	Punched, but not seeded.	37½° C.	All kept perfectly.
5	Punched, not seeded.	37½	All kept perfectly.
5	Punched, not inoculated.	37½	All kept perfectly.
16	Inoculated.	37½	14 spoiled.
3	Inoculated.	37½	All spoiled.
12	Inoculated.	37½	7 spoiled.
5	Inoculated.	37½	All spoiled.

The results, as shown above, prove that spoiling is due to the action of the living bacteria in the cans. Moreover, the cans in which spoiling was thus brought about showed, when opened, the blackening and liquefaction characteristic of the original spoiled cans, thus proving that the bacteria isolated were the specific causes of spoiling.

An investigation was next made of the efficiency of the ordinary water-bath treatment. Sterile cans were seeded, as above described, with germs derived from spoiled cans. After seeding, however, they were subjected to heat in the water bath exactly as is done on a commercial scale, for a length of time varying from two and one-half to four hours. This time was divided into two periods, the cans being tapped between the two heatings. As will be shown by the following figures, quite a large percentage of the cans treated in this manner spoiled:

No. of cans.	Time of heating. (Hours.)	Incubated.	Results.
7	1 + 1 + 1	37½° C.	All spoiled.
8	1 + 1½	37½	All spoiled.
7	1 + 1 + 1	20	All spoiled.
8	1 + 1½	20	All spoiled.
16	½ + ½ + ½	37½	14 spoiled.
8	1½ + 1½	37½	All spoiled.
3	1½ + 1½	37½	All spoiled.
3	1 + 1½	37½	2 spoiled.
63			58

From these figures it is seen that 92 per cent. of the cans spoiled, a far greater percentage of loss than occurs in practice. This is to be accounted for chiefly by the fact that in these cans have been planted thousands of bacteria of species which have withstood this temperature in the original spoiled cans, while in the ordinary packing the admission of these bacteria is a matter of chance. Moreover, the temperature at which these cans are incubated appears to be specially advantageous for the rapid development of those organisms which have not been killed by the heat, so the test is unusually severe. It should be distinctly understood that these results do not necessarily signify that a large percentage of the cans receiving water-bath treatment on a commercial scale should spoil if allowed to stand at blood heat, but are valuable because of the practical demonstration that this process is insufficient when such bacteria are present, and is unsafe at all times because of the possibility of such infection.

Bacteriological examination of cans which have spoiled, as described above, has shown in all cases the presence of living germs like those of the species originally put into the cans. Thus, for example, cans inoculated with a culture of a large bacillus have been found to contain pure cultures of a large bacillus corresponding in every way to the one originally inoculated into the can.

STERILIZATION, OR "PROCESSING" EXPERIMENTS.

Our experiments carried on to determine the comparative efficiency of the "dry retort"[1] and the water bath as agencies of sterilization have, without exception, shown the very great superiority of the former. As indicated above, "processing" in the water bath for two and one-half hours does not always produce complete sterilization. On the other hand, there is no reason to doubt the efficiency of the retort if it is properly used. Of over one hundred cans heated in the retort, but otherwise subjected to the same treatment as the water-bathed cans, not one has swelled or shown any evidence of spoiling even under the severe test of standing in the incubator for a month.

In addition to the water-bath experiments above described, a few

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[1] The term "retort" is a commercial one, and is open to objection, yet no more so than the term "autoclave," which is used so much in bacteriology, and is applied to the same instrument.

tests have been made to show the effect of continuous boiling for various lengths of time upon the bacteria or their spores. Cans inoculated with these bacteria have been subjected to continuous boiling for periods of four, five, six, seven, and eight hours. In these experiments, mixtures of the bacteria were taken for the inoculating material.

No. of cans.	Time of boiling. (Hours.)	Results.
2	4	Both spoiled in 48 hours.
3	5	2 spoiled in 48 hours. 1 spoiled in 64 hours.
3	6	2 spoiled in 48 hours. 1 spoiled in 64 hours.
3	7	2 spoiled in 48 hours.
4	6	All spoiled.
4	7	All spoiled.
4	8	All spoiled.

These results indicate that the organisms here dealt with have very great resistance to heat — a fact of great interest when taken in connection with the readiness with which spore formation occurs.

For practical as well as for scientific purposes it is obviously important to determine with accuracy minimal periods of retorting required in the various branches of the industry. We have experimented in this direction with highly satisfactory results, and have found it possible to preserve clams and lobsters with ease, and in a more perfect condition, with absolute certainty, with much briefer processing period than is ordinarily used, the only essential being the proper control of the temperature. An account of our numerous experiments in this direction is reserved for a second paper.

Biological Laboratory,
Massachusetts Institute of Technology,
March, 1897.


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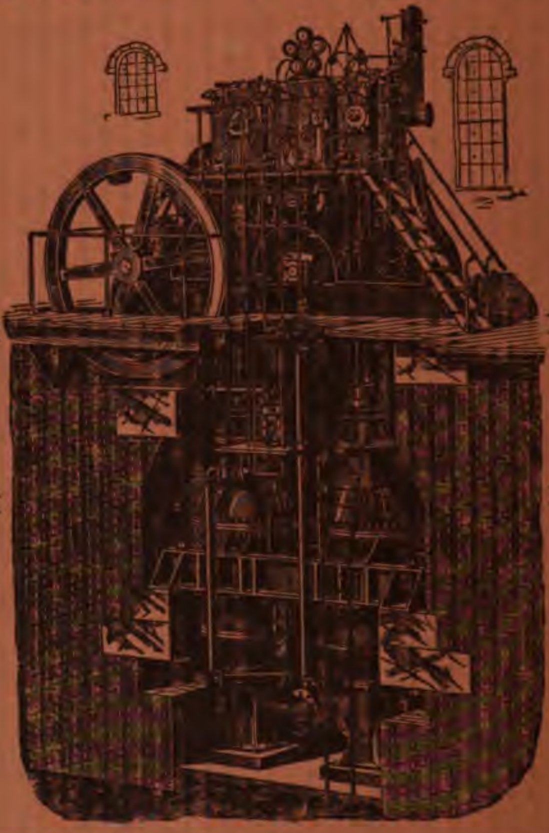

Vol. X. JUNE, 1897. No. 2.

TECHNOLOGY QUARTERLY AND PROCEEDINGS OF THE SOCIETY OF ARTS

CONTENTS

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PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. X. JUNE, 1897. No. 2.

PROCEEDINGS OF THE SOCIETY OF ARTS

TECHNOLOGY QUARTERLY, Vol. X, No. 2.

ERRATA.

Page 260, ten lines from bottom, and also fifteen lines from bottom, for "now superfluous" read "non-superfluous."

Page 266, fifteen lines from bottom, for l'_1 read l_1.

Page 268, seven lines from top, for "intermediate" read "indeterminate."

Page 268, eight lines from top, for "volume" read "volumes."

a subsequent meeting. The Chair appointed the following committee: Colonel E. H. Hewins, Professor E. C. Pickering, and Mr. Thomas Doane.

The Society then proceeded to the election of new members.

Messrs. John D. Hobart, of Malden, Albert P. Norris, of Cambridge, W. Lyman Underwood, of Belmont, and David B. Weston, of Watertown, were duly elected Associate Members.

There being no further business, the Chair introduced Mr. Samuel Cabot, of the Corporation of the Institute, who read a paper on "The


EDWARD·T·HAPGOOD·ARCH'T·
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TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

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PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FIFTH YEAR, 1896–97.

THURSDAY, January 14, 1897.

THE 493d meeting of the SOCIETY OF ARTS was held this day at the Institute, Mr. Blodgett, Chairman of the Executive Committee, presiding.

The Chairman announced that President Francis Amasa Walker had died at his home early in the morning of January 5. The Secretary read a letter from the Executive Committee of the Alumni Association of the Institute, inviting the SOCIETY OF ARTS to coöperate with the Alumni Association in a memorial service. It was voted to refer this communication to the Executive Committee, with power to act as may seem best. On motion of Colonel Hewins, it was voted that a committee of three be appointed by the Chair to draft resolutions in regard to the death of President Walker, and to report at a subsequent meeting. The Chair appointed the following committee: Colonel E. H. Hewins, Professor E. C. Pickering, and Mr. Thomas Doane.

The Society then proceeded to the election of new members.

Messrs. John D. Hobart, of Malden, Albert P. Norris, of Cambridge, W. Lyman Underwood, of Belmont, and David B. Weston, of Watertown, were duly elected Associate Members.

There being no further business, the Chair introduced Mr. Samuel Cabot, of the Corporation of the Institute, who read a paper on "The

Study of the Air for Locomotive Purposes." He pointed out that the study of the soaring of birds forms the basis for the study of the problem of flight by man. The difficulty of the problem is greatly increased when it is attempted to construct machines large enough for practical purposes, the difficulties of starting and stopping being especially great. The importance of momentum in flight was dwelt upon at some length. A large Malay kite and a number of small models of flying machines were exhibited, and the speaker closed with a description of a device of his own invention for applying power to flying machines, in which two pairs of wings are caused to revolve in opposite directions upon a single shaft. A discussion followed, and then after a vote of thanks the Society adjourned.

THURSDAY, February 11, 1897.

The 494th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

Colonel Hewins, Chairman of the committee appointed to draft resolutions in regard to the death of President Walker, presented the following report,[1] which was adopted and ordered to be incorporated in the records:

In accordance with the inscrutable purposes of the Ruler of the Universe, Francis Amasa Walker has been removed by death while yet in the full vigor of life and in the midst of cherished labors only partially completed and in some respects only foreshadowed. In this we realize the frailty of human life and endeavor. The SOCIETY OF ARTS has lost, not only its learned and accomplished President, but a man whose vigor and earnestness have greatly promoted its influence. Whether as soldier, student of social and political economy, as educator, or organizer, we may look to the example set by General Walker for encouragement and instruction in order to increase our usefulness in the world. So may we strive to emulate him according to our abilities and opportunities. Not only has this Society lost its valued head, but the loss to the community, while felt, cannot be wholly measured or known. In so far as we may, we would join in the bereavement of the afflicted family, to whom it must be a material consolation to remember his far-reaching labors, and that his life has been a benefit to mankind.

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[1] Resolutions adopted by the Corporation and the Faculty follow, p. 206.

There being no further business, the Chairman introduced Mr. Alvan G. Clark, of Cambridge, who read a paper on "Telescopes, with Special Reference to the Making of the Yerkes Telescope for the University of Chicago." The history of telescope making was outlined, and it was shown how the size of lenses has been limited by imperfections in the art of glass making. The methods employed in grinding the 40-inch lens for the Yerkes telescope were then described, special stress being laid upon the methods of testing and finishing the glass, for this is the most important part of the work, and requires truly artistic skill. The paper was illustrated by an exhibition of apparatus and specimens of glass. The thanks of the Society were voted to the speaker, and then the meeting adjourned.

THURSDAY, February 25, 1897.

The 495th meeting of the SOCIETY OF ARTS was held this day at the Institute at 8 P.M., Mr. Blodgett in the chair. The record of the previous meeting was read and approved.

Messrs. George W. Rolfe and Alexander W. Moseley were duly elected Associate Members. The Chairman called attention to the "Life and Letters of William Barton Rogers," recently published by Mrs. Rogers, and announced that she had given to the Institute a copy for each of the libraries.

Professor William H. Niles read a paper on "The Evolution of the Great Lakes and St. Lawrence Waterway." Attention was called to the multitude of smaller lakes, which, associated with the larger ones, constitute a system of lakes rather than of streams. It was noticed that the features of the streams as well as the number and arrangement of the lakes show that the system still retains many features of youthfulness. It was not until the close of the mediæval or mesozoic era of the earth's history that the hydrographical basin was closed on the west, and that the first boundaries of the antecedent lake system were established. During the tertiary period the humidity of the climate supplied an abundance of water, while the elevation of the lands gave velocity to the outward flowing streams. The geographic changes resulted in giving coolness to the climate, which with its humidity favored the formation of glaciers. When the ice sheet began to recede from its southern limit, it left large moraines which served to obstruct the valleys and to cause the waters to accumulate between them and the retreating ice front. It was with these glacial lakes that the present system was initiated. In the early stages the water covered considerable areas of what are now dry land bordering on the lake system. The outlet of these waters was first in the region of Chicago towards the Mississippi River. Later, when the ice had retreated somewhat and the land to the eastward had subsided, an outlet was formed along the valley of the Mohawk to the Hudson. Still later the waters flowed southward from Oswego into this channel of the Mohawk, and at a still later time water flowed through the valley of Lake Champlain southward to the Hudson valley. It was shown that these ancient river channels now afford favorable locations for large canals, and opportunities for the development of waterways between the Great Lakes and the Atlantic seaboard of the United States.

It was voted to extend the speaker the thanks of the Society, and the meeting adjourned.

THURSDAY, March 11, 1897.

The 496th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., Professor Cross in the chair. The record of the previous meeting was read and approved.

Dr. Francis H. Williams read a paper on "Some Uses of the Röntgen Rays," in which he gave an outline of the results of his work upon the application of these rays to medical diagnosis. He pointed out that the permeability of a substance to the rays depends upon its thickness and upon its chemical composition; the permeability being less, generally speaking, the higher the atomic weight. The average for the soft tissues is not far from that of water. Calculi can be detected by means of the rays only when they are composed largely of inorganic material. The difference in permeability of the organs and tissues produces the contrast which makes them visible. The method of taking radiographs and the process of examining patients by means of the fluoroscope were described and illustrated. Dr. Williams, continuing, gave an account of the method of locating a bullet, and then he described the series of observations used in making a diagnosis of diseases of the chest. It was made clear that a thorough study of normal subjects by this means is necessary before it can be used successfully to determine pathological conditions. The paper was illustrated by experiments and lantern views. A discussion followed, after which the Society adjourned.

THURSDAY, March 25, 1897.

The 497th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., with Mr. Blodgett in the chair. The record of the previous meeting was read and approved. Messrs. C. A. Hicks, of Needham, Dexter Brackett, of Boston, N. C. Grover, of Orono, Maine, William Jackson, of Boston, A. G. Safford, of Lowell, Frederic P. Stearns, of Dorchester, Charles H. Swan, of Boston, S. E. Tinkham, of Boston, and F. I. Winslow, of Boston, were duly elected Associate Members.

The Chairman introduced Professor C. P. Brooks, Director of the Lowell Textile School, who read a paper on "Technical Education in Europe." He divided technical schools into five classes, and pointed out that, of these, the purely trade school has, perhaps, reached its highest development in Germany, where it has had a most remarkable influence in promoting the prosperity of the country. The schools of this class in Germany, France, Belgium, and Switzerland were described. This was followed by an account of the technical high schools in Germany, and of the technical universities of England, which have a similar function. The speaker passed then to a discussion of technical education in England, of which the Combination Schools of Science, Art, and Technology form the most prominent feature.

The paper was followed by a discussion, after which, on motion of Dr. Thorp, it was voted to extend the thanks of the Society to the speaker for his very interesting and instructive paper. The Society then adjourned

ROBERT P. BIGELOW, *Secretary.*

MINUTES ADOPTED BY THE CORPORATION AND BY THE FACULTY ON THE DEATH OF PRESIDENT FRANCIS A. WALKER.

THE members of the Corporation of the MASSACHUSETTS INSTITUTE OF TECHNOLOGY desire to place on their records an expression of their sorrow at the death of their late President, and their sense of the loss of one who had contributed so largely to the growth and success of the institution with which he was immediately connected, and to the cause of scientific training and education throughout the whole country.

General Francis A. Walker was elected President of the Institute May 25, 1881, at an important period in its history. Barely sixteen years had elapsed since President William B. Rogers opened the School of Industrial Science in a few rooms on Summer Street.

The plans of President Rogers were original, the result of long study and reflection, and formed a new departure in the higher education and the application of science to industry.

The process of development had gone on under the guiding hand of the great founder as rapidly as could have been expected, and was giving promise of success when age and physical infirmity compelled him to resign his place.

President Rogers, with a full knowledge of the kind of man needed for the development of the plans he had formulated, selected General Walker as his successor. He was in the prime and vigor of manhood. He had been thoroughly trained as a thinker and administrator, and had shown his capacity in positions of high importance. He fully comprehended the scheme, new and far-reaching as it was, and he believed in its possibilities. He had energy and a force of will that no obstacles could resist, and an enthusiasm which no discouragement could chill, and in November, 1881, he entered upon the discharge of his duties.

He had rare powers of discrimination in the selection of men, as shown by the character of those he called to the different departments of the institution, and he imparted to them of his own zeal and enthusiasm.

His labors were untiring, and we are the glad witnesses of the success which crowned his efforts.

During the fifteen years of General Walker's administration the number of the buildings for the use of the School of Industrial Science has increased from one to five; the number of professors, teachers, and lecturers from thirty-seven to one hundred and fifty-six, and of pupils from two hundred and fifty-three to upwards of twelve hundred.

These facts are the outward and visible evidence of what General Walker did for the institution. His greater and real influence is not to be so measured, and can hardly be described in words. The character of the men who have graduated from the school, and their work in every part of the country from the Atlantic to the Pacific, constitute the highest tribute to the worth of our late President.

Combined with all his great qualities as educator, administrator, publicist and writer, General Walker was a man of the kindest, warmest heart and tenderest feelings. He won the affection of his Faculty and every student as well. All regarded the President as their friend. His office and his house were alike open to them, where all were welcome, and each one knew where to look for sympathy and encouragement when needing counsel or help.

The members of the Corporation will ever cherish the memory of President Walker, and they tender to his family their warmest sympathy in this their hour of bereavement and affliction.

Francis A. Walker assumed the presidency of the Massachusetts Institute of Technology in November, 1881, and died in office January 5, 1897. For more than fifteen years he lived and labored without stint or favor for its highest welfare. Suddenly his singularly varied intellectual and public career is ended.

His life touched the public service at many points. As citizens we mourn, and as members of the Faculty of the Institute over which he presided, we desire to express and record our sense of loss in the breaking of ties which years of his wisdom, sympathy, coöperation, and good will have formed and bound together.

Among the many qualities which he possessed in eminent degree we wish to record, in particular:

His leadership.

His remarkable and unusual appreciation of departments of knowledge outside his own special and personal domain.

His delicate and keen perception of the proper relations of the various courses of instruction assembled under his charge.

His discriminating and forceful interpretation of the needs and thought of the larger world, gained by a wide range of public service.

His unfailing courtesy, his kind and conciliatory spirit without sacrifice of candor or frank expression of strong conviction.

His generous recognition of the independent judgment and action of the instructing staff in the conduct and development of their individual work.

His powerful influence over students for good, by an unconscious appeal direct to the qualities of manliness and honest endeavor, which he illustrated by personal example, winning a devoted loyalty and confidence sacredly cherished by him.

In President Walker the Institute was honored wherever he was known, so wide was the recognition of his energy, his administrative ability, and his contributions to history, education, statistics, and political economy. No man need covet a nobler monument than the record of his life.

A TRIBUTE TO THE MEMORY OF BREVET BRIGADIER GENERAL FRANCIS AMASA WALKER.[1]

BY COLONEL THOMAS L. LIVERMORE.

COMPANION FRANCIS AMASA WALKER, Commander of this Commandery in 1883-4, died January 4, 1897, at the age of fifty-six. At the outbreak of the war, a student of law in the office of Charles Devens, Jr., in Worcester, he followed the latter into the service and enlisted under him as a private in the 15th Massachusetts Volunteers. He was appointed Sergeant Major of the regiment in August, and his brilliant character and liberal attainments brought him promotion to Captain and Assistant Adjutant General of Volunteers in September, 1861. Taking the field with General Couch, commanding the 1st Division, 4th Corps (afterwards 3d Division, 6th Corps), he made the Peninsular and Antietam campaigns on the staff of that general, and was promoted to Major and Assistant Adjutant General, August 11, 1862. When General Couch, in October, 1862, was assigned to the command of the 2d Army Corps, Major Walker passed to that corps and was identified with it from that time until he resigned from the Army in January, 1865. He was regularly assigned to be Assistant Adjutant General of the corps with the rank of Lieutenant Colonel, January 1, 1863.

The adjutant of a corps commander is his ear and voice. It is he who collects, collates and compares the statistics of numbers from day to day, and detects the increase or diminution of the fighting strength of the corps, intercepts and digests the countless communications which ascend from twenty thousand men to their commander, conducts all correspondence and frames all orders. Even in the saddle, under the enemy's fire, he must, with nerves under control and patience unruffled, catch the spirit of commands from a general, sometimes, perhaps, inflamed with the ardor of combat or oppressed with

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[1] **Adopted at a meeting of the Massachusetts Commandery of the Military Order of the Loyal Legion of the United States, Boston, February 3, 1897.**

the weight of disaster, and translate them in clear, courteous and orderly phrase on the instant, for transmission to subordinate commanders, and withal he must, in time of need, ride the field and penetrate the battle like the youngest aide-de-camp. All these things this volunteer of twenty-two did as if he had been trained to the duties all his life. To serve as he did in this intimate capacity with Generals Couch, Warren and Hancock, soldiers schooled in the severe traditions of the regular army, who maintained the loftiest view of the dignity and methods of their profession, was not an easy duty, but Colonel Walker not only did this, through all the arduous campaigns of 1862, 1863 and 1864, excepting the few months when he was detained from the field by wounds or in the enemy's prisons, but he also won high and repeated commendation from these commanders, both for his work in the bureau and for his valor on the field of battle. He had entered the war with a New England character and training which led him to devote himself to his duty with the utmost conscientiousness, whether at the desk or in the saddle, and he gave to it a scrupulous attention to detail, an exact observance of formalities and an unremitting labor which almost excluded relaxation. Of kind heart, with winning smile and unfailing politeness, he displayed the best qualities of roundhead and cavalier together.

The intellectual powers which afterwards made him famous in another career, guided by the motives indicated in the conduct which has been outlined, overcame all the want of military education, and all the disadvantages of youth, and he began to win high commendation with his first campaign. His name received honorable mention in the reports of many battles, including Williamsburg, Fair Oaks, Malvern Hill, Fredericksburg, Chancellorsville, Bristol Station, Wilderness, Spottsylvania, Petersburg and Ream's Station. At Chancellorsville he was wounded, and at Fair Oaks General Couch reported that he "made a daring personal reconnaissance and had his horse shot under him." General Warren being temporarily assigned to the command of the 2d Army Corps, during the absence of General Hancock, found himself thrown into the intricate and rapid manœuvres between Bull Run and the Rapidan, which took place in the latter part of 1863, with a strange command and a strange staff, a position in which as corps commander he had every opportunity to appreciate the merits and to discover the defects of the adjutant general. Praise was not easily won from General Warren, but in his report of the campaign

President Walker imparted to the students was like that which the successful military leader inspires in his soldiers, and the cheerfulness with which these students, under his extraordinary influence, submitted themselves to the severest and most unremitting intellectual labor was a phenomenon in the history of education. While conducting the work of his office President Walker did a great amount in other fields. His writings in his favorite science of political economy created a high reputation for him in Europe as well as in America, and he was repeatedly honored with degrees by foreign universities. His lectures and addresses were many, and his services on boards and commissions for worthy public objects, and in associations for the advancement of science and the elevation of mankind, were constant. Unmindful of his personal fortunes, he was prodigal of his voice and pen in all good works where his aid was sought, and as he approached his prime the volume of his labors grew to be a torrent, and, with his fine physique and glowing imagination, he threw himself into his labors as careless of the consequences to himself as is the young soldier in the hour of victory.

Amid all the interests which made their demands upon him, his enthusiasm for the old war times was ever ready to blaze forth; his affectionate regard for his comrades in the field was unfailingly awakened with the mention of any name familiar on the rolls of his old command. He gloried in his army, in his corps, in the name of volunteer. He knew no discrimination between his comrades excepting that of merit. It was characteristic of him, in his speech when he received his honorary degree in Dublin University, to praise in enthusiastic terms the valor of his old companions in arms of the Irish Brigade, regardless of the prejudice which made many of his audience hostile listeners. The warmth of his affection for the associations of the war was manifested in his moving oration before the Society of the Army of the Potomac, in 1890, and in his eloquent eulogies of Sheridan and Devens. His brilliant history of the 2d Army Corps, written in hours seized amid a thousand duties, will always stand as a labor of love, dedicated to the fame of his fellow soldiers.

His genial and kindly presence in our commandery is fresh in our memories. In sad sincerity we can say, we shall not look upon his like again.

he singled out Colonel Walker, to say of him: "Thoroughly acquainted with his office duties, so important to the operations of an army corps, he is equally willing and gallant on the field."

Colonel Walker was by General Hancock's side through the unfortunate action at Ream's Station, August 25, 1864, in his heroic efforts to retrieve the disaster which had fallen on a corps whose colors had never before suffered shame, and received honorable mention for his conduct in General Hancock's report. He there suffered the crowning misfortune of capture. General Hancock said in his report that Colonel Walker "was sent to the front with an order just before the troops were withdrawn, and, owing to the darkness, rode into the enemy's lines and was captured." To submit to the hard fate which had befallen him was intolerable to him, and, with the unfaltering resolution which characterized his whole military career, he seized the chance to escape on the march to Richmond, and painfully made his way by night to the Appomattox River, guiding his steps by the stars. Exhausted as he was, he plunged into the stream and swam until he had made the last stroke for which he had strength, only to be again taken by the enemy as he reached the shore. The hardships of captivity accomplished what campaign and battle had failed to do, and the gallant soldier and zealous patriot was compelled by the disability incurred in prison to relinquish his commission after his long career of activity, usefulness and honor. In recognition of his distinguished services and good conduct in the campaign of 1864 he was made Colonel by brevet, to date from August 1, 1864, and for gallant conduct at Chancellorsville and meritorious services during the war he was made Brigadier General by brevet, to date from March 13, 1865.

After the war General Walker devoted himself to the advancement of science and the work of education with the same zeal which characterized his military career. Under the National Government he became Chief of the Bureau of Statistics in 1869, Superintendent of the Census in 1870 and 1880, and Indian Commissioner in 1871. He became Professor of Political Economy and History in the Sheffield Scientific School of Yale College in 1872, and in 1881 he was elected President of the Massachusetts Institute of Technology, which position he filled during the rest of his life. Under him this institution grew from a small school of local reputation to a great one of international fame, and while its numbers increased three-fold, the standard and scope of its work were greatly enlarged. The enthusiasm which

SCIENTIFIC WORK OF THE BOSTON PARTY ON THE SIXTH PEARY EXPEDITION TO GREENLAND.

REPORT B. GLACIAL OBSERVATIONS IN THE UMANAK DISTRICT, GREENLAND.

BY GEORGE H. BARTON, S.B.

Read November 12, 1896.

CONTENTS.

THE western coast of Greenland presents the aspect of a plateau approaching clear to the coast line with no intervening lowlands, with an average elevation of not less than two thousand feet, and with very many summits rising from four thousand to occasionally over six thousand feet altitude.

Backward from the general sea line at a distance of ten to sixty miles lies the frontal edge of the vast ice-cap, which through the explorations of Peary and Nansen is known to cover the whole of Greenland except the narrow marginal area along the coast. Very numerous deep fiords intersect this marginal strip, in some places cutting it completely into islands, as in the vicinity of Godthaab in Southern Greenland, and in the southern portion of Melville Bay in Northern Greenland. Many of the fiords penetrate to the edge of the ice-cap from which great streams of ice pour down, filling the fiords for miles with glaciers which give birth to the numerous icebergs with which the Northwest Atlantic is dotted. These glaciers present bold fronts to the water, often several miles in width and a few hundred feet in height above the surface of the water. In all cases the fiords present means of easy access to the margin of the inland ice.

MAP SHOWING THE REGIONS ABOUT UMANAK FIORDS.

NUGSUAK PENINSULA IS THE LARGER BODY OF LAND SHOWN. THE LARGER ISLAND EAST OF UMANAK IS STORÖEN. SERMIARSUT IS ON NUGSUAK OPPOSITE UMANAK. EKALUIT IS OPPOSITE IKERASAK. AGPAT ISLAND IS NORTHWEST OF SATUT. EKINGA IS WEST OF ITIVDLIARSUK GLACIERS. THE DOTTED LINES INDICATE THE ROUTES OF THE BOAT JOURNEYS AND THE JOURNEY UPON THE INLAND ICE.

Many of the larger islands and peninsulas between the fiords have their own small ice-caps which are usually detached from the main mass of the inland ice. The larger portion of the surface of the islands and peninsulas where not covered by ice is very rough and broken, being traversed by numerous small streams flowing into the fiords, which have cut sharp, deep gulches and valleys, thus rendering travel across country very difficult.

Umanak fiord is the southern of two large arms of the largest indentation of the coast, except possibly Disko Bay, a body of water lying between Swarten Huk peninsula on the north and the great Nugsuak peninsula on the south, and which is nearly bisected by the parallel of 71°. Ubekyendt and Upernivik islands separate the two arms. The highest summits on the former island reach 3,640 feet, and on the latter, 6,650. The average elevation of Nugsuak is above 3,000 feet on its northeastern side with summits rising to above 4,000 in many cases, and in one to 6,250 feet.

Umanak fiord broadens inward and then is divided into a series of smaller fiords, the more important of which are the Kangerdluarsuk, Ignerit, Itivdliarsuk, Sermilik, and Karajak fiords. Between these are islands and peninsulas with peaks rising to 3,000 and 6,400 feet. The Karajak fiord lies directly along the northeastern side of the Nugsuak peninsula, and is bounded on the northeast by the island of Umanak, which has one single sharp peak rising to 3,720 feet, the remainder of the island having an elevation of only a few hundred feet; Storoen (the great island), whose highest peak is 4,450 feet, the island of Ikerasak, low but with one isolated peak 2,550 feet, and a peninsula, not named, with elevations of 3,000 feet. All these islands and peninsulas present precipitous faces to the water often nearly vertical, to a height of 1,000 and 2,000 feet. Each of the fiords mentioned above extends back to the margin of the inland ice, and their upper portions are occupied by glaciers which pour down from it. The margin of the inland ice lies upon land which has an elevation of 1,000 to 3,000 feet, in consequence of which, as the glaciers pour down from this level to that of the bottoms of the fiords, the crevassing which is caused by their drainage from the inland ice extends for many miles inland, similar to the current in a large body of water when a dam has given way. Small valleys and narrow gorges pass down from the upper levels of Nugsuak peninsula, many containing glaciers, some of which reach the waters of the fiord, but the larger number do not.

Along the margin of the inland ice there are many isolated peaks, nunataks, rising above the level of the ice, sometimes lying wholly within and entirely surrounded by the ice, in other cases lying at the edge of the water and surrounded by varying proportions of ice and water. None of these lie at any great distance within the ice margin, as recorded in other places, no instance being noted of a greater distance than about a mile between these and the main portion of the land.

The Inland Ice. — The edge of the inland ice as it lies upon the Nugsuak peninsula, upon the nunatak between the Great and Little Karajak glaciers and upon Ekinga, the point just northwest of the Itivdliarsuk glaciers, is usually nearly vertical. Its height or thickness varies from 10 feet to about 40 feet. In some cases it is slightly overhanging, in others slightly retreating, but in nearly all cases showing the edge of the layers of which the mass is made up. Here usually the layers are inclined toward the margin. In a few cases the edge has a slope of a sufficiently low inclination to allow it to be ascended, but is always steep.

The marginal area is penetrated on the surface by numerous holes varying in size from the fraction of an inch in diameter up to at least 3 feet, and having an average depth of about 2 feet. At the bottom of each one is a thick layer of dust, which being dark in color causes the hole to appear to be of great depth. So numerous are these where most abundant that they occupy nearly one-half the entire surface. The area occupied by them is perhaps a mile in width, extending inland from the extreme edge of the ice. The same area is very rough and uneven, the surface consisting almost wholly of hillocks or hummocks having much the shape of sand dunes, and an average height of about 2 feet above the bottoms of the hollows between them. This makes the dragging of a heavily-laden sledge difficult, but does not interfere seriously with walking. Beyond this area the surface is comparatively smooth, and it is hard, solid ice throughout. No drifting snow was seen in any portion, this latter fact being due to its being late midsummer.

Between the crevassed areas and the land the ice is traversed by a series of cracks about parallel in direction to the edge of the ice, which have remained partially open till filled with water which has frozen to form a clear transparent vein of new ice with varying widths up to 6 and 8 inches. These larger cracks produce a strong effect upon the drainage, deflecting the smaller streams for a considerable distance along their own direction and away from the slope of steepest descent toward the land, till the volume of water becomes sufficiently large to break across the little divides between the various cracks. Crossing this series of cracks at a high angle, generally more than 60°, is another series, not so pronounced, however, and seldom showing any trace of vein ice. These two series of cracks divide the ice into large rhombohedral blocks, 10, 20, and more, feet in diameter. The general appearance presented is strongly that of a series of parallel and intersecting joint cracks in slate rocks.

From the highest point reached, having an elevation of 2,960 feet, was obtained a wide range of vision to the south, southeast and north, but to the northeast and bending toward the eastward the surface of the ice rising inland shut off our view within a few miles. The general topography of the inland ice as here seen is rolling and undulating, very similar to the surface of the prairies, and indeed reminds one strongly of them when clothed in snow. The surface of the ice opposite the head of the nunatak between the two Karajak glaciers has an elevation of something less than 2,000 feet. The highest point reached, being 2,960 feet at a distance of about fifteen miles inland, would give an average gradient of about 67 feet per mile, or about 1 in 27. Nansen reports 1 in 23 on the east coast for the same distance.

Numerous small streams abound, flowing with considerable velocity down the steeper slopes or becoming sluggish on the gentler slopes. Those on the slopes directly toward the land fall over the vertical edge of the ice in picturesque little cascades or cut entirely through its thickness, emerging from cañon-like walls. In some of the basin-like depressions the waters from many converging streams collect, forming large, almost marsh-like areas of shallow waters and soft snow. In one case a fine lake of clear water was observed having an area of several acres. The greater number of the streams are small and easily crossed, those serving as outlets for the lakes and marsh-like expanses being the larger, but these are seldom more than 6 or 8 feet broad. The largest stream seen was encountered at the farthest distance inland. This had a width of nearly 20 feet from brink to brink, a depth of nearly 15 feet to the surface of the water, and below that a depth of about 5 feet of water. This river was flowing directly toward the interior, its current having a velocity of three to four miles per hour.

With the exception of the dust found in the dust-holes, no detritus occurs on the surface of the inland ice or in its mass so far as revealed by the numerous crevasses or the cuttings of streams. In the case of the large stream just mentioned the water was absolutely clear and its walls were of clear, transparent, beautifully blue ice, except a thickness of about a foot at the upper surface, which was more or less porous and white. Not a trace of detritus was to be seen in the ice or in the bed of the stream. Along the margin of the inland ice, best seen on the Nugsuak peninsula where there is no tendency toward a lateral movement, there is a well-defined moraine made up of till, which varies in places to sand or clay containing subangular and rounded fragments. This moraine sometimes lies directly against the front of the ice, sometimes is separated from it so as to produce a perfect esker-like ridge. Between the ice and the detached moraine in the latter case, there generally runs a stream of considerable size which has apparently caused the retreat of the ice front by the washing of its current. In only one place was detritus observed upon the ice far enough back from the edge to be entirely detached from the moraine in front. At the extreme upper end of the nunatak lying between the Karajak glaciers, the edge of the ice has a gentle slope sufficiently low to ascend with little difficulty. Here back sometimes a hundred to two hundred feet upon the ice rises the crest of a moraine, but there is no moraine in front. This seemed to be simply the crest of the normal moraine, the snows of the last season or seasons having buried the remainder in a large drift which also forms the gentle slope of the edge. This view is sustained by the fact of the fresher appearance of the surface and its much softer character than elsewhere. There is no indication that this line of detritus is an accumulation of material along the end of a detritus-bearing layer of the ice. No such detritus-bearing layers or zones were anywhere observed in the inland ice or along its edge.

Along the front of the ice in the depressions of the undulating surface of the country are numerous small lakes walled in by vertical or overhanging cliffs of ice on one side, and the basin-like slopes of the country on the other side. The largest of those observed on the Nugsuak peninsula was perhaps a hundred acres in area. This was fed by a large torrential stream flowing for a considerable distance between the moraine and the ice, and formed by the aggregation of a multitude of the small streams flowing off the ice front. At the mouth of the stream the delta deposits were forming a typical sand plain on a small scale. The lake was not of great depth, probably not over 100 feet, but stood at nearly its highest level, its waters having reached and overflowed the summit of the divide on the side opposite the ice. The outlet stream had cut but a short distance downward, so that the waters had been lowered but little.

Evidently the depression now occupied by this lake had recently been filled by a lobe from the ice front, as well-defined moraines lie around its outer margin, and are cut through by the outlet stream. These lie at different elevations above the lake, so that they could not have been formed by the shoving of the surface ice of the lake, and are highest above the waters near the present ice front. The former extension of the main mass of the ice sheet will be discussed in a later portion of this paper.

The Karajak Glaciers. — The general direction of the Karajak fiord as it penetrates the land is southeasterly. Near its inner extremity it bends nearly at a right angle to the northeast, and there is divided into two unequal arms, one about five miles in width, the other about two miles, which are separated from each other by a long, low nunatak. In these two arms lie the Great and Little Karajak glaciers, which in their direction of flow make an angle of about 45° with the general direction of the front of the inland ice. Of these, the former, taking its rise far back in the ice-cap at least fifteen or more miles from its edge, flows down the fiord nearly to the lower extremity of the nunatak a farther distance of ten or more miles, filling it with a mass of ice which rises nearly to an average of 500 feet above the waters, and presenting to them the ordinary vertical face of a glacier terminating in the sea. Throughout the entire length of its course it is deeply crevassed, its surface consisting of an alternation of pinnacles and crevasses, so that it can not be traversed at any distance from its sides except in a bay-like indentation of the nunatak, where, as Professor Burton has demonstrated by measurements, the ice is stagnant or has little motion, in consequence of which ablation predominates over the crevassing and a comparatively smooth surface results. Here the surface can be traversed for about three-fourths of a mile, or less than one-fourth the entire width of the glacier, and here were made the measurements for the determination of the rate of motion. The elevation of the surface of the inland ice where the glacier passes from it is about 1,500 feet above sea level, giving a descent between this point and its face of 1,000 feet, an average gradient of 1,000 feet in about ten miles, or of 1 in 52. The gradient of the upper third of its length, however, is much greater than that of the lower two-thirds, much of which is quite low.

The vertical character of the edge of the ice is more marked even in the case of the glaciers than with the ice-cap itself. With the exception of the single place where Professor Burton ascended by means of a moderate slope to the surface of the ablation area, the whole length of the glacier on the side next the nunatak has a nearly vertical face of pure, mostly transparent blue ice, with an average height of 20 feet, and often of 30 and 40 feet. (See Figure 1,[1] where the height is about 20 feet.) Although verticality is the normal rule, the face is sometimes slightly retreating, sometimes slightly overhanging. The cause of this vertical character seems to be partially if not largely due to the lateral streams and waters of the small marginal lakes undermining the edge, blocks from which fall off, the fractures in such cases being nearly vertical. The low angle of the sun's rays may also have a share in the work as discussed by Professor T. C. Chamberlin, for the glaciers farther north. The overhanging faces in many cases are apparently due to a shearing motion of the upper layers over the lower. This was indicated quite strongly in one instance, where a layer projecting slightly beyond the ones above had caught a little detritus as it rolled down. This same ledge continued from the slightly inclined face along a portion of the overhanging face, and here still the detritus remained which had been caught in its descent before the shearing motion had changed this part of the face to an overhanging one. A cavern presented a chance for a study of the material forming the layer upon which the detritus had lodged, and also for several feet above, showing them to be free from detritus and consequently that the detritus could only have come from the upper surface and caught upon the shelf while the face was inclined, and that its present overhanging form was due to the shearing motion of the upper portion of the ice.

The surface of the glacier is much higher toward the central portions than along the margin. No measurements were made to determine this central elevation, but it could not be less than fifty feet above the marginal areas.

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[1] The illustrations used in this article, with a few exceptions, are from photographs made by members of the Boston party, especially by A. M. Dodge.

Fig. 1. The Vertical Edge of the Great Karajak Glacier, about 20 Feet High. The Smooth Surface in the Foreground is a Portion of the Glacier, which is Held in a Bay-like Indentation of the Land, having Little or no Motion.

FIG. 2. SMALL ARCH LEFT AFTER FALLING OF MAIN PORTION OF ROOF OF SUB-GLACIAL STREAM NEAR EDGE OF GREAT KARAJAK GLACIER. THE VERTICAL FACE PRODUCED BY THE FALLING OF THE ROOF IS SEEN ON THE LEFT.

FIG. 3. LATERAL LAKE WITH DELTA AND MEANDERING STREAMS AT THE SIDE OF THE GREAT KARAJAK GLACIER. THE INCLINED EDGE OF THE GLACIER IS SEEN AT THE LEFT. NEAR THIS POINT ASCENT WAS MADE TO THE SURFACE OF THE INLAND ICE.

Numerous small caverns presented an opportunity for the study of the internal structure. In nearly every place so studied the ice presented a moderately well banded appearance evidently due to shearing, with an inclination of the layers toward the center of the glacier at an angle of about 30° in the steepest cases, and varying from that to nearly horizontal. Of the coarser banding or stratification that might be produced by the seasonal accumulation of snows, nothing was seen, though in a few instances broad bands darker than the general mass of the ice were seen, which possibly are due to this cause.

Numerous small streams flow from the surface of the ice toward the land over the uncrevassed area. Falling over the vertical face as in the case of the streams from the ice-cap, they produce a series of very picturesque cascades, one of which attained a sufficient size to have the roar produced by its plunge into the lake below heard at a distance of a half-mile. These small streams give rise to a large lateral stream which in portions of its course flows with torrential velocity. This flows along the margin of the glacier in varying positions, sometimes with the vertical face of the ice forming one of its walls. sometimes bending directly into the ice in caverns of the most beautiful blue color, and disappearing thus for many rods to again reappear and continue its external course; again it winds away from the ice front and flows between the lateral moraine and the land. When near the ice front or within it the bed of the stream is usually of clear, transparent ice through which the stream has not cut to the bed rock, or is often of sands and gravel accumulated upon its ice bed; but toward the lower portion of the glacier the ice for long distances does not rest upon the underlying rock surface, and here the stream flows directly over the bare rock and is broadened out into a thin, much broken sheet of water, which sometimes retreats for a long distance from the edge of the ice below the mass of the glacier. The caverns formed by the stream have usually low broad arches, rendering access within them very dangerous, owing to the falling of fragments from above or the falling of the whole roof, but in a few cases they have narrow high arches perfectly safe for penetration. It is to the falling in of these arches that the vertical face of the ice edge is due in most places. In some cases a small portion of the arch is left, forming a pillar as shown in Figure 2.

In the numerous bay-like indentations of the coast line of the nunatak, the waters of the marginal stream accumulate and swell out into the expanse of lakes of various sizes up to an area of many acres. The largest of these is near the head of the glacier and not far from the point where ascent to the inland ice was made. This lake is long and comparatively narrow, as are nearly all those which occur alongside of the glaciers. Its greatest length may be something over a half-mile, while its width is nowhere greater than an eighth of a mile. The detritus washed into its upper end by the large stream flowing into it has built a broad fan-like delta, over which the waters of the river meander in a series of small streams. A view of this looking down stream is shown in Figure 3.

The lake next largest in size, shown in Figure 4, is situated about two miles from the front of the glacier. Here a broad valley in the side of the nunatak has permitted the formation of a lake of considerable width, but of which a large part has been drained so that its waters had fallen to a level about 20 feet below their former surface. The upper level of the water is shown by the line of melting seen in the view. Through the large amount of detritus which had accumulated along the margin of the lake, a little stream coming down the valley has cut its way, nearly keeping pace with the fall of the waters of the lake. In the little valley thus cut through the detritus, as well as along the whole margin, wave marks showing the successive stages of water level are well shown, as seen in Figure 5.

Over the larger proportion of the surface of the glacier there is no detritus to be seen. The pinnacled area is very clear and white as far as it could be seen on the surface, and the crevasses show clear transparent blue ice with scarcely a trace of detritus of any size, except within a very short distance of the sides next the land. On the surface of the bay-like expanse where melting has predominated over crevassing, sufficient dust has accumulated to cause the whole area to have a dirty color, but excepting directly along the margin there are no fragments, and only an occasional pebble or bowlder. The marginal ice as seen by means of the caverns and tunnels along the streams is extremely transparent, so that fragments of rock within it could be seen when imbedded from 8 inches to a foot from the surface. In no place would the detritus held in the ice amount to more than 1 per cent. of the total mass. The great tenacity of the ice is shown in some cases where large fragments held by it project downward from the roof of a cavern. This was shown in one case by a bowlder fully 3 feet in length, of which only a third was held in the

FIG. 4. LATERAL LAKE, IN WHICH THE WATER HAS RECENTLY FALLEN FROM A LEVEL ABOUT 20 FEET ABOVE THE PRESENT ONE. THE VERTICAL EDGE IS ALSO SHOWN AND THE SLOPE OF THE SURFACE FROM THE CENTRAL PORTIONS OF THE GLACIER TOWARD THE SIDE.

Fig. 5. Wave Marks Formed at Successive Levels of the Retreating Lateral Lake, and the Cutting Made by a Small Stream in Its Own Delta as the Lake Subsided.

ice, while the remaining two-thirds projected at such an angle as to produce a very strong leverage (see Figure 6), yet it was immovable by any ordinary force that could be applied by the hands.

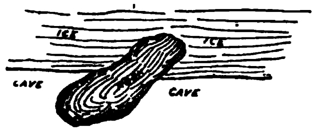

FIG. 6. BOWLDER THREE FEET LONG, HELD SUSPENDED FROM THE ROOF OF AN ICE CAVE, SHOWING THE EXTREME TENACITY OF THE ICE.

A lateral moraine of considerable size, reaching a height in some cases of about 30 feet, borders this glacier throughout its whole length along the nunatak. The material of which it is composed consists of fragments of all sizes up to blocks having a diameter of 20 feet, and of finer gravels, sands, and silt. The larger blocks are almost entirely angular, but the medium in size and smaller ones are mostly rounded or subangular, more often the former shape. A coating of very fine silt covers all the surface from which the water has recently receded as the lakes drained. The outline of the moraine differs considerably in various places. In some places it is a very distinct ridge entirely detached from the margin of the ice, and often then the lateral stream flows between it and the ice. In other cases it lies directly against the side of the ice, and then the lateral stream commonly flows between the moraine and the slope of the nunatak. In still other cases it is very irregular in outline, and perhaps divided into two prominent ridges. In either of these latter cases the irregularity seems to be due to the morainal matter having covered some of the ice, causing irregular melting, as shown in Figure 7.

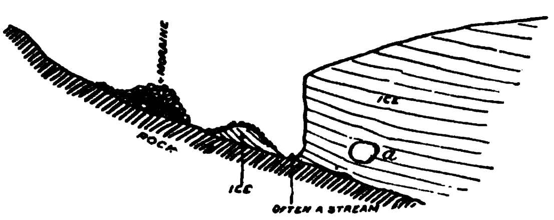

FIG. 7. RELATION OF LATERAL STREAMS AND MORAINES TO MARGIN OF GLACIER. *a*, CAVERN IN WHICH FLOWS AN ENGLACIAL STREAM WHICH MAY BE LATERAL ABOVE AND BELOW THE POSITION OF THE SECTION SHOWN.

The ice front standing 500 feet above the waters of the fiord, strongly crevassed and pinnacled, shows no trace of detritus except in the portions immediately marginal to the land. Owing to the danger from the waves produced by the fragments falling from above, or the large masses rising from below, the ice front can never be very closely approached excepting on the land, and from here, so far as could be seen with a good glass, the main mass of the ice is of that clear transparent blue and green that is seen in the inland ice especially. In the broader crevasses a mass of ice debris from the falling pinnacles collects to form a conglomeritic or a brecciated structure presenting a very peculiar appearance when detached and floating away as a berg, especially when making up the larger portion of the berg, as it sometimes does.

No streams of any size flow from the front of the glacier above water level, and those that must flow from it below the surface give little indication of their presence — a fact which is probably due to the very numerous fragments of all sizes which completely cover the surface for a long distance from the ice front, and also that the surface is in a state of almost constant commotion from the falling fragments. Small fragments are constantly falling with reports like pistol or rifle shots, and larger blocks quite often, the latter producing a series of reports like artillery, and occasionally the whole face for a long distance falls with a tremendous roar that reverberates from the sides of the fiords. Bergs so produced are sometimes a hundred or more feet in length, but never very high above the surface of the water, as the fall and the plunge into the water produce shocks which cause the large mass to crack into numerous small fragments, sometimes entirely to a mass of small debris. The larger bergs are produced by the masses derived from below which are not numerously filled with cracks originally, and are not subjected to the impact with the water surface, as is the case with the falling masses. These masses are detached from that portion of the glacier which projects from the vertical face of the ice out under the water, and seldom detaches any portion of this face in their own evolution.

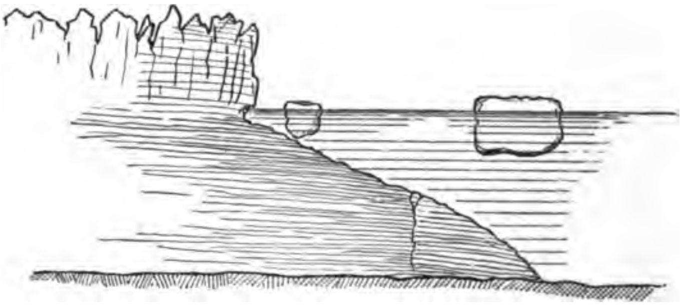

FIG. 8. IDEAL SECTION OF THE END OF THE KARAJAK OR ITIVDLIARSUK GLACIERS.

The face of the glacier has an outline as in Figure 8, produced by the breaking off of the face of the glacier above water level by the action of gravity on this highly crevassed portion of the mass, and the constant motion of the glacier itself.[1] The lower portion of the glacier is less crevassed than the upper, is consequently more coherent, and is not affected by the sun's rays or by gravity. As the upper portion arriving at the front breaks off and floats away, the under portion passes out under the water until its buoyancy, increased by loss of the weight of that part that has broken away above, becomes sufficiently great to cause it to crack off in very large masses and rise to the surface. All the larger bergs observed in the process of formation had this latter origin. They form immense masses having great length and breadth, and rising high above the water, probably to a hundred feet or more. In rising to the surface they produce dull, grumbling roars, and a much greater disturbance of the water than in the case of the blocks falling from above, as the disturbing power is deeper seated. Although the radiating waves may have died out on the surface before the shore is reached, so that scarcely a gentle swell is noticed, yet the water along the beach is churned into foam and spray dashed into the air a hundred feet in height. Before coming to rest the bergs must seek a position of stable equilibrium, and before reaching this they vibrate up and down or revolve over many times, and often end by the side that rested upon the bottom of the fiord being largely or completely exposed to view. These bottom surfaces are smooth and often broadly grooved, but with the exception of those formed near the shore, free from all detritus, consisting of pure ice with no discoloration. This implies that the glacier is moving over a bottom of the fiord that has been cleared of all detritus, that has become completely smoothed into probably roches moutonnées surfaces, and that the glacier contains no detritus in its mass. Occasionally bergs are seen that are highly discolored with mud or silt, but these, so far as observed, are detached from portions near the margin where the detritus has been carried into the ice by the lateral streams. That animal life is abundant in the waters directly in front of the ice is indicated, as already shown by Professor Tarr, by the gathering of

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[1] Since the above was written, I. C. Russell's "Glaciers of North America" has been published, in which the author advocates the same view as here adopted. See pp. 85, 86 of that work. Reid's view as presented by Russell, p. 85, would be untenable for the phenomena as seen in Greenland.

the gulls about every point of disturbance to reap a harvest of food from the waves.

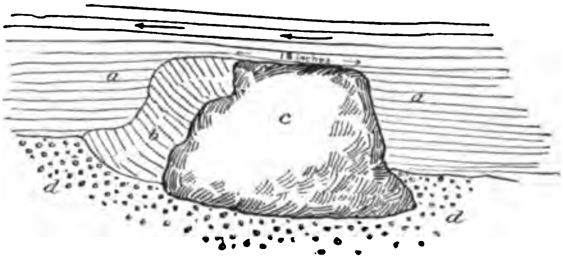

Fig. 9. Glacier, *a a*, flowing over projecting point of rock, *c*, with ice, *b*, flowing downward and backward to fill space left vacant by the motion. Direction of motion from right to left.

Professor Burton has demonstrated that at the place where he measured the movement of the glacier there is an area which has little motion, and even that nearest shore being slightly up stream, while at a distance of about two-thirds of a mile from shore there is a motion at the rate of 2.42 feet per day, and at a distance of 2.4 miles, a rate of about 19 feet per day. In the region of slow motion along the margin where bowlders and ledges project upward into the lower portion of the ice, the latter after having passed over the obstruction has flowed backward and downward so as to keep in contact with the lee side of the rock, producing a fan-shaped structure in so doing, as shown in Figure 9. In cases where the motion is more rapid, the same tendency to flow backward and downward with the fan-like structure is marked, but this latter motion has not been able to keep pace with the movement of the glacier, and a vacant space is left on the lee side of the rock, as shown in Figure 10. In this particular case of Figure 10 there would seem to be a variation in the ratio of the two movements, as the fan structure shows an exact mold of the surface of the rock in its outline, thus indicating that this structure had at one time kept pace with the movement of the glacier, but that more lately the latter movement had increased its rapidity. In those portions where the motion is most rapid the open space on the lee of the projection is very large, and there seems often to be no tendency of the ice to flow downward or back-

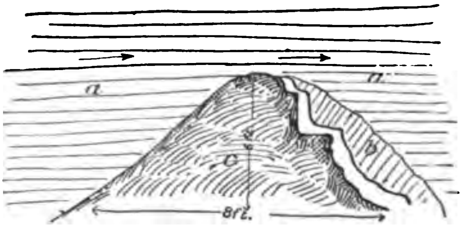

Fig. 10.

Fig. 12. The Smaller Karajak Glacier.

Fig. 14. Cliff Face of the Itivdliarsuk Glacier. Height about 200–250 Feet above Water Level, in Highest Portions. (*From National Geographic Magazine.*)

ward to fill this space (see Figure 11), while in other cases there is a large area of the radiate structure.

In the region of least motion, generally, the laminæ of the ice on the stoss side end directly against the projecting boss of rock, with no tendency to curve upward and pass over the obstruction (Figures 9 and 10), while in the region of more rapid motion the laminæ very commonly curve upward and tend to pass above (Figure 11). In no case, however, was any detritus observed passing upward into the ice by means of this slight upward flow.

In the region of greatest motion near the end of the glacier, the ice does not rest upon the rock except upon the larger projections of the bed, leaving large areas of open space between the bottom of the ice and the rock surface below, so that one can often penetrate to a hundred or two hundred feet beneath the mass. The height of this open space varies up to a maximum of about 3 feet, but is usually not more than 1 or 2 feet. Bowlders in this portion are rolled along without being frozen in the ice, and, striking the projecting bosses of rock, are sometimes fractured, sometimes splinter off portions of the boss; smaller bowlders caught between the bosses and the larger bowlders are often crushed to powder.

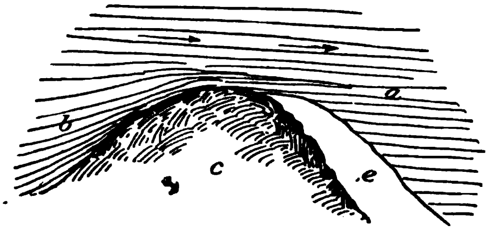

FIG. 11. UPWARD BENDING OF ICE LAYERS ON STOSS SIDE OF PROJECTING ROCK, SEEN ONLY IN CASES OF RAPID MOTION.

Smaller Karajak Glacier. — From a well chosen position on the nunatak between the two Karajak glaciers, the smaller one can be seen throughout its whole extent from the point where the crevassing of its current first begins in the inland ice to its frontal face. It is not more than two miles in width nor over five or six miles in length. Its gradient is high (see Figure 12), and consequently it is strongly crevassed in every portion. On the western side there is a large continuous moraine, but on the eastern side a portion of the nunatak bordering the glacier is very precipitous, and at the foot of these vertical faces there is no moraine. Along the less precipitous portions and the valleys there are well-defined moraines. No position was obtained where the height of the frontal face of this glacier could be estimated.

Itivdliarsuk Glaciers. — About twenty miles north of, and parallel to, Karajak fiord is the Itivdliarsuk fiord, which is a little less in size than the former. Between the two is the Sermilik fiord, still smaller than either. The glacier at the head of the latter fiord was not visited, though numerous bergs were passed which were derived from it.

At the head of Itivdliarsuk fiord its waters abut directly against the high point of land which lies between this and Sermilik fiord. Along the northeastern side, just below the end of the fiord, a broad area of ice enters the water. This is divided by long narrow nunataks into smaller glaciers, two of which are shown in Figure 13. The lower one, shown in Figure 13, was visited, while the upper was only seen from a distance. The width of this as it enters the water is about three miles, while the height of its face is not above 250 feet. The broad deep crevasses often reach down to the level of the water, producing the effect of a much more irregular frontal face than in the glacier previously observed. (See Figure 14.) Its entire length is about the same as that of the Greater Karajak, and its width is nearly constant throughout, about three miles.

The average gradient of this glacier is a little less than that of the Karajak, probably, but no determinations were made. Not far from the front the central surface is slightly higher than it is a half-mile farther up stream. The whole surface is strongly crevassed, even to the shore. (See Figure 15.) The sides are less steep and high, however, and the glacier was entered for a distance of a few rods at several places, though at no place could any great distance be reached. The vertical character of the edge of the ice is not so marked in this glacier, but it is still prominent. Marginal streams and lakes are also characteristic, and several large lakes on the surface, winding in and out among the pinnacles, were seen from a position overlooking the full width of the glacier. No distinct surface streams were seen.

The general mass of the ice here is also free from detritus. A lateral moraine holds the same relations as before, and is extremely till-like in its characteristics, containing a very large amount of fine silt, and when dry having the tenacity of till. A marginal strip of the ice a few rods in width is highly discolored with fine detritus, but only a few fragments are present. Near the head of the glacier and not far from its center lies a small nunatak, which gives rise to a medial moraine as seen in Figures 16 and 17.

Figures 16, 17, and 18 present views of the inland ice and the upper portions of the Itivdliarsuk glacier as seen from Mt. Ekinga

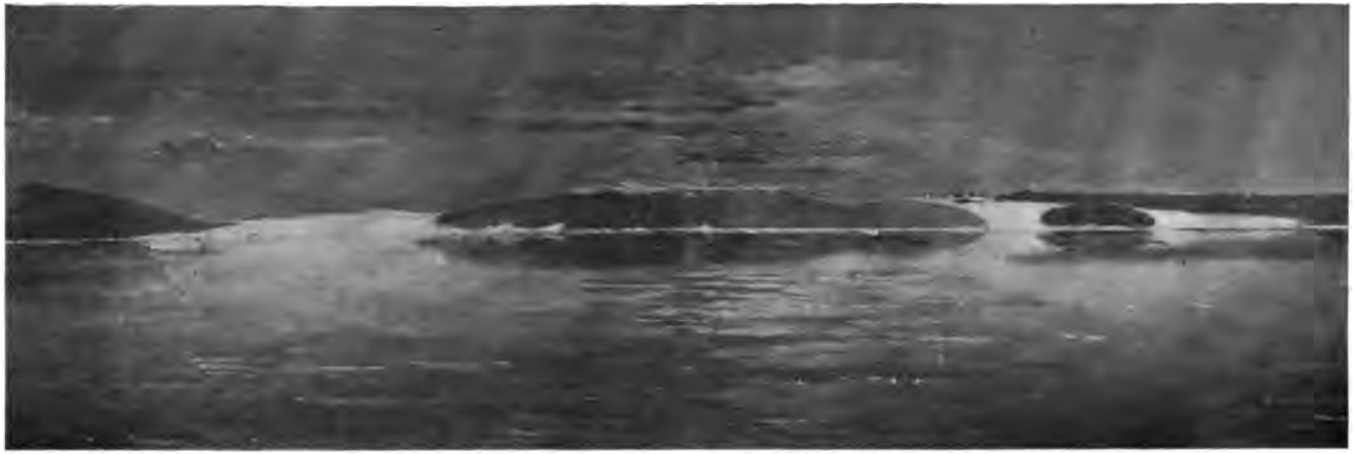

Fig. 13. The Itivdliarsuk Glaciers and Nunataks from the Opposite Side of the Fiord. The Summit of Ekinga is Seen upon the Left.

Fig. 15. Characteristic Surface of the Itivdliarsuk Glacier.

just northwest of the glacier. Figure 16 shows the upper third of this glacier and portions of the nunataks and glaciers to the southeast. The direction of the motion is shown by the medial moraine proceeding from the small nunatak. The greater volume of the ice comes from the eastward of the nunatak, and striking the stream from the west, deflects it strongly westward into the bay-like indentation on the Ekinga side. Figure 17 gives a nearer view of the small nunatak, and presents just the upper point of the larger nunatak on the east side. This view shows a strong difference in the crevassing of different portions of the glacier. The western side of the portion which flows between the nunatak and Ekinga is highly crevassed and pinnacled, while the eastern portion is comparatively much smoother. Again the lateral portions of that part which flows from the east of the nunatak are highly crevassed and pinnacled, while the central portions are smoother. These conditions continue nearly to the front of the glacier. Figure 18 presents the extreme upper portion of the glacier between the small nunatak and Ekinga and the edge of the inland ice stretching away to the northward. The head of the Ignerit glacier is seen between Ekinga and the first high peak beyond, from which a long, sharp spur projects into the ice. These three views all show the surface of the inland ice looking over its vast undulating expanse toward the interior. The horizon line of ice and sky is considerably higher, 2½ degrees, than that of our point of view, presenting a fair view of the gradient of the marginal area of the ice sheet. Figure 19 is taken from nearly the same point as the three preceding on the summit of Ekinga, 3,100 feet altitude, but looking northward and showing the edge of the inland ice as it lies upon the highlands north of the region shown in Figure 20. The ice on the extreme left as here seen is a portion of the local ice-cap lying upon the large peninsula northeast of Agpat island.

The Small Valley Glaciers and Glacial Tongues or Lobes.—Into the small valleys and gulches which are sharply incised in the northeast side of the Nugsuak peninsula, flow streams of ice from the local ice-cap of Nugsuak, some of which are broad, rounded lobes, some long, narrow ribbons of ice, while others present the ordinary forms of valley glaciers, which in a few cases reach down to sea level and enter the waters of the fiords. Nearly all these small valleys and gulches are practically at right angles to the general trend of the coast. Ekaluit and Itivdlek are larger valleys which are exceptions, their trends being at sharp angles with the coast. The latter of these contains no glaciers; the former has several which occupy small lateral valleys, but none of which reach the bottom of the larger Ekaluit valley itself. As the Nugsuak ice-cap lies wholly upon the south of this valley, the glaciers are necessarily limited to that side also. The two nearest the mouth of the valley only were visited, but several others were seen with the glass. Figure 20 presents a view but a short distance up stream, and shows the first two glaciers which were visited, and also a small detached portion of the ice-cap at the upper right of the view. The first glacier is fully shown in the view at a distance of an hour's walk. It plunges down through a narrow cañon with nearly vertical walls in its upper portion, with a very steep angle of descent which was not measured; then broadening, it loses its steepness and flows for a considerable distance with an average inclination of about 12°, and then changing again to an angle of 28°, which rises to 35° at its terminus. The upper and lower portions are strongly crevassed, but the middle portions only slightly so. The central portion throughout its whole length is much higher than the sides, the inclination of the surface from the sides toward the center being sufficient to make a pike staff necessary for the ascent. Small surface streams flow from the uncrevassed portions, forming large lateral streams.

As seen in the view the lateral moraines are very broad toward the lower end. These lie almost wholly upon the ice, and the stream flows between them and the pure ice of the glacier. The moraines thus appear to be much larger than they really are. As the stream cuts down into the ice, the detritus falls into it on the side next the moraine, the result being that the stream constantly encroaches upon the glacier as the detritus constantly follows and pushes it. Toward the upper end where the cliffs are nearly vertical, there are no moraines. At the foot there is a very definite fresh terminal moraine. The ice of the glacier is firm, compact, and blue in color. The largest stream from this glacier bursts directly from the foot of the ice and plunges down the valley in a torrent. The detritus borne by this stream has been spread out in a broad, low, alluvial fan over which its waters flow by several divergent branches. The glacier seen to the left in Figure 20 is not connected with the ice-cap above, but flows from a large cirque which is indistinctly seen in the view. On the left the walls are steep and high, on the right they retreat, the narrow valley above becoming broad and cirque-like. A portion of the glacier flows around

FIG. 18. THE INLAND ICE AS SEEN FROM THE SUMMIT OF EKINGA, 3100 FEET ABOVE SEA LEVEL, WITH A PORTION OF THE LOWER ITIVDLIARSUK GLACIER AT THE RIGHT.

FIG. 20. EKALUIT VALLEY WITH TWO OF ITS LATERAL VALLEY GLACIERS, AND A PORTION OF THE LOCAL ICE-CAP OF NUGSUAK PENINSULA AT THE RIGHT.

a projecting boss of rock into this cirque, giving rise to a series of very highly contorted flowage lines much resembling those of basic lavas. In its first plunge from the cirque the glacier has an inclination of 55°, this area having large crevasses ; the inclination then changing to 30° till broadening out to the wide expanse below, it has an inclination of 18° with very slight amount of crevassing. The lower portion very much resembles a huge shell in shape with the edge of the layers simulating its lines of growth. Lateral moraines are not so marked here, but the terminal moraine is very large and characterized by many very angular large blocks. The end of the glacier rests directly upon the fresh bare rock which forms the bottom of the valley for a short distance below the foot of the ice, then becoming steeper it sinks below a large mass of detritus and entirely disappears. The lateral stream upon the left side is of moderate size, that on the right is lost below the ice and in the detritus ; these uniting flow down the valley in a foaming torrent which has cut into the detritus above mentioned a depth of at least 30 to 40 feet without reaching the rock below. A broad, low, alluvial fan is also formed by this stream. The streams from the various glaciers unite to form the Ekaluit River flowing through the large valley, which in some portions of its course is torrential; in others it broadens out into small lakes in which the water is so clear that the bottom can be plainly seen for long distances from the shore.

The long narrow strip of ice seen at the upper right of Figure 20 is a part of the ice-cap which has been separated from the main mass by the melting of the thinner portion lying upon the sharp edge of the plateau. The inclination of its surface is about 25°. Its material is hard, compact, firm ice. Along its lower edge, which has an altitude of about 3,000 feet above sea level, is an exceptionally fine example of a bowlder pavement, the angular fragments being well fitted together, and the surface being nearly as smooth as an ordinary street pavement. This was visited during a heavy rain, so that there was no opportunity to obtain photographs of it.

From Ekaluit to the neighborhood of Sermiarsut the small glaciers are very numerous, some reaching sea level, but the majority only approaching it. In one case a little valley reaching back to the ice-cap ends with a nearly vertical face. Over this face the ice falls in large blocks which break into fragments and melt at its foot without accumulating to any amount. The vertical face of ice so produced above the valley shows its thickness to be at least 100 feet. Few of these lateral valleys show any cutting below sea level, the streams from the glaciers coming with torrential velocity to their mouths at the margin of the fiord. In a very few cases the waters of the fiord enter the valleys for a very short distance. A small glacier only a few hundred feet in width at most enters the water in one of these valley inlets.

Just east of Sermiarsut two large glaciers from closely adjacent valleys not only reach sea level, but push out slightly into the fiord. A very large amount of detritus has been brought down by the streams and by the ice, which the glaciers now seem to be over-riding as though advancing with considerable rapidity. The gradient of both these glaciers is very low as compared with all others of the valley glaciers. Extremely large lateral moraines come nearly to the very front of the glaciers, passing out a few hundred feet beyond the fiord margin.

On the island of Disko local ice-caps cover portions of the surface, which is a plateau of varying elevation, seldom below 2,000 feet above sea level and rising in summits to between 5,000 and 6,000 feet. Just back of Godhavn the ice-cap comes almost to the edge of the vertical basalt cliffs. The character of this small ice-cap is very different in many ways from that of the main inland ice. Its edge is extremely attenuated, the margin often decreasing to the thickness of an inch or less, and small detached portions being found at a distance of a few rods from the main mass. The ice rises to a broad dome-shaped form with an average inclination of about 13° on the surface. The surface was soft at this time, August 3, making walking quite difficult, each step plunging to the depth of six inches to a foot. Occasional narrow crevasses occur not over a foot in width, indicating a general motion of the whole mass. West of Godhavn a glacier plunges sharply down a narrow valley. The source of this glacier in the ice-cap is surrounded by crevasses which do not extend far back. Northeast of Godhavn is Blase Dale, whose glaciers have been described by Chamberlin and Salisbury. Here again the crevassing at their source extends back but a short distance into the ice-cap. This feature is in marked contrast to the great extent of the crevassed areas seen at the source of the Karajak and Itivdliarsuk glaciers. The lack of crevassing here is due to the smaller size of the ice stream, and to its sharper precipitous plunge. It is of interest to note that a spring similar in all characteristics to the one described and figured by Salisbury[1] was found in strong action on the same glacier.

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[1] Journal of Geology, IV, 1896, p. 809.

FIG. 16. THE UPPER PORTIONS OF THE ITIVDLIARSUK GLACIERS WITH INLAND ICE IN THE BACKGROUND. THIS VIEW IS TAKEN FROM THE SUMMIT OF EKINGA, 3100 FEET ABOVE SEA LEVEL.

FIG. 17. UPPER PORTION OF LOWER ITIVDLIARSUK GLACIER WITH SMALL NUNATAK IN CENTER AND THE INLAND ICE IN THE BACKGROUND. TAKEN FROM THE SIDE OF EKINGA.

The Former Extension of the Ice. — With one or two exceptions all the large valley glaciers, whether terminating in the sea or on the land, and the glacial lobes, exhibit evidences of diminution in size recently, and also during a long period of time. At Sermiarsut, nearly opposite the village of Umanak on the Nugsuak peninsula, the two glaciers as described above have brought down a large amount of detritus, and have projected it into the fiord. The material is all fresh, not covered with lichens, and the ice is apparently overriding the portions deposited in front, passing out over it for some little distance beyond the walls of the fiord, but not entering the water, the detritus bringing it above sea level. Nowhere else was any evidence of advance observed, and this may be more apparent than real.

Along the sides of the valley of the Greater Karajak glaciers at an elevation of from 60 to 100 feet above the present lateral moraine, there is a definite surface at most points but obliterated in others, marking a former level of the glacier at this height. Below this level the valley's sides are well covered with morainal material, all of which is well covered with black lichens except the material of the present moraine. This upper line can be traced along the whole length of the valley from below the present terminal face of the ice to the head of the nunatak, holding approximately the same elevation above the present moraine throughout its course.

At the Itivdliarsuk glacier the point of land forming its western boundary rises at Ekinga to an elevation of over 3,000 feet. At the southwest it is very precipitous from the summit downward till within a height of 400 or 500 feet above the sea, sending out here a long low point of about this elevation. Through this point runs a small valley diverging from the large Itivdliarsuk at nearly a right angle. At a time when the Itivdliarsuk glacier was larger than at present, it sent a branch down through this valley which entered the sea two or three miles farther down the fiord than the main mass. The upper surface of the lateral moraines formed on either side of this branch are well preserved. This moraine is also more or less continuous up the large Itivdliarsuk valley toward the inland ice.

In the valley of the Ekaluit there is no glacier to-day, except the small ones in the lateral valleys leading into it, but there is good evidence of its being formerly occupied by one. The northeast side of the valley is precipitous, nearly vertical in places, so that old moraines cannot be traced easily on that side, though at the foot of the precipices there is a general mingling in large masses of fresh talus and old morainal material, the latter being mostly buried, however. The southwest side of the valley has a comparatively gentle slope, and here the old moraines are well preserved. In some places the whole side of the valley from the bottom upward to the foot of the more precipitous upper portions is covered with a morainal sheet of considerable thickness. The streams issuing from the small lateral glaciers cut downward through this sheet, sometimes reaching its lower surface, sometimes not; in one case cutting to a depth of at least 30 to 40 feet without reaching the underlying rock. The material of this thick sheet is a mixture of rolled or rounded and subangular fragments with some finer material. Lying more especially at the mouths of the lateral valleys, it may have been derived partly from the terminal moraines of the small lateral glaciers when they extended farther than to-day. Between the valleys the underlying rock is often at the surface.

Running along the sides of the valley at a considerable elevation above its bottom are three very distinct and parallel old lateral moraines. These are practically continuous as far as the valley was seen, except where cut by the lateral valleys and glaciers, as was done in each case. All three moraines are sharp, well-defined ridges, maintaining about the same elevation above the valley bottom all along its course, dropping as it drops as they approach the sea. The altitude of the crest of the lower one of the three just seaward of the first lateral glacier is about 875 feet above sea, and 500 to 600 feet above the valley bottom. The altitude of the second, 1,065, and of the third about 1,150 feet above the sea, or more than 700 and 800 feet above the valley bottom. The depth of the glacier that formed this upper moraine must have been nearly or quite 1,000 feet. The foot of the present small glacier in the first lateral valley reaches down to a point about 1,125 feet above the sea, just a few feet lower than the crest of this old moraine. The sides of the lateral valley, where not too steep, also have old lateral moraines nearly 100 feet above the present glacier, and distinct old terminal moraines occur at some distance down the valley below the present ice front.

In the Itivdlek valley bowlder pavements and lateral moraines were seen, but no observations were made upon them. Back from this valley the edge of the inland ice at Iterpiluak gives evidence of having quite recently sent a lobe downward to occupy a small shallow depression which is now occupied by a lake. A moraine extends from the present moraine of the ice front around the lake at a slight elevation above its present surface. The larger portion of the material of this moraine is not covered by the black lichens which cover all old detritus, showing that it is comparatively of fresh formation.

Many of the small glaciers along the Nugsuak coast from Ekaluit to Sermiarsut have large moraines lining the valley sides high above their present level and large enough to be distinctly seen from the sea. Large terminal moraines can also be seen in most of the valleys far below the present ice front. The valley bottoms are sometimes well rounded, and in some cases the present stream has cut a gorge down into the rounded floor, as shown in Figure 21.

Along the more or less precipitous sides of the Nugsuak peninsula are occasional pieces of old moraines at various altitudes, some well defined, some indistinct. The same is to be seen on the north side of Storöen, especially well at an elevation of between 500 and 1,000 feet above sea level.

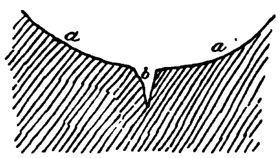

Fig. 21. Rounded bottom, *a a*, of old valleys along Nugsuak peninsula, with gorge, *b*, cut by stream from the retreating glacier.

The islands of Umanak and Ikerasak present types of topography essentially like each other, but differing from all others in this region. Each consists principally of a moderately low surface, not much if any over 1,000 feet in altitude in its highest portions, well glaciated, and rounded into roches moutonnées. Resting upon this smooth and comparatively broad pedestal rises a sharply angular elongated peak with almost vertical sides and ends too steep for ascent. No smoothing is apparent above the level of the roches moutonnées; all outline above is due to the effect of frost action. The contrast is exceedingly marked and striking. The summit in each case is sharply serrate, but in the case of Umanak when seen from one position a single cleft with rounded peaks on each side form an outline resembling the lobes of a heart; whence the Eskimo name *Uma*, heart, *nak*, like.

The peak of Umanak rises to a height of 3,720 feet above sea level, and that of Ikerasak to 2,550 feet. At the foot of each peak lies a lateral moraine distinctly marked in each case, but better seen at Umanak. Figure 22 shows the southwestern side of Umanak Peak with the moraine at its base. The sharp contrast between the smooth-flowing outlines below and the angular above is also well brought out in this view. Figure 23 is a view of the peak of Ikerasak showing the contrast in topography again, but not sufficiently near to show the moraine at its base. The material forming the ridge seen in Figure 22 is of true morainal character, angular, sub-angular, rounded and striated fragments with considerable sand and clay intermixed. It is entirely distinct from the talus which is mostly accumulated on the steep lower slopes of the peak, though many fragments of the latter have reached and lie upon the moraine. Most of the morainal material is covered with black lichens, while the talus material is largely free from them and fresher in appearance. There is no soil except in sheltered nooks on these low islands, and practically none at all on the higher islands and peninsulas. Finer drift material is also very scarce, but coarser drift is common. The low main portions of Umanak and Ikerasak islands are liberally sprinkled with bowlders of all sizes up to many tons in weight, and in many cases they almost entirely cover the surface.

Gneiss and schists, cut by granite and by numerous dikes of very dark color and high specific gravity, are the only rocks which form those portions of the mainland, of Nugsuak peninsula and of the islands which we visited. The rocks of later age occur farther westward on Nugsuak. The gneiss is very highly folded and contorted. Figure 22 shows indistinctly an overturned fold. All of these rocks are abundantly represented among the bowlders on Umanak and Ikerasak, but no other variety is found. The bowlders of eruptive rock often show a large amount of decomposition which has taken place since their transportation, some having crumbled entirely, while in others the polished glaciated surface has remained as a shell from which a portion of the remainder has fallen away. The dikes show no greater erosion by glacial action than the inclosing gneiss, being ground and polished to the same level only, not below that of the gneiss, indicating no great preglacial decomposition below their present surface. The surface of the gneiss, while not generally retaining the polish and finer striæ of glacial action, does retain the coarser striæ and grooves, disintegration having taken place but slightly since the disappearance of the ice.

On the nunatak between the two Karajak glaciers, the same conditions prevail as upon the lower portions of Umanak and Ikerasak. Its form is long and narrow, lying parallel to the Great Karajak glacier, and nearly at right angles to the Karajak fiord. Its highest summit on the north is 2,245 feet, and the one on the south a little

FIG. 19. THE EDGE OF THE INLAND ICE AS SEEN TO THE NORTHWARD FROM THE SUMMIT OF EKINGA. UPON THE EXTREME LEFT IS THE LOCAL ICE-CAP OF AGPAT ISLAND.

lower. The most typical roches moutonnées occur on both summits with striæ and grooves well preserved, and in some cases the polish is also well preserved, but this is exceptional. The direction of motion here was transverse to that of the present Karajak glacier and to the axis of the nunatak, and nearly parallel to Karajak fiord and the Nugsuak peninsula. Bowlders are numerous over all parts of the nunatak. So far as seen they are entirely of gneiss, schist, granite, and the same dark eruptive rock as before noted. Here the eruptive rock, though showing much decomposition in the bowlders, has resisted erosion more strongly than the inclosing gneiss, so that the dikes and intrusive areas sometimes stand out in relief above the gneiss. This is most strikingly shown in an exceptionally fine high roche moutonnée, which consists entirely of the eruptive rock with the polish and striæ well preserved on the stoss side, where it is 10 to 12 feet high and 8 to 10 feet broad. On the Nugsuak peninsula between Itivdlek and Iterpiluak the same general characteristics are found. The bearings of the striæ are quite constantly about parallel to the direction of Karajak fiord, with some local variations.

On the point Anat just west of the Itivdliarsuk glacier, Mt. Ekinga rises to a height of about 3,100 feet. Its summit is finely glaciated, showing some of the finest roche moutonnées. The striæ and grooves are well preserved, and in some cases the polish still remains. Here again the direction of the motion was nearly or quite parallel to the direction of the Itivdliarsuk fiord, and consequently to Karajak fiord. This shows a parallel movement over an area of many miles in width in this region.

Bowlders of gneiss, schist, granite, and the dark eruptive rock are scattered in profusion over the lower portion and to the highest summit. In addition, all over this little peninsula, so far as seen, there are bowlders of limestone slightly fossiliferous, and of a red sandstone that so closely resembles the triassic sandstone of the Connecticut Valley that it could easily be mistaken for it. Neither of these rocks occur in place so far as a careful search would reveal. Their presence here as bowlders implies that they do occur in place farther inland under the present ice-cap. The fragments vary in size all the way from small pebbles to bowlders of 5 or 6 feet in diameter.

Ekinga was the highest point actually reached, and this in common with all lower ones gives the strongest evidence of having been overridden by the ice. From this and other high points, as well as from the surface of the inland ice, transverse and rear views of higher peaks were obtained. The general topographical appearance changes as much on a large scale according to the point of view from which it is seen, as does one of our smaller roches moutonnées areas when seen from the stoss or lee sides, or transversely.

Seen from the west, and especially when seen from the water level, the general appearance is of strong angularity, so sharply marked in many cases that it is difficult to believe that it has been overridden and smoothed by ice action. Seen from the south or north, and better when viewed from a moderate elevation, the same region shows usually a sharply serrate character, but with the peaks shaped something like the teeth of a circular saw, steep and precipitous on the west, and with moderate or gentle slopes on the east. This characteristic outline so strongly marked over the whole region is well shown in Figure 24, which is a sketch of a portion of the summit of Agpat Island as seen from the water to the southward between Agpat and Storöen.

FIG. 24. SKETCH OF A PORTION OF THE SUMMIT OF AGPAT ISLAND SEEN FROM THE SOUTHWARD, SHOWING THE MARKED STOSS SIDE OF SUMMITS, WHICH APPEAR ANGULAR FROM THE WESTWARD. *a a*, LOCAL ICE-CAP.

Again when seen from the ice-cap to the east, the angularity very largely disappears, if not entirely so. The Nugsuak peninsula, as seen from the highest points we reached to the east and northeast, presents these features so strongly as to convince the writer that its surface even to its extreme outer point has been overridden, and that the ice must have passed into the waters beyond. Professor Angelo Heilprin informs the writer that he has been upon the summit of the outer end of Nugsuak, and finds that it has been glaciated to its extremity. As seen from Ekinga, Agpat presents a very smooth surface with well-rounded outlines, as does all the remainder of the region except the distant and sharp peaks of Upernavik and Ubekyendt islands, the higher points of the former rising to 6,850 feet, being the greatest elevation attained by any summits in this region. Of all the peaks seen in Greenland, these only left a doubt in the mind of the writer as to their having once been covered by the former extension of the inland ice. Professor Heilprin states that he has also been upon the

Fig. 22. The Southwestern Side of Umanak Island, showing the Marked Contrast between the Angularity of the Peak and the Rounded Outline of the Lower and Main Portion of the Island. A Very Large Lateral Moraine is Seen at the Left of the Foot of the Peak. A Well-Defined Overturned Fold in the Gneiss is Shown on the Side of the Peak. The Peak is Believed to have been Buried by the Greatest Extension of the Ice, and Its Present Angularity to be Due to Later Frost Action.

summits of both Upernavik and Ubekyendt islands and found abundant traces of glaciation produced by ice moving westward.

There seems to be strong and abundant evidence that all of the Umanak fiord region south of the Svarten Huk peninsula which was not seen, and consequently can not be discussed, has been covered even above the highest summits with a sheet of ice having a definite and strong motion in a direction something north of west, about parallel to the general trend of the Nugsuak peninsula and of the Karajak and Itivdliarsuk fiords. That the motion must have been a strong one is shown by the considerable amount of rounding that has been impressed upon the topography even to the outermost points, and by the fact that a large proportion of the bowlders so numerously scattered everywhere show evidence of transportation for a considerable distance in their often well-rounded character. It is unfortunate that the underlying rocks of the region have the same general characteristics throughout, preventing the determination of the distance of transportation. The only exceptions to this are the sandstone and limestone bowlders found at Ekinga, and the lateness of the season when these were found prevented the determination of the limit of their distribution westward. That the ice passed over the summits of Upernavik island nearly 7,000 feet above the sea indicates a great thickness at its maximum over this region, soundings indicating as great a depth in the fiords as 385 fathoms being given on the chart. With these facts in view it is difficult not to believe that the present inland ice sheet once extended over all this portion of Greenland, passing out beyond the farthest limits of the present coast line into the open waters of Baffin's Bay. How far beyond the present limits of the coast line it passed, there are no facts yet known to justify a conclusion. Whether it met and coalesced with the ice sheet from the American side, seems idle speculation for the present. That it ever passed to the American side is disproved by evidence on that side, and that view is not now seriously entertained by any glacialist so far as known.

During its maximum extension the fiords must have been entirely filled and practically obliterated from the ice topography. As the ice sheet diminished in thickness, their influence became more marked till it became dominant in their region. It is probable that at one stage of the retreat, and that a very long one, confluent glaciers from Karajak, Itivdliarsuk, and other small fiords, united in one large Umanak fiord glacier. During this stage the lower portions of the islands of Umanak and Ikerasak were covered and passed over by the ice, while the higher portions rose above its surface as nunataks. Probably well rounded when first exposed, frost action then and since has produced its results upon them as upon the sides of the fiord, and given them their present angular outlines as seen in Figures 22 and 23. That they must have been covered by the ice sheet is proved by the fact that the higher and neighboring summits of Nugsuak and of Storöen, and of the point northeast of Ikerasak are glaciated. It would be difficult to conceive of the glaciation of these summits by a sheet that did not cover all the lower summits. If this view is correct, then it follows that present angular characteristics such as are shown in these two cases of Umanak and Ikerasak do not preclude the possibility of previous glaciation, but only that its effects have been obliterated by later frost action and atmospheric erosion in general.

With this possibility in view the writer would suggest the same solution as possibly being applicable to the instances cited by Chamberlin[1] in the case of Dalrymple rock, and others farther north. This is merely a suggestion made with diffidence, as that region has not been visited by the writer. Indeed, the view of Dalrymple Island as given by Chamberlin presents a marked stoss and lee side, apparently in their appropriate positions as related to the mainland topography seen in the distance. (See Figure 25.)

Disko island, the largest on the coast of Greenland, is essentially a plateau having an elevation of 2,000 to 4,000 feet above the sea, with peaks rising to 5,000 and nearly 6,000 feet. It is surrounded on all sides by precipitous cliffs, which at the south just back of Godhavn rise vertically from not far above sea level to an altitude of over 2,000 feet. The base of the island is the same characteristic gneiss found in the Umanak region. This gneiss forms the whole of the low promontory, probably not exceeding 200 feet in its highest elevation, upon which is situated the settlement of Godhavn and in which is inclosed the fine little harbor of that place. This promontory is well glaciated by ice which had a westward motion, as noted by Chamberlin, and which the writer would have no doubt came from the mainland, as suggested by the above authority. The upper portion of the island consists of a thick cap of basalt resting upon the gneiss together with

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[1] Journal of Geology, 2, 1894, p. 661.

FIG. 23. THE PEAK OF IKERASAK, SHOWING ANGULARITY, IN CONTRAST WITH THE ROUNDED OUTLINES OF THE LOWER AND MAIN PORTION OF THE ISLAND. IT IS BELIEVED THAT THIS PEAK HAS BEEN BURIED BY THE FORMER EXTENSION OF THE ICE. THE FOREGROUND IS OCCUPIED BY AN ESKIMO CHURCH.

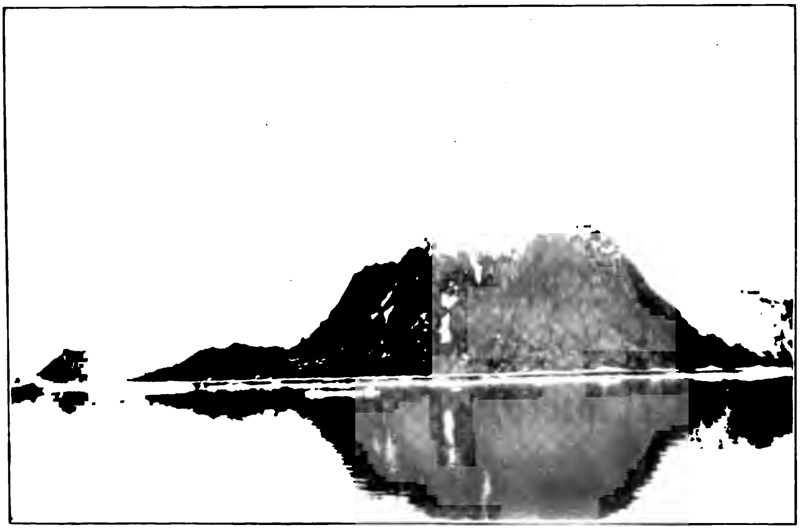

FIG. 25. DALRYMPLE ROCK, AFTER CHAMBERLIN.

beds of sandstone which occur farther north, and especially along the Waigat. So far as known, gneiss does not rise far above sea level at any point on the island. Bowlders of gneiss, however, are scattered over the surface of the low promontory, and also in the steep, sharp valleys cut into the basalt cliffs and even upon the surface of the plateau. Opportunity was not given to search for evidence of the former extension of the inland ice of Greenland over the plateau surface of Disko, but if it did cover the Umanak fiord region and the Nugsuak peninsula, then it must also have enwrapped the whole of Disko Island, and have filled the Waigat. The bowlders of gneiss on the Disko plateau have probably come from the mainland, and do not, as suggested by Chamberlin, indicate a central core of gneiss rising to the surface in the interior of Disko, and from which they have been brought by the action of the present local ice-cap. So far as known to the present writer, however, there are no facts as yet observed on Disko to sustain either view. The view here presented simply follows directly in the line of the argument in the preceding pages.

On the American side of Davis Strait and Baffin's Bay the evidence of former glaciation is generally of the same character as on Greenland. The coast was closely skirted from the Strait of Belle Isle to north of Cumberland Sound, and landings were made at Turnavik in Labrador, on Big Savage Island, and the mainland of Meta Incognita in Hudson Strait, and on the south shore of Cumberland Sound at Niantilik harbor.

At Turnavik the rock is completely rounded into roches moutonnées, which near sea level retain a good degree of polish and have the striæ well preserved. Higher above the sea the rock has been more fully decomposed, and the striæ and polish have largely or entirely disappeared, though still seen on the highest summit, about 300 feet in altitude. The general direction of the motion here was about northeast, or about normal to the coast line. Erratics are rare, if not entirely wanting. The principal rock is a coarsely porphyritic granitoid gneiss cut by numerous dikes, one series of which is closely parallel in direction to the motion of the ice. Several dikes of this series have been eroded by the ice to a depth in some cases of 15 to 20 feet below the inclosing walls, as shown in Figures 26 and 27. In this, evidence is given of a large amount of preglacial decomposition in the dike rock as already noted by Professor Tarr. It also indicates a difference in conditions as compared with those of Greenland, where the dikes are not eroded below the level of the inclosing rock. In the latter case the preglacial decomposition may not have been so great as in the former, due to a much earlier formation of an ice sheet in Greenland than in Labrador, or the erosive action of the ice has been greater, wearing down the whole surface below the limit of greater decomposition in the dike rock.

The coastal region of Labrador from Turnavik to Cape Chidley, as seen from the vessel, has the general appearance of a well glaciated region in its rounded contours and flowing outlines. In the vicinity of Cape Mugford, latitude 58° 30′, Table Hill, White Bear Island, and the Kig-la-pait mountains, 2,000 feet high, all appearance of rounding is lost when seen directly off shore, only sharp peaks or serrated edges being seen, giving the impression that the country here has never been overridden by an ice sheet. However, when seen from farther south in a direction transverse to the direction of the ice motion if it passed from the land toward the sea, as the evidence at the points actually visited proves, rounded outlines are sufficiently distinct to justify the conclusion that the ice did override this as well as other portions of the Labrador coast.

On the southern shore of Baffin Land along Hudson Strait the general rounding effects of glacial action are very apparent, but except near the sea level, polish and striæ have entirely disappeared. The rock is a very garnetiferous gneiss, sometimes highly ferruginous. Post-glacial decomposition has acted rapidly upon this rock, so that the entire surface is coated with its debris. Transported bowlders are also numerous, among them being many fragments of a finely crystalline limestone. Topographically the surface consists of a series of alternate high, narrow ridges, and deep, narrow valleys running about parallel with the strike of the gneiss, N-20-30-E (mag.). These valleys are possibly due to differential erosion of more highly calcareous layers. A few transverse valleys are apparently due to highly crushed and jointed areas. The ridges and hills are well rounded, the motion of the ice having been diagonal to the ridges. Professor Tarr[1] has already called attention to the fact that the principal topographical features here are preglacial, and to the evidence of the slight amount of glacial erosion here as compared with that farther south. It is also much less than any seen in Greenland.

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[1] Am. Geol., 19, 1897, 194.

FIG. 26. WALL OF A DIKE AT TURNAVIK, LABRADOR, WHICH HAS BEEN REMOVED BY GLACIAL ACTION, INDICATING PREGLACIAL DECOMPOSITION.

FIG. 27. DIKE ERODED BY GLACIAL ACTION, INDICATING PREGLACIAL DECOMPOSITION. TURNAVIK, LABRADOR. (*From American Geologist.*)

At Big Savage Island the highest elevation visited is about 250 feet above the sea. Along this summit there is a well defined moraine continuing for several hundred feet with an average width of about 150 feet. It consists of fragments varying in size from pebbles to those 5 feet in diameter, nearly all well rounded. The general contour of the island is well rounded, showing the motion of the ice to have been southeasterly, but no striæ were found. All the valleys show a series of well preserved raised beaches, the highest being at an elevation of 250 feet above sea. These have been well described by Mr. T. L. Watson,[1] of the Cornell party. The rock here is a well banded gneiss, containing no garnets. The erratics are the same as the underlying gneiss, except a few limestone fragments and some dike rock. No fragments of the garnetiferous gneiss of the mainland were found, the motion of the drift having been sufficiently eastward to carry it north of this island. The limestone occurring in bowlders was not found in place.

At Niantilik harbor on the south shore of Cumberland Sound the gneiss is very highly disintegrated on the surface, so that at first sight there is an appearance of a non-glaciated surface, but rounded contours prevail and transported fragments are numerous. The direction of the ice motion here was southeasterly, nearly parallel to the axis of the Sound.

As previously mentioned, post-glacial decomposition is much more marked in Labrador, Meta Incognita, and Baffin Land, than any observed in Greenland, though, as noted by Professor Tarr in the article above cited, there are some indications of the comparatively recent withdrawal of the ice in these regions; still it was probably long anterior to the withdrawal of the Greenland ice-cap from the summits, 3,000 feet in altitude, or more, in the vicinity of Karajak and Itivdliarsuk fiords. On the latter the striæ and polish even are often still well preserved where the range of temperature is fully as low as in Baffin Land, and with greater variation between that of summer and winter, giving at least fully as good conditions for rapid disintegration.

In conclusion, the brief observations made along the Labrador coast and in Baffin Land would indicate that this whole country was once buried by a sheet of ice that in general had a motion outward toward the waters of Davis Strait and Baffin's Bay, and that this sheet

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[1] Journal of Geology, 5, 1897, 17-34.

retreated from the immediate coastal region at least at an earlier date than did the Greenland sheet from the region of Umanak fiord. Though not proved by direct observation that it covered the highest peaks, yet by what has been seen it seems evident that, could these peaks be visited, they would furnish evidence to that effect. But as said in regard to the Greenland ice sheet, to determine how far the Labrador and Baffin Land ice extended into Davis Strait and Baffin's Bay, or whether it ever coalesced with the sheet from Greenland, there is as yet no evidence. Further investigation is needed of this most interesting problem.

A NOTE ON SOME OF THE REQUIREMENTS FOR A SANITARY MILK-SUPPLY.

BY WILLIAM T. SEDGWICK, PH.D.

Received May 10, 1897.

IT is now generally recognized that the milk-supply problem is one of the most pressing in American sanitation, and I am frequently asked to give an opinion as to the merits of this or that remedial measure. I have therefore thought it worth while to lay down very briefly, but I hope clearly, the fundamental principles which must be carefully kept in mind in seeking to introduce sanitary reforms into this important industry.

The fundamental, indispensable, and all-controlling requirement of a sanitary milk-supply is that milk when consumed shall be as nearly *normal* as possible. Normal milk is milk as it flows from the mammary gland of a normal animal, and a normal animal is obviously one that is healthy and well fed. From such an animal under normal conditions the milk supply of its young passes almost instantaneously, and without exposure to dust and air, from the milk ducts of the mother to the stomach of the suckling. Such milk is absolutely fresh, warm, and free from dirt. It is not only undecomposed, but nearly or quite free from the germs (bacteria) of decomposition.

Ordinary city milk, on the contrary, is neither fresh, warm, nor free from dirt, and if not already far on the road towards decomposition, is always richly seeded with bacteria. It is not always derived from healthy or well-fed animals, and is seldom drawn under clean and sanitary conditions, so that even at the outset it may be, and often is, very far from normal. It is also too often transported over long distances so that it still further loses its original freshness, and it is frequently manipulated by unclean, and sometimes by diseased, workmen. By the time it reaches the consumer, therefore, it is not only no longer normal milk, but usually stale, dirty, more or less decomposed, and sometimes also diseased.

Some of the steps to be taken in securing a more sanitary supply are easily deduced from the foregoing facts, and are as follows:

1. Milch cows should be healthy, well fed, well kept, and well cared for.

2. Milk should be derived from such cows only, and with all possible precautions in regard to sanitation and cleanness. Cows as sources of food should be tended as carefully as, or more carefully than, horses used only for burden or pleasure. The operation of milking should be looked after with special care. Above all, the hands of the milker should be carefully washed just before he begins to milk, his own personal cleanliness being even more important than that of the cow.

3. When drawn, milk should be immediately filtered and chilled, as means of retarding decomposition, and all articles with which it comes in contact, such as filters, pails, cans, etc., should be scrupulously clean.

4. The milk thus prepared should be delivered, if possible, at once.

5. If it is impossible to deliver the milk immediately, it will be impossible to deliver normal milk, and such milk cannot, in fact, generally be obtained in cities. The best that can be done, probably, is to deliver as speedily as possible two kinds of milk, viz.:

(*a*) The milk thus far described, kept as nearly normal as the conditions will allow.

(*b*) The same milk carefully *pasteurized* either (and preferably) on the farm where it is produced, or at some central point accessible from a number of farms, or, if this be impracticable, at some good distributing point in or near the city to be served.

The former (*a*), which may be called "chilled milk" or "raw milk" or "ordinary milk," will be preferred by some. The latter (*b*), which may be called "pasteurized milk" or "sanitary milk," will be preferred by many as being certainly free from the germs of infectious disease.

There can be no doubt that any individual or company which honestly strives to displace the present highly objectionable milk-supply of American cities by a supply such as has been here described, deserves, and will secure, the support and the confidence of the more intelligent portion of the community.

BIOLOGICAL LABORATORY.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY.
May, 1897.

A FLAVOR-PRODUCING MICROCOCCUS OF BUTTER.

BY SIMEON C. KEITH, JR., S.B.

Received May 24, 1897.

IN April, 1896, I was studying the effects of various bacteria upon cream, and in the course of my experiments I isolated from a mixture of bacteria growing in an agar tube a micrococcus that was found to produce a decided butter flavor and aroma when grown in milk or cream. This proved to be a new species, for which I propose the name *Micrococcus butyri-aromafaciens.*

It has always been the custom to allow cream to sour or "ripen" before churning it for butter, because after this process the butter comes better and more quickly, is of better texture and flavor, and keeps better than butter made from sweet cream. Lord Lister and Pasteur, many years ago, showed that the souring of milk and cream is due to a process of fermentation during which the milk sugar is converted into lactic acid, and that this is due to the activity of minute micro-organisms. It remained for Professor Vilhelm Storch, of Copenhagen, however, to introduce the use of pure cultures of milk-souring bacteria in butter making. Storch found that several kinds of acid-producing bacteria are concerned in the normal souring of cream, and he isolated three species that impart especially fine flavors to butter under favorable conditions.

A similar line of work was taken up by Professor Weigmann, of the Agricultural Experiment Station at Kiel, in Germany, and by Professor H. W. Conn, of Wesleyan University in this country.

Of the bacteria that have been described as producing a beneficial effect in the ripening of cream, *Micrococcus butyri-aromafaciens* (Figure 1) most nearly resembles Conn's *Bacillus No. 41*[1] (Figure 2), in its effects upon milk, but it differs in its morphological and in many of its physiological characters. It is a micrococcus growing at 37° and 20° C. It liquefies gelatin slowly, and does not grow well on potato. It may

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[1] Storrs Agricultural Experiment Station, Bulletin 12, and Report for 1894.

be noted in this connection, however, that recent cultures on gelatin seem to show that the organism has lost to a considerable extent its power to liquefy gelatin during a year's cultivation in the laboratory.

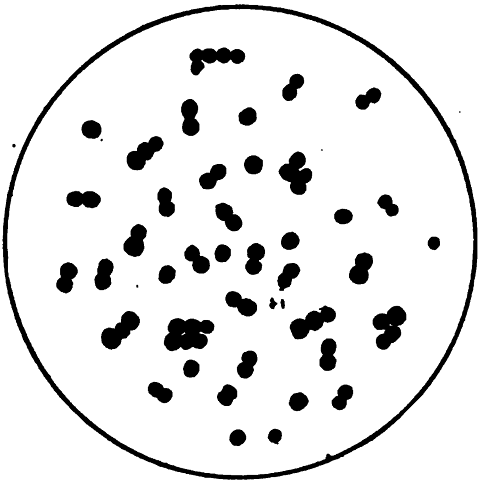

FIG. I. MICROCOCCUS BUTYRI AROMAFACIENS.
MAGNIFIED 1,500 DIAMETERS.
DRAWN FROM A MICROSCOPICAL PREPARATION MADE FROM A GROWTH ON AGAR.

The culture of the micrococcus for use in creameries is propagated in bouillon in Fernbach flasks (broad flasks so constructed that a large surface of liquid is presented to the air). When ready for shipment, the culture is transferred to sterilized bottles under aseptic conditions and hermetically sealed by means of sterilized corks and melted paraffine. Put up in this way, the culture may be kept for an indefinite time without danger of infection by any other organism, but in the sealed bottles the micrococcus loses its vitality so rapidly that after eight days it will no longer produce the best results. Experiments made on a commercial scale show that cream ripened with the aid of fresh pure cultures of this organism produces generally better butter than the same cream ripened in the usual way. The distinguishing characters of the species are given in the following systematic description.

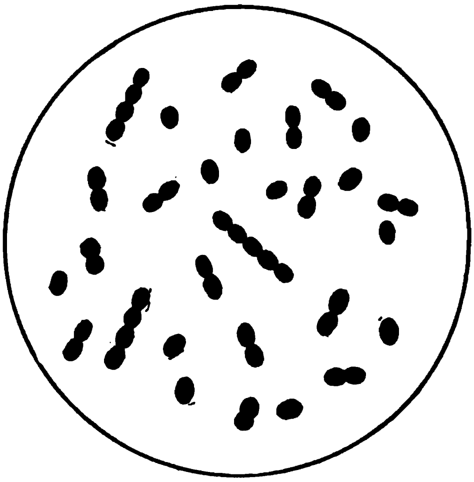

FIG. 2. BACILLUS 41, CONN.
MAGNIFIED ABOUT 1,500 DIAMETERS.
DRAWN FROM A PHOTOMICROGRAPH KINDLY SENT BY PROF. CONN.

MICROCOCCUS BUTYRI-AROMAFACIENS, Nov. Sp.

Occurrence.	Isolated from a mixed culture growing on agar in April, 1896.
General Characters.	*Shape and arrangement:* A micrococcus occurring generally in pairs. *Size:* 0.5–0.7 μ in diameter, occasionally reaching 1μ. *Motility:* Non-motile. *Spore formation:* No spores. *Relation to temperature:* Grows rapidly at 37° and 20° C. *Relation to air:* Aërobic. *Relation to gelatin:* Slow liquifier. *Color:* Non-chromogenic (white). *Stain:* Stains well with carbol-fuchsin.
Gelatin.	*Stick culture:* Five days. The gelatin is liquefied in the form of a deep cup ⅜'' in diameter. The liquefied gelatin remains clear, with a white film and sediment. The growth below the point of liquefaction is a moderately thick, white dotted line. *Plate culture:* Surface colonies: The colony first appears as a white raised dot which soon sinks in a pit of liquefied gelatin, and ultimately becomes surrounded by a slight whitish ring along edge of the liquefied gelatin. Submerged colonies: The submerged colonies occur as smooth spherical dots.
Agar.	*Streak culture:* A very white, smooth, shining growth, which is fairly abundant. The growth is of equal thickness throughout. *Plate culture:* Characters of no diagnostic value. *Lactose-litmus-agar:* Litmus reddened slightly.
Potato.	There is very little growth on potato. In two weeks it appears as a very thin, white line, barely visible.
Milk.	Not coagulated. A slightly sourish, pleasantly aromatic, "buttery" flavor. Slightly acid.
Smith Solution.	No gas produced. The growth occurs mostly in the open limb of the fermentation tube, the bouillon of the closed limb being only very faintly turbid.
Nitrate.	Reduced to nitrite. Recent cultures do not seem to give this reaction very strongly, although when first isolated it was very marked.
Bouillon.	Two days, 25° C. Very cloudy with sediment. One week, no further change. Two days, 37° C. Very cloudy with sediment and ring growth on tube at surface of the liquid.

SOME FUNDAMENTAL PROPOSITIONS RELATING TO THE DESIGN OF FRAMEWORKS.[1]

BY FRANK H. CILLEY, S.B.

Received November 27, 1896.

PART I. — THE EVOLUTION OF THE FRAMEWORK — THE ARBITRARY NATURE OF THE DISTRIBUTION OF STRESS IN INDETERMINATE FORMS.

IN ancient times the builder practically disposed of but two sorts of material suitable for his purposes — stone and wood. The former, adapted only to resisting compression, permitted of no higher development in construction than the arch; and the latter, although in addition well suited to the carrying of transverse loads, was so limited by its tendency to split and shear, and the consequent difficulty of making strong connections, that it hardly admitted of a more complex combination than the braced beam. These forms appear to have been known almost from time immemorial, and it is possible that to this day we should have remained limited to them had not metal, with its more extended qualities, come within the range of building materials. Metal, it is true, had also been known from most ancient times, but only as rare and costly material. It is the very modern cheapening in production of certain of its forms, particularly of iron and steel, which has permitted of its employment for ordinary structural purposes, and thereby given rise to the numerous forms of construction existing to-day.

These forms, however, did not at once come into existence, but rather were gradually evolved from the earlier forms in the attempt

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[1] The principal results of this article, viz., the arbitrary nature of the distribution of stress in an indeterminate framework and the economic superiority of statically determined construction, were obtained in February, 1896, and embodied in a communication of that date to Professor George F. Swain. In June, 1896, Professor Swain returned the manuscript of the above communication, advised rewriting it in popular form, and suggested a second and independent proof of the economic superiority of statically determined frameworks. The present article, completed in July, 1896, was the outcome.

to utilize with higher economy the still very expensive new material, taking advantage of its resistance to tension as well as compression, and of the ease with which it could be given any desired form, and the strength with which different pieces could be united. Commencing with mere imitations of the manners of use of the older materials, it was soon observed that such massive construction in metal was as unnecessary as uneconomical, and sections such as the T, the I, the O, and others of great stiffness, with relatively little material, were developed and employed. With the extensive production of malleable metal came the construction of built-up sections; the plate girder sprang into existence, and was followed by the more economic lattice girder; then the latticing was gradually reduced and concentrated in fewer and fewer pieces, thus approaching more and more the typical framework of to-day, in which each piece is called on to perform but a single definite and simple function, the support of a direct stress of tension or compression.

Such is, briefly, the history of the evolution of the framework, at least for Europe. There it resulted simply from the reduction of the solid beam and arch to a skeleton form in the effort to secure economy. The new forms were regarded merely as modifications of the old, and the recognition of the existence in them of a new type of construction was and is far from universal.

In America the history of this evolution runs somewhat differently. Here wood was extensively employed in early times, and we were already thoroughly familiar with the idea of bracing a timber construction with stiff struts when metal for structural purposes became a possibility with us. The value of its employment for tension pieces was at once appreciated; new forms in which it could thus be utilized were rapidly devised, and the framework of mixed metal and wood, or all metal, soon became a distinct type of construction. But evolved, as it had been, in so different a way, it very naturally differed in many important respects from the European production; and our manner of viewing it was also different and more correct, yet not wholly free from bias, for in many cases the framework had developed as bracing or stiffening for certain principal members, and still continued to be regarded only in that light.

In the process of evolution of structures here outlined theory has played a small, although ever-increasing, part. The arch and beam in the far past were dimensioned almost wholly from experience, with the aid, perhaps, of a little most general and loose reasoning. The later structures have hardly followed a more royal road. It was largely through experience and observation that their proportions were at first determined, certain sources of weakness having been noted in similar existing structures, which it was sought to remedy through larger dimensions or the introduction of new parts. Approximate theories based on the comparison with beams were employed at first, in Europe; hardly less arbitrary *views* as to how the stress was shared were early in vogue here. The fact is, the structures themselves were in fault, being of such complexity, from an analytic point of view, as to make their exact solution practically impossible even by eminent mathematicians of this late day. Moreover, the early forms on which they were based, the beam and the arch, with all their apparent simplicity, offer analytic problems of the greatest difficulty which have not yet received exact solutions.

However, as the structures became more and more complex outwardly they had been growing more and more definite in the functions of their parts; each part was there for a more and more definite purpose, and only for that; the theory was in reality growing simpler. And when at last came the idea of so constructing that each part should have but a single definite function — to resist a push or a pull — the theory was brought within the range of application, the idea of the typical framework was conceived, and it became possible for theory to take the reins and drive where before it could not even follow.

All the older forms of construction were characterized by a complex interdependence of their inner stresses and strains. A mere knowledge of the form of such a structure did not suffice for a determination of the inner stresses due to a given loading. The elastic nature of the material and its variations had to be considered; the theory of elasticity, as well as the elementary principles of statics, was involved, and in a most complex manner; the structures were highly statically indeterminate. But in the development of structures this degree of indetermination became less and less, while what then remained became more and more simply and sharply definable; and in the typical framework we can define and determine all the stresses through simple linear equations without aid of the calculus. Such a theoretic construction may even be wholly free from indetermination, that is, statically determined.

The theory of the typical framework, then, may be said to be, not only possible, but relatively simple. It should therefore be clearly understood by engineers and others who employ such construction. They should know just what powers of design lie in their hands and how they may best use them. Neither prejudice due to older empirical ideas, nor illusions based on imperfect knowledge, should be able to lead them astray. It is to contribute to this end that the present article was written, to make somewhat clearer the general conception of the nature of these most important structures, and to point out sharply some very important fundamental propositions concerning their design commonly overlooked or unknown.

The leading characteristic of the typical framework is, as has been pointed out, the simplicity in function of its parts. Each member or bar should be called on to support only pure tension or compression. Such is the ideal condition for which engineers and constructors should strive; for through its attainment alone the highest degree of certainty in the calculations, and of efficiency in the employment of material, is possible. In order to attain this end, however, the framework must be constructed in a certain manner. Its rigid members (or bars) must be connected with each other only at their ends and by joints whose resistance to slight changes in the relative angles of the bars is negligible; and all external forces, such as loads and reactions, must be applied practically at the joint points. The bars are preferably of prismatic form, and their axes should meet at a point in each joint. Such, in brief, are the most essential requirements in the details. As to the general form, *that* may be defined simply through the geometric figure of lines formed by the axes of the bars. In order that our framework should be capable of performing its function of properly supporting loads it is necessary that its figure should be defined so fully under the given reaction limitations, through the lengths of its lines, that no change in its form would be possible without corresponding change in some of these lengths. The knowledge of the figure alone suffices to determine the static conditions which the stresses in such a framework must fulfill.

This description of the typical framework is more or less ideal. The degree of freedom at the joints of actual structures is far from what it should be. The loads are often applied away from the joints where they should not be, and in any case, our bars being material and of more or less considerable dimensions and weight, transverse loading from wind and weight is not wholly avoidable. Thus the absence of other than direct stresses in its members is an ideal condition for a framework, which in practice is never more than partially attained. Nevertheless, here, for the sake of simplicity and to elucidate some characteristics of frameworks, otherwise easily masked by the complications of a more exact study, we will confine ourselves chiefly to this ideal case.

At each joint of an ideal framework we have to deal only with forces meeting at a point, the joint center. These forces are partly known (loads) and partly unknown (bar-stresses and reactions at supports), but they must at each joint satisfy the static conditions of equilibrium of forces at a point — that the algebraic sum of the components of these forces (inner and outer) in any three directions (non-planar framework) shall be zero.

This furnishes us with three equations between the known forces (loads) and the unknown forces (bar-stresses and reactions) for each joint, and, if the framework have n joints, this gives $3n$ such conditions in all, which are statical requirements following purely from the figure of the framework, and which must in any case be fulfilled. Let m be the number of bars and r the number of limitations at the supports of the frame, then we have $m + r$ unknown quantities to determine for each loading of the framework. These may not be less in number than our $3n$ static equations if our framework is stable (of determinate figure). Should they equal in number the static equations ($m + r = 3n$) the framework may be calculable without further data, *e. g.*, statically determined. But should they be in excess of the number of static equations ($m + r > 3n$), then other "elastic" equations will be necessary to complete the determination; that is, our framework will be statically indeterminate. It is to this latter general class of frameworks, of which the statically determined may be regarded as a limit form, that we will now turn our attention.

In statically indeterminate frameworks, then, we have more unknown quantities than equations furnished by statics. What follows? Usually it is answered, certain further conditions furnished by the theory of elasticity enable us to complete the solution. But this is not precisely the truth.

If only the sections of the bars (or, in the case of a new design, the intensities of stress to exist in them) be given in addition to the geometrical figure of the framework, and its loading, as usually is, in fact, the case, the problem remains indeterminate. It is only when both the sections *and* the intensities of stress are given for all the superfluous bars and the sections or intensities of stress of the non-superfluous bars, or, what is equivalent, the sections and the *exact* lengths, center to center of joints, of the unstrained bars are given, that the problem becomes determinate. The last of these cases is the one on which calculations are very frequently founded, yet rather insecurely, as will later be seen. If it is a case of new design, we will ordinarily have given only the allowable intensities of stress in addition to the figure of the framework and its loading. Then, as will now be shown, we can in an infinite variety of ways fix the stresses in the bars or determine their sections.

First consider the determination of the stresses in this latter case. In our given data there is nothing which limits the stresses further than the $3n$ equations of statics already noted, and which are absolute. So, if we have k unknowns in excess of these, we have a k^{tuple} degree of indetermination, which admits of ∞^{k} different solutions, as the principles of analysis show. Or, to make this more objective, we find that the stresses in as many bars as are in excess may freely be assumed, these bars being any such that the remaining bars form a statically determined framework for the support of the given loading, together with these assumed stresses regarded as outer forces. Our procedure in calculation is simply to regard these superfluous bars as removed and replaced by pairs of equal and opposite forces, acting at their end joints and equivalent to their assumed stresses. Thus the calculation of the stresses in the remaining bars reduces to that for a statically determined framework, and may be proceeded with by any of the usual methods. From the stresses thus found, and the given intensities of stress, the sectional areas at once follow. It only remains to insure that these given intensities be attained. This we may do, at least in theory, by giving to the superfluous bars suitable primary lengths.

In such a design it is to be noted that primary stresses, that is, stresses without loading, would exist.

Suppose that instead of assuming the *stresses* in the superfluous bars we had assumed their *sections*. Thence from the given intensities of stress would at once follow their stresses — thence, as before, the stresses in the remaining bars and their sections.

We must observe, however, that in no case could we assume more of the stresses than there were superfluous bars, the requirements of statics not permitting of that. And should we assume the sections of more than the superfluous bars, the intensities of stress in a corresponding number of bars could (in general) no longer be as given.

Another way of viewing our power of varying the details of a design of a framework of given figure, loading, and intensities of stress is found in the following. Under these conditions we may design so that the stresses shall be apportioned among the various bars in any way consistent with the static conditions of equilibrium of forces.

In all these cases the intensity of stress borne by each bar may be anything we please (within limits). It may therefore be set at the maximum allowable value for each bar, so that our infinite variety of proportions may all be made to fulfill the requirement, that each bar shall be carrying its maximum allowable load, that is, working at its maximum efficiency. And in this connection be it noted that the maximum allowable stress may be set independently and, if desired, differently for each bar; so that, if bars in certain positions should be more or less favored than bars in other positions, or if bars in different positions be of different materials, as wire cable for tension members and cast metal for compression members, or even of entirely different substances, as iron or rope tension members, and stone or wood compression members, we can employ the corresponding working stresses and still retain our powers of variation. That is, these powers hold perfectly for mixed wood and iron truss construction, or for suspension bridges, whose cables and numerous ties are of wire cable, and the stiffening truss of other material.

ILLUSTRATIONS OF ARBITRARY PROPORTIONING OF A STATICALLY INDETERMINATE FRAMEWORK.

The principles of design expounded in what precedes will be rendered clearer by consideration of the following simple illustrations:

Let it be required to design a square frame ten feet on a side, with two diagonals, supported by a vertical wall and supporting a load of 100 tons at its lower outer corner (see Figure 1). We are required to employ a maximum intensity of stress of, say, five tons per square inch in tension, four tons per square inch in compression (without regard to post formulæ, for simplicity). The material has uniformly a modulus of elasticity of, say, 14,000 tons per square inch.

Let us regard the diagonal from the lower inner corner to the upper outer corner as the superfluous bar, and we will require it to take, say, 40 tons compression. Consider this bar removed and replaced by a pair of forces of 40 tons. Our frame thus reduces to

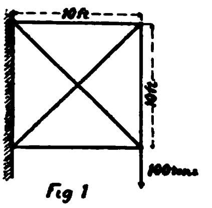

Fig 1

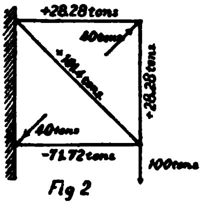

Fig 2

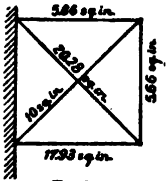

Fig 3

a statically determined frame, whose stresses are shown in Figure 2. The section areas at once follow from the prescribed intensities of stress, as shown in Figure 3.

It only remains to calculate the primary lengths of our bars which shall insure the assumed distribution of stress. The primary lengths of all except the superfluous bars are made simply the dimensions of the figure of the frame in the unstrained state, as in Figure 4. But the primary length of the superfluous bar can only be calculated

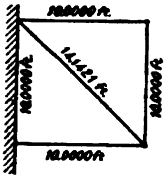

Fig 4

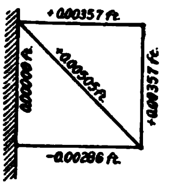

Fig 5

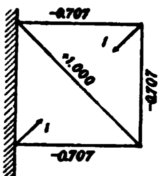

Fig 6

from a knowledge of its length when the frame is distorted by the stresses shown in Figure 2. There, the intensities of stress being five tons for members under tension and four tons for members under compression, tension bars were lengthened $\frac{5}{14.000}$, or .000357 of their lengths, and compression bars were shortened $\frac{4}{14.000}$, or .000286 of their lengths, the consequent strains being as shown in Figure 5. Note that no strain along the wall is assumed. The shortening of the missing diagonal corresponding to these strains we find most simply by application of the method based on the principle of virtual work. Let us imagine a pair of forces of unity each, applied at the end joints of the missing diagonal, then the stresses it would cause are shown in Figure 6; and if we multiply each of these with the corresponding strain shown in Figure 5 and sum these products algebraically, the result will be the work of unity in shortening the distance along the missing diagonal. This we find to be—

$$\begin{array}{lll}
(-\ .707) \times (+.00357) = & & -.00252+ \\
(-\ .707) \times (+.00357) = & & -.00252+ \\
(+1.000) \times (+.00505) = & +.00505 & \\
(-\ .707) \times (-.00286) = & +.00202 & \\
\hline
 & +.00707 & -.00505 \quad = +.00202 \text{ ft. units.}
\end{array}$$

The missing diagonal was therefore 14.1421 — .0020 = 14.1401 feet long. But this length corresponds to a state of compression of 4 tons per square inch. The unstrained length would therefore be $\frac{4}{14\cdot000} \times$ 14.14 feet, or .00404 feet greater, that is, 14.1401 + .0040, or 14.1441 feet, which differs from the length of the other diagonal bar .0020 foot.

To find what primary stresses this design involves we proceed as follows: Our superfluous bar is designed .0020 foot longer than it would be were there no primary stress. It must therefore be under such compression, and the rest of the frame under such consequent stress, that the shortening of our diagonal and the separation of the joint centers at its ends together amount to this .0020 foot. Now one ton *tension* in our diagonal would cause the stresses shown in Figure 6, and the strains corresponding are as in Figure 6*a*. The shortening of the diagonal distance calculated as before is—

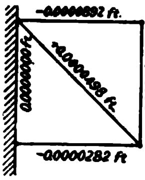

Fig 6a

$$\begin{array}{ll}
(-\ .707) \times (-.0000892) = & +.0000631 \\
(-\ .707) \times (-.0000892) = & +.0000631 \\
(+1.000) \times (+.0000498) = & +.0000498 \\
(-\ .707) \times (-.0000282) = & +.0000199 \\
\hline
 = & +.0001959 \text{ ft.,}
\end{array}$$

therefore for every ton primary *compression* in the superfluous diagonal its end joints in the frame will *separate* .000196 foot. But the diagonal itself, whose section is 10 square inches and length 14.1441 feet, would be shortened $\frac{1 \times 14.1441}{10 \times 14{,}000} = .000101$ foot by every ton of compression it bears. Every ton of compression in the diagonal therefore corrects (.000196 + .000101) foot = .000297 foot of the difference of its length and the length for no primary stress. The whole difference, or .00202 foot, will be corrected by $\frac{.00202}{.000297}$ tons, or 6.8 tons, which is the primary stress in the diagonal. The complete distribution of primary stress is shown in Figure 7.

It is interesting to note with what extreme exactitude the lengths of the bars must be calculated, and how accurately the construction would have to be carried out. Moreover, the assumption that the distance along the wall between the points of support remains invariable, although similar to those usually made in calculation of statically indeterminate structures, is evidently open to objection. Any curving of the posts under compression would cause further error, the bar axis shortening from $2d^2$ to $2.7d^2$, where d is the ratio of middle deflection to length. $d = \frac{1}{200}$ corresponds to an error of .7 to .9 ton per square inch.

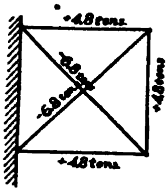

Fig 7

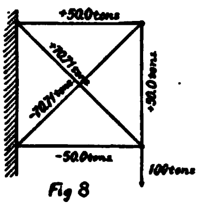

Fig 8

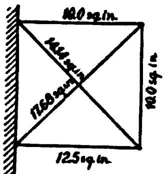

Fig 9

To illustrate another apportionment of stress than the arbitary designation of the stress in the superfluous bar, let us take a framework of the same figure as before and so design it that the two diagonals shall equally share the shear. Then our stresses at once work out as in Figure 8; and with the same allowable intensities of stress as before, that is, five tons per square inch in tension and four tons per square inch in compression, the section areas become as shown in Figure 9. As for the primary *lengths* in this case, since the stresses are all of the same intensities *and same kind* as in the preceding case, these remain unchanged; but the relative areas are no longer the same, so that the primary *stresses* necessary to account for the .0020 foot excess of length of the superfluous diagonal will presumably not be as before. We find for this case, in Figure 6*b*, the strains corresponding to one ton *tension*

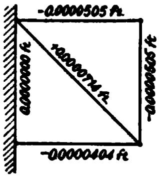

Fig 6b

in this diagonal (see stresses in Figure 6). The shortening of the diagonal distance, calculated as before, is —

$$
\begin{array}{rl}
(-.707) \times (-.0000505) & = +.0000357 \\
(-.707) \times (-.0000505) & = +.0000357 \\
(+1.000) \times (+.0000714) & = +.0000714 \\
(-.707) \times (-.0000404) & = +.0000286 \\
\hline
& = +.0001714 \text{ ft.,}
\end{array}
$$

for every ton tension in the superfluous diagonal, or the same increase for every ton compression. The diagonal itself would be shortened $\frac{1 \times 14{,}1441}{17.68 \times 14{,}000}$ or .000057 foot for each ton compression. Its primary stress must therefore be given by $\frac{.00202}{.000171 + .000057} = \frac{.00202}{.000228}$ $= 8.8$ tons. The complete distribution of primary stress is shown in Figure 10.

As a final case in design, which only too frequently is met in practice, consider that in which the exact primary lengths of all bars are given in advance. Usually in this case these lengths are given by the requirement that there shall be no primary stresses; but then, as previously noted, under loading as many intensities of stress as there are superfluous bars cannot be set in advance, but will be determined through the intensities assumed to exist under loading in, say, the now superfluous bars. The stresses or sections of our superfluous bars, however, remain, as before, wholly within our control. Let this be illustrated with the same framework as before, and suppose the same distribution of stresses as in Figure 8 assumed. The intensities of stress in the now superfluous bars being the same as before, we know the superfluous diagonal will have been shortened .0020 foot, which corresponds to an intensity of stress of $\frac{.00202 \times 14{,}000}{14.14}$ $= 2$ tons per square inch; therefore, since this bar carries 70.7 tons, its section area must be made $\frac{70.7}{2} = 35.35$ square inches. All other sections remain as in Figure 9. This gives our superfluous bar double the area and volume it had in the preceding illustration, showing clearly the loss of efficiency which may result from insisting on the condition of no primary stress in the framework.

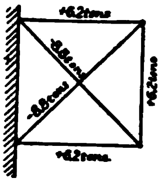

Fig 10

In this, as in the preceding two illustrations, we could have assumed the section areas instead of the stresses in the superfluous bars; but should we assume the section areas of all the bars, as well as a condition of no primary stress, then all stresses and stress intensities would thereby be determined and no longer within our control. And such is, perhaps, just what most frequently occurs with present methods of design as well as in the calculation of existing structures. Usually in design all the sections are tentatively assumed (in an existing structure they are given), and the supposition of no primary stress being made, often unwittingly, the problem becomes wholly determinate. In an existing structure the supposition of no primary stress will be more than questionable, and in a design it will be a foolish limitation, for the intensities of stress should be as prescribed, and should determine the design — not be determined by it.

To illustrate the results and one method of calculation for this case, suppose we were given the framework, with sections as in Figure 9, but subject to no primary stresses. Regard the same

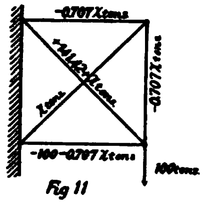

Fig 11

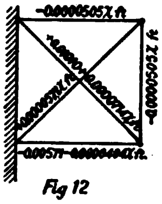

Fig 12

diagonal, as before, as superfluous, and let x be its stress; then the stresses in our frame would be as shown in Figure 11. The consequent changes in lengths of bars we find, as usual, by multiplying these stresses by the bar lengths and dividing by the areas and modulus of elasticity, the result being as shown in Figure 12. Now the shortening of the line of the superfluous diagonal calculated from the strains of the other bars by aid of Figure 6, as before, is —

$$\begin{array}{lll}
(-.707) \times (-.0000505x) & = & +.0000357x \\
(-.707) \times (-.0000505x) & = & +.0000357x \\
(+1.000) \times (+.01010 + .0000714x) & = & +.0000714x + .01010 \\
(-.707) \times (-.00571 - .0000404x) & = & \underline{+.0000286x + .00404} \\
 & = & +.0001714x + .01414
\end{array}$$

$= -.0000571x$ (see Figure 12), the *shortening* of the diagonal itself. Thus $x = \dfrac{-.01414}{.000171 + .000057} = \dfrac{-.01414}{.000228} = -62.0$ tons, and the actual distribution of stress under these circumstances would be as shown in Figure 13. There is by no means an equal division of shear between the two diagonals. As for the intensities of stress, they are as shown in Figure 14. It is seen that the tension diagonal and the lower horizontal are both overstrained, and the remaining bars bear less than their fair loads if we keep to the earlier criterion of 5 tons allowable for tension and 4 tons for compression. The results are some 12 per cent out. If this were a design it might be attempted to improve these results by correcting the sections, but with little satisfaction so long as primary stresses were excluded. The system is, in fact, one of design by blind trial, and well illustrates the general lack of acquaintance by designers with what are really very elementary principles of the distribution of stress in frameworks.

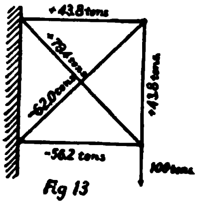

Fig 13

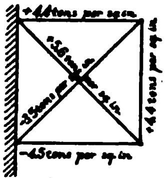

Fig 14

PART II. — ECONOMIC CONSIDERATIONS — INFERIORITY OF INDETERMINATE FRAMEWORKS.

At first it would seem as if our power of varying the distribution of stresses and so distribution of material in our framework, as set forth in the preceding part, was almost unlimited, but a little closer observation will show that in reality it only extends to as many options as there are superfluous bars, thenceforth all being fixed and determinate. Moreover it must be noted that the power of variation only extends over such parts of the frame as are affected by the stresses in the superfluous bars, that is, the statically indeterminate portions of the framework.

Further, in order to make use of even this power with which the designer is invested, exceedingly exact and laborious calculation of all elements in the design is *absolutely* essential, in particular it being necessary to calculate very exactly the lengths, center to center of joints, of the unstrained bars, and it is equally essential that the construction should be exactly carried out in order that the supposed conditions of the calculation be fulfilled. How very exact work this means, will be appreciated from the fact that errors of a thousandth of a foot in 10-foot bars are far from negligible, involving errors in stress as great as 30 to 35 per cent., the allowable stress. Moreover it is seen that the calculation should properly take into account the yielding, both permanent and elastic, at the reactions, and at the joints and splices. And aside from the excessive accuracy necessary, the (often considerable) primary stresses we may find it desirable to introduce may create difficulties. In the face of these and other real and very important objections to the employment of statically indeterminate frameworks, objections from which statically determined frameworks are wholly free, it may well be asked why should indeterminate frameworks be employed; what real advantages do they possess?

It has already been pointed out how the evolution of the framework was an outcome of experience, rather than theory. And experience is a very slow teacher. But many will follow in her tracks alone, paying little heed to the straight path to their goal which theory points out to them. Thus the early frameworks having been statically indeterminate in their figures, as well as departing from the ideal in other respects, such as in the fixtures of the bars at intermediate points as well as at the ends, and the use of stiff joints, all these defects have been perpetuated even in modern constructions. And the constructor, to whom these features are pointed out as defects, is apt to question the theory on which the criticism is based. He may even have a theory of his own which proves to his satisfaction the superiority of these very features. And as the theory of such structures is exceedingly difficult and complicated — so much so that closely approximate single solutions have only been attained by the most modern methods of calculation, and these in but very few instances — the difficulty of correcting these delusions by an analysis that is both general and exact may be imagined. Only for the typical framework are we in a position to make such an analysis which shall be fairly general, and at the same time even approaching exactitude. This we will now undertake.

Three of the most important claims urged in favor of frameworks with superfluous bars are that they are stiffer, that they are safer, and that they are more economic in material used. Let us examine these claims.

The deflections of a frame under a given loading are absolutely determined by the intensities of strain in the bars of the statically determined portion left after eliminating the superfluous bars. If the bars of this portion have a determined maximum stress, therefore strain under load, the deflections are also determined, whatever the number of superfluous bars. Only by a reduction in the intensities of strains, that is, in the efficiencies, can increased stiffness be secured, and this is independent of the use of superfluous bars. The first claim, therefore, is unfounded for a fair basis of comparison, fixed intensities of strain.

The rupture of a bar of a framework with superfluous bars will not less surely cause its downfall than in the case of a framework every bar of which is necessary, unless the ruptured bar chances to be one which may be regarded as superfluous. The ratio of such bars to the whole gives a rude measure of the extent of this possible security. But its true value depends on whether such a bar being ruptured, the rest of the bars are strong enough to bear the load alone, especially when we consider the probable accompanying shock of rupture. A certain degree of additional security undeniably exists, but what?

There remains the claim of superior economy. But before making a more exact examination of this, let us ask on what is such a claim based. And to which of the innumerable designs of frameworks of a given figure supporting a given loading, which have been shown in Part I of this paper to exist, does it apply? We may answer that the claim is based on practically nothing except the fact that the continuous girder and the arch are more economic than simple girder spans. And this unfair comparison may now be set aright by the introduction of the really comparable statically determined forms, the cantilever and the three-hinged arch. As to the second of the above questions, the partisans of frameworks with superfluous bars, being for the most part unaware of these possible variations, could give no answer. We will, then, answer for them. A design in which the stresses of as many bars as are superfluous are zero, that is, a statically determined framework whose figure is included in the given figure, will be the most economic. This, a direct contradiction in terms, of the claim of superior economy of an indeterminate form, we will now prove.

Suppose we have given any one of the possible designs by its bar-sections, and the stresses in the bars under the given loading. Let us determine the effect on the quantity of material employed, of varying this distribution of stresses and material without varying the external loading or the intensity of stress in any bar. For the sake of simplicity we will suppose that the intensities of stress in question are simply the mean intensities obtained by dividing total stress by area of section. And we will suppose the mean strain to be proportional to the mean stress, that is, the shortening due to possible curvature of a bar to be negligible. The first assumption which neglects the effect of post formulæ on design we will correct later. The second assumption is usual in all calculations, and since the shortening of the axis due to bowing of a bar is between $2d^2$ and $2.7d^2$ of its length, d being the ratio of deflection to length, this supposes no deflection exceeding, say, 1/200 the length which would correspond to a shortening of from .00005 to .000067 the length, and with a modulus of 14,000 tons would be equivalent to the effect of an intensity of stress of from .7 ton to .9 ton per square inch. It may be objected that these and even larger deflections are both possible and probable, and that it is unfair to neglect them. This may be true, but since this supposition alone makes the calculation of frameworks with superfluous bars possible, it will at least not be objected to by the partisans of such construction.

We assume, then, our external forces invariable, our bars always straight, and the sections varying in the same proportion as we vary the stresses, so that the mean intensities of stress are maintained constant. Let our given frame have m bars, of which k are superfluous under the given reaction conditions. Let any such k of the bars as may be regarded as superfluous be selected out leaving us with a statically determined framework of $m-k$ bars which we will denote by the numbers 1 to $m-k$ inclusive. Consider in connection with this statically determined portion any one of the superfluous bars which we will denote as the bar $m-k+1$. Now suppose under the given loading and the stresses in the remaining superfluous bars, maintained constant by the unvarying mean intensities of stress in our bars 1 to $m-k$, we vary the distribution of stress between these $m-k$ bars and the bar $m-k+1$, varying the sections correspondingly, and note the effect on the quantity of material employed. Let e denote any one of the bars 1 to $m-k$, S_e its stress, l_e its length, and σ_e its (constant) mean intensity of stress. And let S'_e denote the stress (tension) that would be caused in the bar e by a tension of unity in the bar $m-k+1$, all other superfluous bars being removed. Then any increase in tension dS_{m-k+1} in the bar $m-k+1$, since the stresses in the other $k - 1$ superfluous bars are kept constant, will simply be accompanied by the corresponding changes in stress $dS_e = S'_e\, dS_{m-k+1}$ in each bar e of the remaining bars. Their corresponding changes in section will be $dA_e = \frac{dS_e}{\sigma_e} = \frac{S'_e dS_{m-k+1}}{\sigma_e}$ and in volume will be $dV_e = l_e dA_e = \frac{l_e S'_e dS_{m-k+1}}{\sigma_e}$ or for the whole frame, summing over all $m - k + 1$ bars, and putting i for 1 to $m - k + 1$ and $S'_{m-k+1} = +1$.

$$dV = dS_{m-k+1} \sum_{1}^{m-k+1}{}_i \frac{l_i S'_i}{\sigma_i}$$

It is to be observed here that l_i is always + and σ_i and S'_i either + or —, according as they are tension or compression.

Now the expression for dV thus formed will in general be either + or —, according to the sign we give dS_{m-k+1} (unless very exceptionally

$$\sum_{1}^{m-k+1}{}_i \frac{l_i S'_i}{\sigma_i}$$

be zero), so that by suitably choosing the sign of dS_{m-k+1} we can in general effect a saving in material through our variation in distribution of stress.. But during this variation the quantities l'_i and S'_i remain unchanged whatever its range, and the σ_i can only change through the stress in some bar becoming zero, that is, through our $m - k + 1$ bars reducing to a statically determined combination of $m - k$ bars bearing the same outer loading and the same stresses of the remaining superfluous bars, and having the same intensities of stress as before. It follows, therefore, that we can so vary our distribution of stress as to eliminate one bar of our $m - k + 1$ bars, and leave the remaining bars performing the same function under the same conditions, but with the use of less material (exceptionally with the same quantity of material).

In the same way we may now treat these $m - k$ modified bars together with one of the remaining superfluous bars when we shall again find that we may eliminate a bar to advantage, and so, successively eliminating bar by bar, we eventually arrive at a statically determined framework of $m - k$ bars in all, so modified in section that they bear alone the whole original loading with stresses of the same kinds and intensities as those in the corresponding bars of the given framework, and with the employment of less material (or by exception the same amount).

Thus, under the limitations of our analysis, it appears that

No given design of a framework with superfluous bars may support a given loading with more economy of material than some statically determined framework whose figure is included in the figure of the given framework, and whose stresses are of the same kinds and intensities as those in the corresponding bars of the given framework.

And since this is true of *any* design of a framework of a given figure and loading, it follows that (under our limitations)

The framework which will support a given loading most economically will always be statically determined.

Another very simple and much more objective proof of the same proposition is the following, subsequently suggested by Professor George F. Swain, to whom the author is indebted for his early training in the statics of structures, and also for a review of the present article and much valuable advice in connection with it. To Professor Swain's steadfast support of statically determined construction was due the author's interest in this subject, leading to the study whose outcome was the general demonstration of its economic superiority, here given, it is believed, for the first time. We may hope that this superiority, hitherto frequently claimed for indeterminate construction, will henceforth be recognized universally as an attribute of determinate construction.

Suppose we have given any framework with superfluous bars, and its loading, stresses, intensities of stress, etc., and that we have found a series of statically determined frameworks, whose figures are included in the figure of the given framework, all of the bars of the given framework being represented in these separate frameworks, and in each of which the given loading would cause the same kind of stress in the bars as in the corresponding bars of the given framework. It is evident, then, that if to each of these statically determined frameworks we assigned a suitable fraction of our given loading, the stress in any bar of the given framework would be equalled by the arithmetic sum of the stresses in the corresponding bars of the statically determined frameworks; and further employing the same mean intensities of stress in the design of all corresponding bars of these statically determined frameworks and the given framework, the section area of any bar of the given framework would be equalled by the arithmetic sum of the section areas of the corresponding bars of the statically determined frameworks, since all stresses in all corresponding bars are, by supposition, of like kind. It follows that the total volume of material in the given intermediate framework is also equalled by the arithmetic sum of the volume of material of all our statically determined frameworks. Therefore, the efficiency of our given framework, measured, if we please, by the quotient of its total loading divided by its total volume of material, will lie between the efficiencies of the most and the least efficient of our statically determined frameworks, which may in a way be regarded as elements into which our given framework has been decomposed. It follows, therefore, since the given framework cannot be more efficient than the most efficient of these elements, that *the given framework cannot be more efficient than some statically determined framework, whose figure is included in the figure of the given framework, and the stresses in whose bars are like in kind and intensity to the stresses in the corresponding bars of the given framework.* (Q. E. D.)

It may occur that we are not able to find the necessary statically determined forms whose figures are included in the figure of the given framework, and the stresses in whose bars under the given loading are like in kind to those in the corresponding bars of the given framework. If there be k superfluous bars, we see that $k + 1$ such statically determined frameworks are necessary in order that each bar of the given framework should have a corresponding bar in at least one of these.

Suppose, now, that we could not find a statically determined framework under our conditions which should include a certain bar. It can readily be shown that we can at least always find some one statically determined framework fulfilling our conditions, and so, by supposition, not containing this bar. Then the introduction of this bar, with stress of the amount and kind it must have in the given framework, into this statically determined framework, clearly must simply increase the stresses (therefore correspondingly the section areas) of all bars of this framework which are affected at all thereby, and our bar forms with our statically determined framework a statically indeterminate framework with one superfluous bar, whose stresses are like in sign and intensity those in the corresponding bars of the given framework, but which, supporting only the same loading as our first or primary statically determined framework, while containing more material, is less efficient than this primary. Thus, we can *always* find a series of statically determined frameworks and of indeterminate frameworks with one superfluous bar derived from these primaries, whose figures are included in the figure of the given framework, among which each bar of the given framework has at least one corresponding bar, and in each of which the given loading would cause the same kinds of stress in the bars as in the corresponding bars of the given framework. Then, providing the primaries corresponding to the indeterminate frameworks of one superfluous bar are among our series, all the same consequences as before follow, and the given framework cannot be more efficient than the most efficient among these elements. But among these elements the statically determined primary frameworks are always more efficient than the derived frameworks with one superfluous bar; therefore the given framework cannot be more efficient than one of its statically determined elements. (Q. E. D.)

Our first preceding proof was given under one limitation (merely for the sake of simplicity), which was quite unnecessary. We supposed the sections to vary simply as the stress, but it suffices that under the rule of design (post formula) actually employed, the rate of increase in supporting power of a member does not at any time diminish as the area of section is increased. Such is the case for the usual formulæ (for all of the Gordon-Rankine type), so our conclusion holds for designs under the usual rules of dimensioning of members. In such designs the relation between area and stress for each bar having been put in the form $S_i = \phi_i\,(A_i)$ we would find for the change in area corresponding to a small change in stress $dA_i = \dfrac{S'_i dS_{m-k+1}}{\phi'_i\,(A_i)}$ whence the change in volume would be expressed by

$$d\,V = dS_{m-k+1} \sum_{1}^{m-k+1}{}_{i} \frac{l_i\,S'_i}{\phi'_i(A_i)}$$

$\phi'_i\,(A_i)$ replacing σ_i of the simple formula. In order that this expression which now contains the variables $\phi'_i\,(A_i)$ should not change sign during variation, at least until some bar stress reduces to zero, it suffices that $\phi'_i(A_i)$ should in no case diminish numerically as A_i increases, the analytic expression of our preceding statement. This holds, as mentioned, for formulæ of the Gordon-Rankine type, and also for the even simpler forms $S = \sigma A - C$ and $S = \sigma A - K\sqrt{A} - C$, which the author believes may find sufficient recommendation for introduction into practice as safe and simple substitutes for the unprofitably complicated, if more correct formulæ.

ILLUSTRATION OF ECONOMIC EFFECT OF VARIATION OF PROPORTIONS OF STATICALLY INDETERMINATE FRAMEWORKS.

To render more clear the significance of the preceding analysis and its application, consider the following simple illustration in which for simplicity we neglect post formulæ and employ the simple rule, stress = constant working stress × section area. Consider the design previously discussed whose stresses are shown in Figure 8, and whose section areas are shown in Figure 9 (both reproduced here). Through the employment of primary stress this design was made economical in character, since all intensities of stress are the maxima allowable. The quantity of material in each of its bars and the total quantity are as shown in Figure 15. Taking the same diagonal from the lower inner corner to the upper outer corner as the superfluous bar, as before, the stresses S' of our formulæ are those given in Figure 6 (reproduced here), and our formula becomes

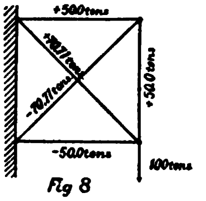

Fig 8

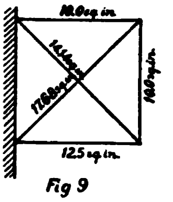

Fig 9

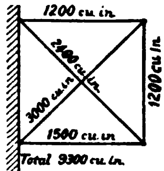

Fig 15

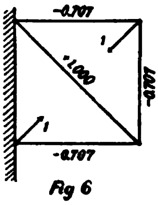

Fig 6

$$dV = dS \left\{ \begin{array}{lrr} \dfrac{(-.707) \times 120 \text{ in.}}{5} = & & -17.0 \\ + \dfrac{(-.707) \times 120 \text{ in.}}{5} = & & -17.0 \\ + \dfrac{(+1.000) \times 169.7 \text{ in.}}{5} = & +34.0 & \\ + \dfrac{(-.707) \times 120 \text{ in.}}{-4} = & +21.2 & \\ + \dfrac{(+1.000) \times 169.7 \text{ in.}}{-4} = & & -42.4 \\ \hline & +55.2 & -76.4 \end{array} \right\} = \begin{array}{r} \\ +55.2 \\ \hline -21.2 \end{array}$$

$dS \times (-21.2)$ that is, dV is negative when dS is positive. So by increasing the tension (that is, diminishing the compression) in our superfluous diagonal we decrease the amount of material necessary at the rate of 21.2 cubic inches for every ton reduction in our superfluous diagonal, and this rate of saving we may maintain until the stress in some bar reduces to zero. But this happens simultaneously to the superfluous diagonal, the vertical and the upper horizontal, the stress in the superfluous diagonal having diminished 70.7 tons with the consequent saving of $70.7 \times 21.2 = 1{,}500$ cubic inches in material, and our frame having reduced to the simple statically determined frame (triangle) shown in Figure 16. As this frame requires but 7,800 cubic inches the original frame required $\frac{9.300 - 7.800}{7.800}$, or nearly 20 per cent. more material. By Professor Swain's method we should have found the elementary frames (Figures 17 and 18), which together would be equivalent to the given framework (Figures 8 and 9). The efficiency for Figure 17 is .00093, for Figure 18 is .00128, while for the given framework it was $\frac{100}{9.300} = .00107$ or intermediate. Clearly, Figure 18 is a more economical form.

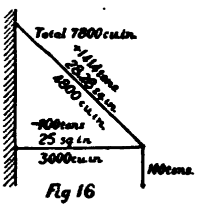

Fig 16

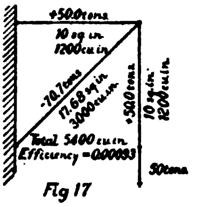

Fig 17

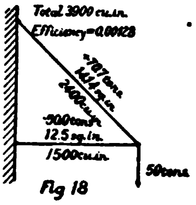

Fig 18

The amount of saving shown in this illustration need not be insisted on. With frameworks of other proportions or figure, differences as high as 50 per cent. have been found, while in other instances they were but a few per cent. Employing post formulæ in design the saving comes out slightly greater. The main point to note is that the indeterminate forms, that is, those with superfluous bars, do not employ less material than some included statically determined design of like stresses in kind and intensity.

We may make a very interesting extension of our result. Suppose the bars to be of different materials, so that not the *quantities* but the *values* of change in material employed, are of interest. Let a_i be the value per cubic unit of the material of the bar i, then $\frac{a_i l_i S'_i}{\sigma_i} dS_{m-k+1}$ would be the increased *value* of material employed in the bar i as a result of the increase dS_{m-k+1} in tension in the bar $m-k+1$, and for the whole framework

$$dC = dS_{m-k+1} \sum_{1}^{m-k+1} {}_i \frac{a_i l_i S'_i}{\sigma_i}$$

would be the increase in cost of material employed. If a_i be taken constant, this would result as before in a statically determined form being cheaper, with these same materials in its corresponding bars. This applies particularly to construction in different materials, such as wire cable and cast metal, or different substances, as iron and wood. The result is very general and conclusive in negating the claim of a superior economy for construction with superfluous bars, at least for the support of one definite loading.

We might, theoretically, consider further the modifications of cost of abutments, accompanying the changes in the reaction forces during our variations, but practically this would hardly be feasible. However, if, in the process of reducing from an indeterminate to a determinate form, we find it possible to reduce the number of reaction limitations, we may be sure that the cost will only be favorably affected thereby.

One feature of our result should be particularly noted, that in *each* case we can find a more economic statically determined framework among those whose figures are included in the figure of the given indeterminate framework, and whose stresses in its corresponding bars are of the same intensities and *kinds*. Therefore, nothing need be altered in the manner or material of construction of such a framework which could employ the same materials in its bars as in the corresponding bars of the given framework. However, if we were seeking *the* most economic framework whose figure was included in that of the given framework, and in which we could employ, as we found most advantageous, any materials employed in the given framework, then these limitations would disappear. And it follows from our preceding result that we would only need to seek among the statically determined forms for that furnishing the most economic design.

Thus far we have treated only the case of a single definite loading, and shown that for that the claim of superior economy of material on the part of statically indeterminate construction is untenable. There remain, however, the cases so common in practice, of frameworks which are called on to support a number of different loadings.

Before considering these further, there are certain facts that it will be well to note. Frequently, perhaps usually in practice, some one loading or combination of loadings determines the dimensions of almost all the principal members of the framework, the members not thus determined affecting the total quantity of material employed but slightly. This is particularly the case for large structures in which dead weight plays a leading part, and where the total quantity of material employed is so large that economy in this direction is particularly desirable. In such cases one loading virtually rules the economic design, and our foregoing results hold approximately true. *The consideration of the effects of changes in loading in these cases,* although of great importance as far as strength of the structure goes, *is of wholly secondary significance from our economic point of view.*

It may happen, however, that loadings of comparable importance but widely different character are to be supported. For such cases it no longer necessarily holds that a *single* statically determined framework can be found whose figure is included in that of a given framework, and which will more economically support these several loadings than the given framework. We must here employ several of the statically determined forms in combination.

For example, a weight W could most advantageously be supported by a vertical post, thus  ; a horizontal pull P, by a triangular truss, thus  ; but the weight being much larger than the pull, a statically indeterminate frame of the form  would support either of these loadings (not both united) more economically than any of the statically determined forms obtainable by eliminating a bar, as . But here *two* statically determined forms taken together will even more economically perform the *two* functions. We have only to design a triangle  sufficiently strong to bear the horizontal pull. For the vertical load we calculate how much this triangle will carry, and then design a free vertical post, merely for the balance. In this way there is no interference such as occurs in the indeterminate form, where the diagonals are not permitted by the post to carry their full share of the vertical loading. All parts contribute with their full efficiency.

For other cases we would find similar solutions. For multiple loadings, multiple statically determined forms ; such is the dictate of maximum economy. ***Statical indetermination in a structure is always to be regarded as self-interference with efficiency.***

Hitherto we have gone on the supposition that it is fair to compare statically determined and indeterminate frameworks, on the basis of the same working stresses. But this is by no means the case. The uncertainty that the conditions of calculation will be fulfilled in construction (we have noted the exactitude as to the lengths of the bars, and the effects of curvature under stress on this), the uncertainty that they will remain as designed (permanent deformation, settlement of abutments, etc.), uncertainties which do not affect statically determined designs, certainly demand much larger factors of safety in the design of statically indeterminate than in determinate construction. Add to this the frequently enormous stresses introduced by temperature changes in indeterminate designs, from which the determinate designs again are free, and all doubts as to with which economy as well as most other virtues lie, will disappear.

We may sum up with the conclusion, that in all cases the best, the most economic results will be obtained through the use of statically determined construction. Let us hope that this may soon be universally recognized, that no more avoidable indeterminate structures such as two-hinged arches and indeterminate suspension bridges will be constructed, and that statically determined construction will become the engineer's ideal.

ONSET, MASSACHUSETTS.
July, 1896.

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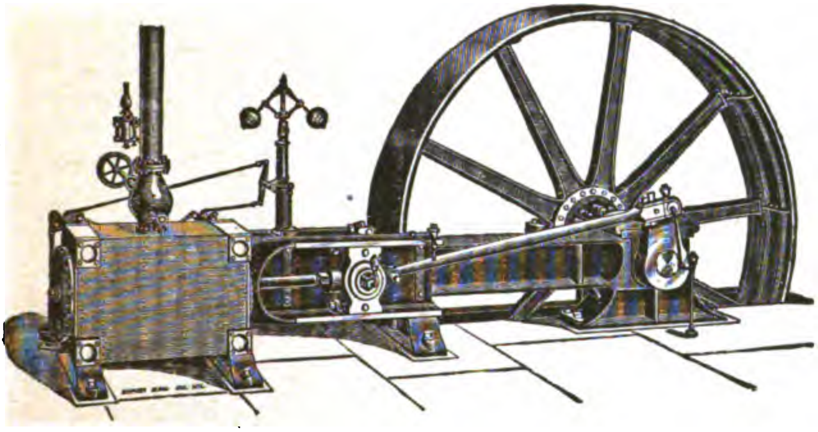

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Vol. X. SEPTEMBER, 1897. No. 3.

TECHNOLOGY QUARTERLY AND PROCEEDINGS OF THE SOCIETY OF ARTS

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
BOSTON.
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EDWARD·T·HAPGOOD·ARCHT.
HARTFORD·CT.

TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. X. SEPTEMBER, 1897. NO. 3.

PROCEEDINGS OF THE SOCIETY OF ARTS.

THIRTY-FIFTH YEAR, 1896–97.

THURSDAY, April 8, 1897.

THE 498th meeting of the SOCIETY OF ARTS was held at the Institute this day at 8 P.M., with Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

Messrs. Frank L. Fales, of Boston, Levi G. Hawkes, of Saugus, F. Herbert Snow, of Brockton, Otis Bigelow, of Washington, D. C., George W. Fuller, of Louisville, Kentucky, and Miss Grace A. Van Everen, of Brooklyn, New York, were duly elected Associate Members.

The Chairman introduced Mr. L. H. Parker, of Schenectady, New York, who read a paper on "Heavy Electric Railway Service." The paper opened with an account of the development of the electric motor, and then descriptions were given of various devices used in electric railway service, such as the electric brake, the automatic circuit breaker, magnetic fuse box, conduit plow, regulating devices, and switch boards. Then the advantage of electric power over steam for elevated roads was discussed, and its superiority was attributed to the more rapid acceleration which it allows. The use of the third rail was spoken of as applied to both surface and elevated roads, and the speaker closed with a description of the electric locomotive of the Baltimore & Ohio Railroad. The paper was illustrated by models and lantern views.

Professor Swain and others took part in the discussion which followed. It was voted to thank Mr. Parker for his very interesting paper. The Society adjourned.

THURSDAY, April 22, 1897.

The 499th meeting of the SOCIETY OF ARTS was held this day at the Institute, at 8 P.M., with Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

The Secretary presented a report from the Executive Committee recommending that the BY-LAWS of the Society be amended by striking out the word "four" in the last sentence of Section II, and inserting in its place the word "three," so that the sentence shall read, *Three members shall constitute a quorum for the transaction of business.* A letter from the Secretary of the Corporation was read, showing that this amendment had been approved by a vote of the Corporation, March 10, 1897. The amendment was then laid upon the table, as required by the BY-LAWS, to be considered at the next meeting.

On motion of Colonel Hewins it was voted that the Chair appoint a committee of five to nominate the Executive Committee for 1897–98. The Chair appointed Messrs. James P. Monroe, E. K. Turner, Charles A. Stone, A. E. Burton, and Charles T. Main.

There being no further business, the Chairman introduced Mr. George B. Francis, resident engineer of The Boston Terminal Company, who spoke on "The Engineering Problems of the New Southern Station." The history of the project was sketched briefly, and then a number of the problems involved were stated, and it was shown how it is proposed to solve them. In order to provide separate platforms for baggage, the number of stub tracks had to be reduced to 28, only 3 more than the aggregate of the present southern stations. But electricity as a motive power and the growth of suburban traffic had to be taken into account. The necessity of providing larger facilities under these conditions leads to the introduction of one of the most interesting features of the plan. This is the underground suburban loop, consisting of two tracks with a radius of 262 and 242 feet, respectively. In order that there shall be no steps in the approaches, it was necessary to put the loop tracks 2 feet below high-water level. The waterproofing presented the most difficult problem. Gravel concrete is used to avoid cutting the waterproof material. The drainage area of the roof of the train shed is 12½ acres. The tracks will require the largest interlocking plant in the world. There are at present 650 trains daily leaving and entering the southern stations, of which about 400 are suburban. The loop track will give double the capacity of any existing station.

During the discussion which followed Mr. Francis said that borings show that the foundation is blue clay, overlying strata of clay, sand, and gravel. The waterproofing consists of courses of felt with tar, etc., and the concrete is used to hold it in place. The roof is to be so strong that the snow may be allowed to remain upon it.

On motion of Colonel Hewins it was voted to extend to the speaker the thanks of the Society. The Society then adjourned.

THURSDAY, May 13, 1897.

The 35th Annual Meeting (500th meeting) of the SOCIETY OF ARTS was held at the Institute at 8 P.M. on this day, Mr. Blodgett in the chair.

The record of the previous meeting was read and approved.

Messrs. John Balch Blood, of Boston, George H. Hamlin, of Orono, Maine, Everett Morss, of Boston, Thomas M. Lothrop, of Brookline, Henry K. Rowell, of Brunswick, Maine, were duly elected Associate Members of the Society.

The Secretary read a communication from the Committee on Nominations, in which the following gentlemen were named as candidates for the Executive Committee: George W. Blodgett, Desmond Fitz Gerald, Thomas Doane, E. H. Hewins, and F. W. Hodgdon. Ballots having been cast, it was found that a quorum was not present, and all business appertaining to the Annual Meeting was laid on the table.

The following papers were presented by title:

"A Tribute to the Memory of Brevet Brigadier General Francis Amasa Walker," by Thomas L. Livermore.

"Claims of Modern Life on Education," by William T. Sedgwick.

"Some Data on the Heating Error in Resistance Coils," by F. A. Laws.

"Studies of the Eskimos of Baffin Land and Umanak Fiord, Greenland," by R. W. Porter.

"Formation of Diacetylenyl (Butadiine) from Copper Acetylene," by A. A. Noyes and C. W. Tucker.

"A Note on Some of the Requirements for a Sanitary Milk-Supply," by W. T. Sedgwick.

The Chairman introduced Captain John Bigelow, Jr., 10th United States Cavalry, Professor of Military Science at the Institute, who read a paper on "Military Education." He said that from the point of view of the soldier, a man consists of three parts — physique, morale, and intellect. The various qualities of each of these parts should be developed by a military education. He gave an outline of the course of instruction at West Point, and pointed out how far this meets the requirements of a complete military education. Post instruction and service schools were then spoken of as valuable features of the American system. The paper closed with an argument for special schools for staff officers where they could receive instruction of a university grade.

A discussion followed, after which a vote of thanks was extended to the speaker for his valuable paper, and the Society adjourned.

THURSDAY, May 27, 1897.

The 501st meeting of the SOCIETY OF ARTS was held this day at 8 P.M., Professor Richards in the chair.

The record of the previous meeting was read and approved.

By unanimous consent the other business of the evening was postponed until after the reading of the papers.

The following papers were presented by title:

"Velocity of Reaction between Ferrous Chloride, Potassium Chlorate, and Hydrochloric Acid," by A. A. Noyes and R. S. Wason.

"Some Fundamental Propositions Relating to the Design of Frameworks, a Study of Primary Stress in Indeterminate Frameworks, and Demonstration of the Economic Superiority of Statically Determined Frameworks," by Frank H. Cilley.

"A Flavor-producing Micrococcus of Butter," by S. C. Keith, Jr.

Mr. Timothy W. Sprague was introduced and read a paper on "Application of Electricity to Mines," in which he gave a history of the progress made in employing electricity in various mining operations, such as hauling, hoisting, drilling, coal cutting, and pumping. He closed with some remarks on the electrical transmission of power to mines.

A discussion followed, after which it was voted to extend to the speaker the thanks of the Society.

The unfinished business from the Annual Meeting was then taken up. The following report was presented by the Executive Committee:

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

With the close of this thirty-fifth year of its existence the SOCIETY OF ARTS will have passed its five hundredth meeting. During the present year there will have been held fourteen meetings, at which fifteen papers will have been read. One meeting was a special one held jointly with the Boston Society of Civil Engineers to listen to a paper on "The Tampico Harbor Works," by the eminent engineer, Mr. E. L. Corthell. Three notable papers have been presented showing the summer work of the Institute. One of these was by Professor Homer, on the "Summer School of Architecture in Europe." The other two were by Professors Burton and Barton, on the "Scientific Work of the Boston Party on the Sixth Peary Expedition to Greenland." All three of these papers will be published in the current volume of the TECHNOLOGY QUARTERLY, and, in addition to these, an exceptionally valuable article on the "Pendulum and Magnetic Observations" has been contributed by Mr. Putnam, a member of the Boston party. Another paper that deserves special mention, both because of its intrinsic value and because it embodied the results of original work done by a member of the Society, and largely in the laboratories of the Institute, is the paper read by Dr. Williams on "Some Uses of the Röntgen Rays."

The endeavor has been made, as far as possible, to publish the papers presented before the Society in the TECHNOLOGY QUARTERLY, but some papers have been crowded out or have been much delayed owing to lack of space. As it is, the size of the last two numbers of the QUARTERLY has been much greater than the finances of the Society will warrant, and future numbers will have to be smaller, even if that necessitates the omission of valuable contributions. The "Results of Tests Made in the Engineering Laboratories" are regarded as an especially valuable feature of the QUARTERLY, and, although a source of very considerable expense, they will continue to be published as presented.

The most momentous event in the history of the Society during the year is the death of President Walker, which has been felt more keenly, perhaps, by the members of the Executive Committee than by the other members of the Society, for their duties brought them into closer personal relations with him, and they have been better able to observe the thoughtful interest and wide knowledge of affairs that General Walker brought to the aid of the Committee in its efforts to guide the course of the Society.

At the time of the previous Annual Meeting the Society had 67 Life Members. Eight of these have died during the year, leaving 59 as the present number. The number of Associate Members a year ago was 289; 3 have died and 11 have resigned. This loss has been more than offset by the election of 35 new members, making the present number of Associate Members 310.

The Life Members who have died during the year are Thomas T. Bouvé, George O. Carpenter, William O. Grover, Henry D. Hyde, G. F. H. Markoe, O. W. Peabody, John Ruggles, and George W. Wales; the Associate Members, are Henry A. Craigin, James H. Stanwood, and Francis A. Walker.

Respectfully submitted,
GEORGE W. BLODGETT,
PERCIVAL LOWELL,
ROBERT P. BIGELOW,
For the Executive Committee.

The election of officers being next in order, ballots were cast and the candidates for the Executive Committee presented at the previous meeting were declared duly elected. Mr. Blodgett reported that the Executive Committee had nominated Dr. Robert P. Bigelow for Secretary for the ensuing year. The Society proceeded to ballot for Secretary, and Dr. Bigelow was duly elected.

Mr. Elisha Lee, of Port of Spain, Trinidad, was elected an Associate Member. It was then voted to adjourn.

ROBERT P. BIGELOW, *Secretary.*

SOME DATA ON THE HEATING ERROR IN RESISTANCE COILS.

By FRANK A. LAWS, S.B.

Received January 27, 1897.

In spite of the fact that Wheatstone bridges and resistance boxes of precision are in common use in our laboratories, there seems to be a lack of reliable data as to the heating error that is likely to occur under the ordinary conditions of use; and I am not familiar with data which will allow one to form a just estimate of the error likely to occur when a coil of a given resistance and of a specified size of German silver wire, wound on a wooden bobbin and inclosed in the neighborhood of other coils in the ordinary closed box, is subjected to a specified current for a stated time.

It was with a view to supplying some of the important data mentioned above that the following experiments were undertaken. They were performed under my direction at the Rogers Laboratory of Physics, by Mr. K. A. Pauly, in connection with his thesis during the spring of 1896.

The box tested was a Wheatstone bridge, the coils of which were wound with double silk-covered German silver wire of the sizes recommended by Professor Holman in his *Physical Laboratory Notes; Part II, Electrical Measurements.*

The coils were wound on wooden bobbins 7.5 cm. long; the diameter of the core was 1.0 cm. They were supported in the box in the usual manner by brass rods 0.5 cm. in diameter. The coils were paraffined by immersion in hot wax under the bell jar of an aspirator, and were well drained so that there was no excess adhering to the outside. The inside dimensions of the closed box containing the coils were 36.5 x 20. x 13.5 cm. For the determination of the increase of resistance a special Wheatstone bridge was arranged as indicated in the sketch, where it is shown without the complications of the other necessary connections.

Nominally equal resistances were unplugged in *Br* and *X*, and an exact balance obtained by the slide wire. If the extension coils, which are of equal value, be properly proportioned to the resistance of the slide wire, one turn may be made to represent a given percentage change in *X*, in our experiments $\frac{1}{10}$ per cent. The boxes *X* and *Br*, as well as the extension coils, were all placed in a large constant temperature tank. The galvanometer circuit was kept closed, and that of the battery made and broken by the special switch shown in the accompanying sketch (Figure 2), the closing of which, besides making the battery connection, transferred the coil under test from the heating circuit to the bridge without loss of time. The action of the switch is evident from the drawing and the diagram of the entire apparatus (Figure 3). The mercury cups (well amalgamated) forming the bridge connections were placed on rubber cushions, so that a good contact would be obtained and no irregularity introduced in consequence of variations of contact resistance.

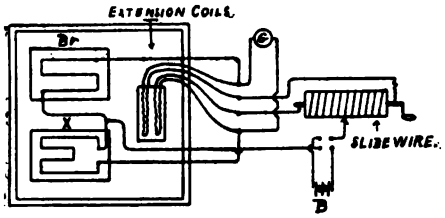


FIG. 1.

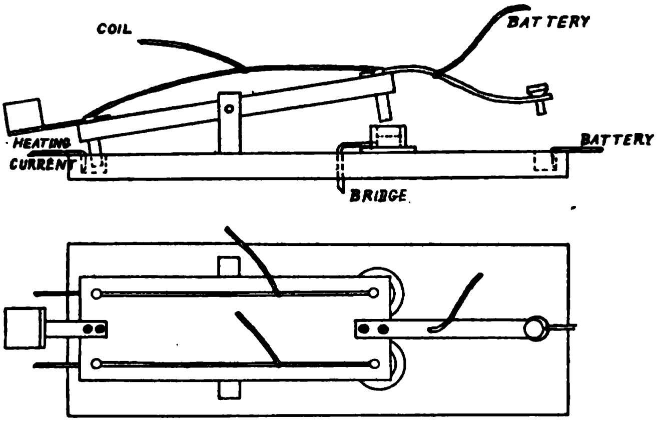


FIG. 2.

When the low resistance coils were under test, it was found that the heating of the coil introduced thermo-electric disturbances, in some cases of sufficient magnitude to send the spot of light off the scale. This was remedied by compensation, by an opposing *P. D.* in the galvanometer circuit. The effect increased as the heating progressed, so that at every reading it was necessary to adjust this *P. D.* anew, but by a little practice the observer was able to anticipate the change, so that this adjustment was a matter of only a few seconds.

The heating currents were measured by Weston ammeters, and as instruments of the proper range were not always obtainable, the bridge under test was shunted with another, the ammeter being placed in series with it and the heating current calculated by the law of shunts.

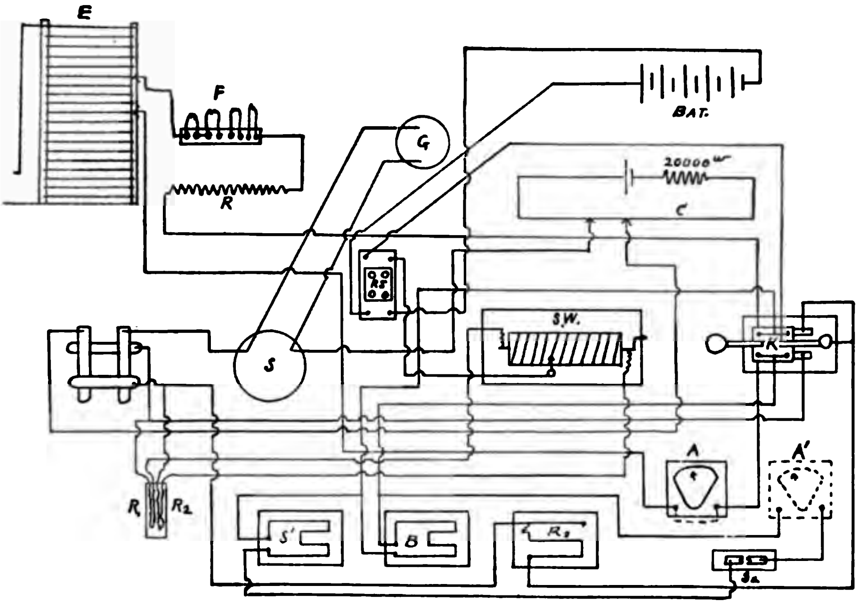


FIG. 3.

The accompanying sketch (Figure 3) shows the arrangement of the entire apparatus.

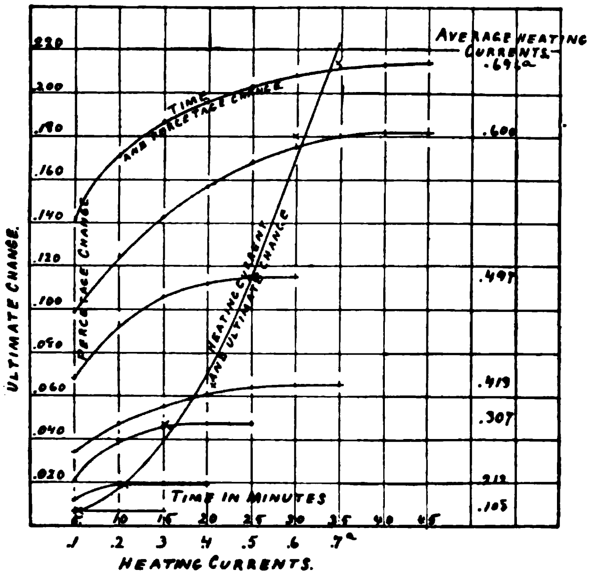
At *E*, *F*, *R* are seen the resistances for controlling the heating currents which were derived from the 110-v. lighting circuit of the laboratory. *C* is the compensation arrangement before mentioned; *R S* the reversing switch in the circuit; *S* the galvanometer shunt; *S W* the slide wire which is wound on a cylinder; *K* the combined coil, changing switch and battery key mentioned above; R_1 and R_2 the extension coils. *S′* is the shunt used in connection with ammeter *A′* for measuring the heating current when ammeter *A* in direct circuit is not available. For the purpose S_2 is the plug for cutting out S' and A' when the coil is being measured. B is the bridge under test, and R_8 the resistance box forming the fourth side of the special bridge. The galvanometer used was a 7-ohm Thomson, having a very carefully prepared astatic suspended system. The balancing could be effected to within $\frac{2}{1000}$ of a per cent. except in the case of the coils of very high resistance where the precision was considerably less.

The procedure during the tests was as follows: The coil to be tested was allowed to remain at a constant temperature for a time sufficient to allow the temperatures of its various parts to become the same; a balance was then obtained and a reading of the slide wire taken. A measured current was then sent through the coil, and the balancing repeated every five minutes until the resistance came to its permanent state for the particular heating current employed. The results of the experiments will now be given in the form of plots, and for greater convenience the same scales of time, percentage change, and ultimate change are used throughout. The scale of heating currents is varied to suit the case in hand. The plots of current and ultimate change enable one to design a coil of a specified resistance, to be made of the size of wire here used, which will carry a given current indefinitely and not increase in resistance more than an assigned percentage, provided the increase be less than $\frac{2}{10}$ of one per cent.

To use these curves it is, of course, necessary to wind the coils of the same diameter as those tested, and to vary the resistance by altering the length of the coil. The dimensions of the coils are only approximate, as no attempt was made to wind them in layers; this is especially true of some of the smaller coils which were very loosely wound.

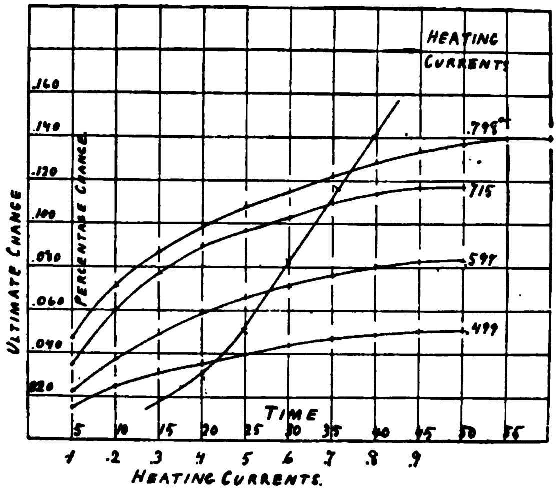
I hope shortly to be able to furnish more complete data which will avoid the necessity of winding the coils to a specified diameter. In addition to the tests on the bridge coils, measurements were made on one of the later forms of standard ohms as furnished by Elliot Brothers, C. L., No. 205. The results of these tests are given in Plot XV.

PLOT I.



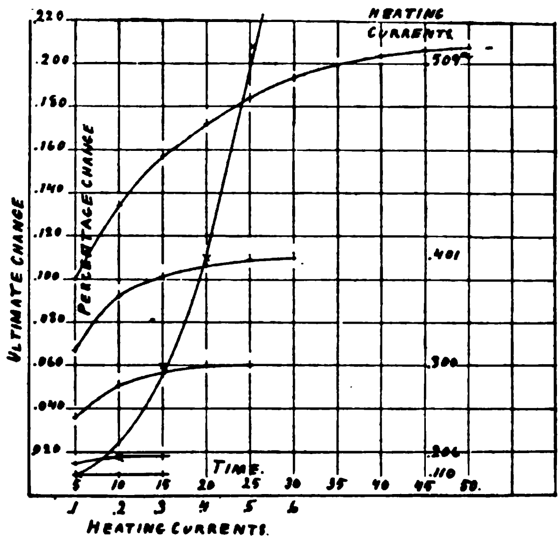
One-ohm coil in rheostat.
No. 18 B. & S. gage German silver wire.
Diameter of core 1.0 cm.; same for all coils.
One layer + of wire.
Resistance per linear centimeter 0.15 ohm.

PLOT II.



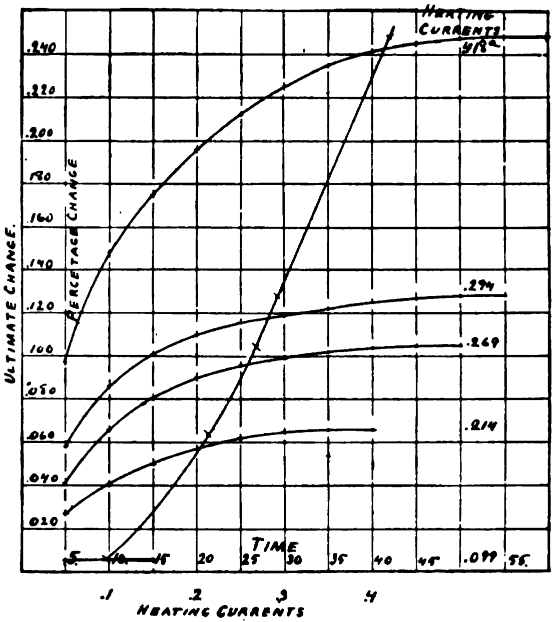
One-ohm coil in balance arm.
Composed of two 2-ohm coils in parallel.
No. 16 B. & S. gage German silver wire.
Diameter of coils 2.3 centimeters.
Resistance of each coil per linear centimeter 0.33 ohm.

Plot III.



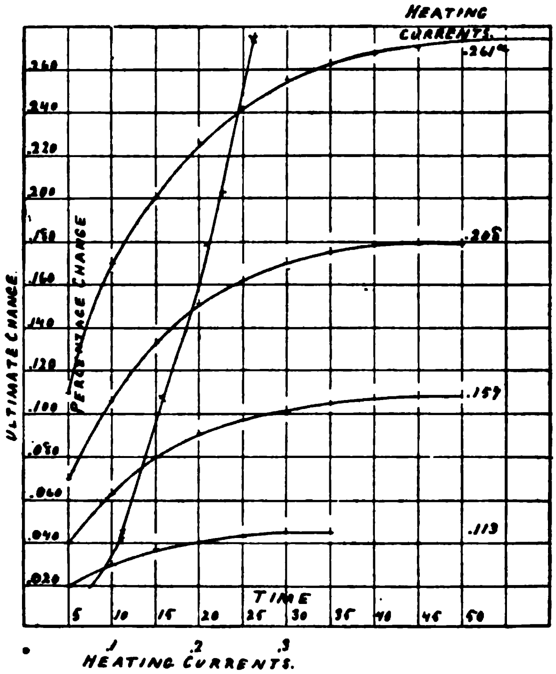
Two-ohm coil.
No. 18 B. & S. gage German silver wire.
Diameter of coil 1.5 centimeters.
Resistance per linear centimeter 0.29 ohm.

Plot IV.



Five-ohm coil.
No. 18 B. & S. gage German silver wire.
Diameter of coil 2.2 centimeters.
Resistance per linear centimeter 0.69 ohm.

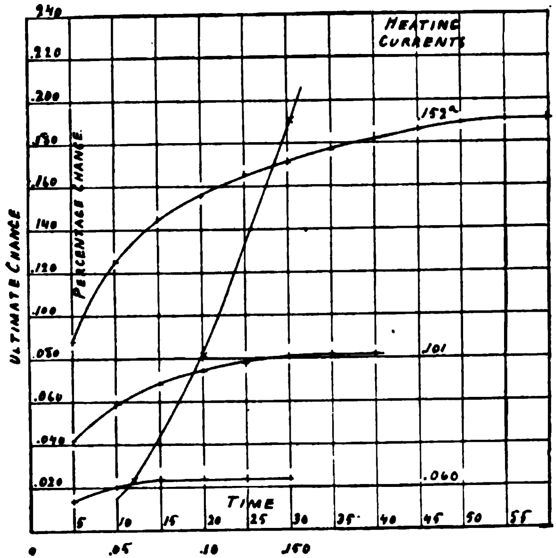
PLOT V.



Ten-ohm coils.
No. 20 B. & S. gage German silver wire.
Diameter of coil 2.1 centimeters.
Resistance per linear centimeter 1.3 ohms.

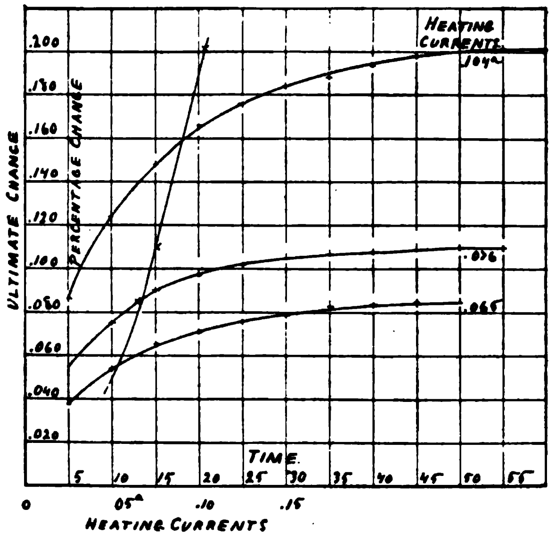
Points marked + on the ultimate change curve are from the coil in the balance arm.

PLOT VI.



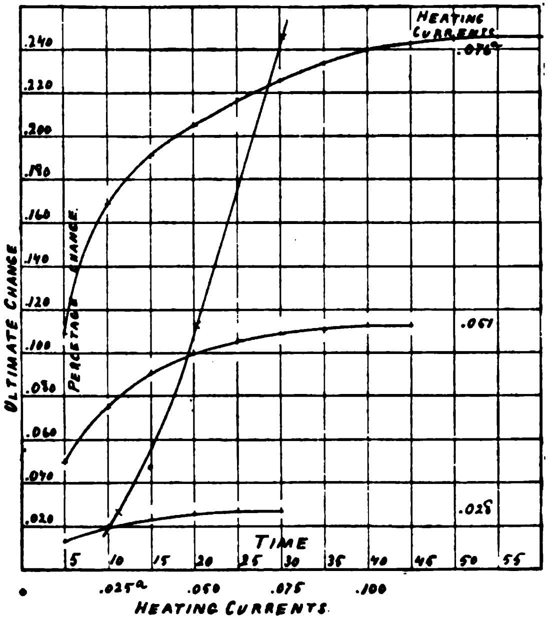
Twenty-ohm coil.
No. 22 B. & S. gage German silver wire.
Diameter of coil 1.9 centimeters.
Resistance per linear centimeter 2.7 ohms.

Plot VII.



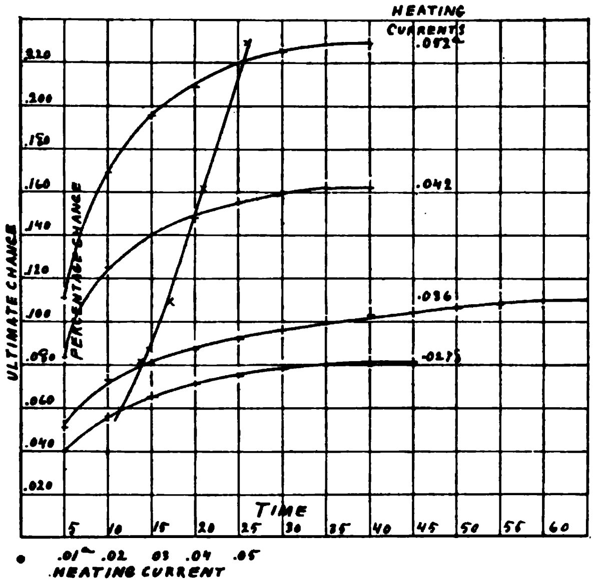
Fifty-ohm coil.
No. 24 B. & S. gage German silver wire.
Diameter of coil 2 centimeters.
Resistance per linear centimeter 7.1 ohms.

Plot VIII.



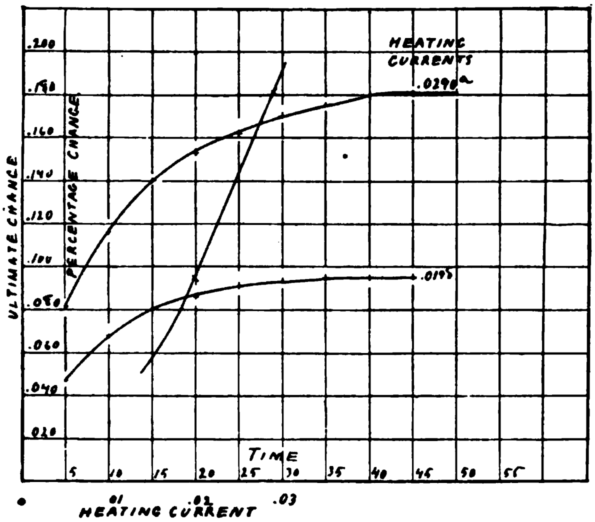
One hundred ohm coil.
No. 26 B. & S. gage German silver wire.
Diameter of coil 1.8 centimeters.
Resistance per linear centimeter 13 ohms.

Plot IX.



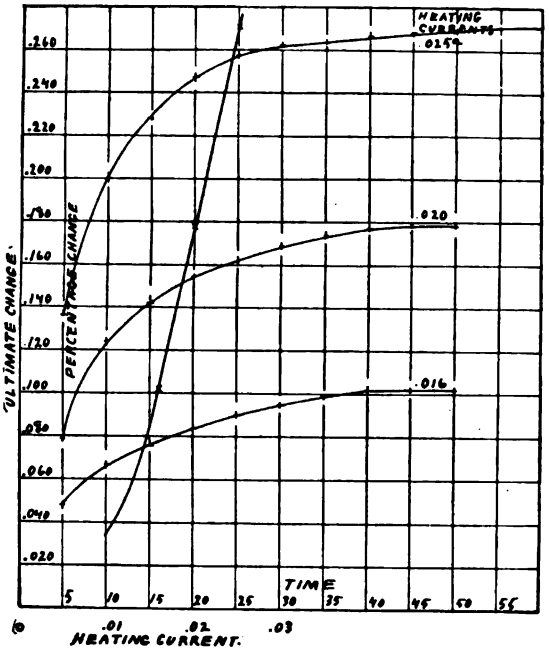
Two hundred ohm coil.
No. 28 B. & S. gage German silver wire.
Diameter of coil 1.6 centimeters.
Resistance per linear centimeter 27 ohms.

Plot X.



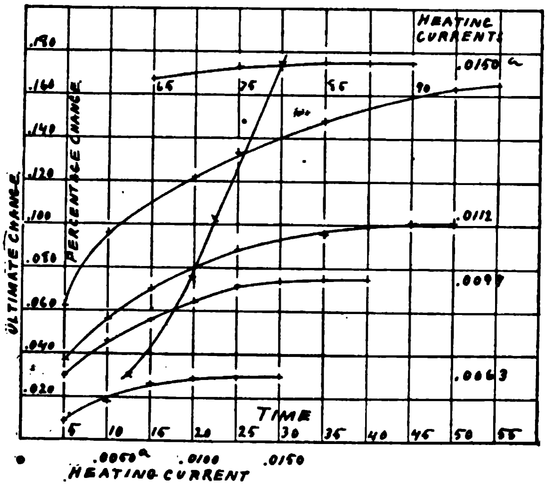
Five hundred ohm coil.
No. 30 B. & S. gage German silver wire.
Diameter of coil 1.8 centimeters.
Resistance per linear centimeter 67 ohms.

PLOT XI.



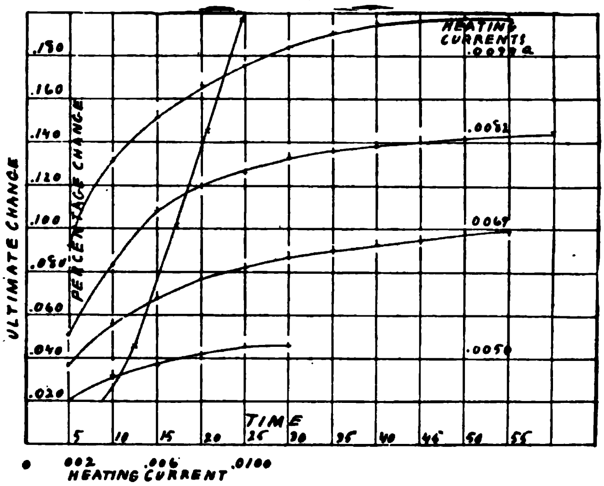
One thousand ohm coil.
No. 32 B. & S. gage German silver wire.
Diameter of coil 1.7 centimeters.
Resistance per linear centimeter 134 ohms.

PLOT XII.



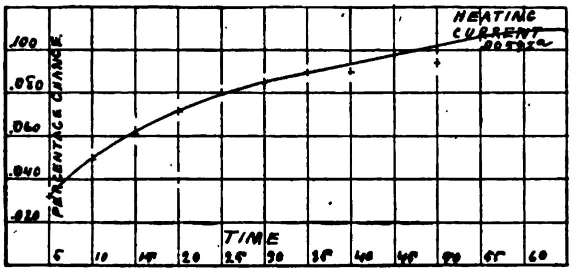
Two thousand ohm coil.
No. 32 B. & S. gage German silver wire.
Diameter of coil 2.1 centimeters.
Resistance per linear centimeter 273 ohms.

Plot XIII.



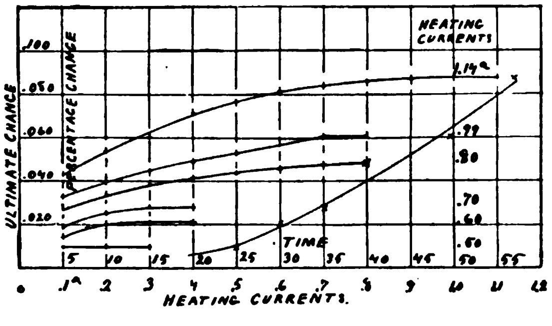
Five thousand ohm coil.
No. 34 B. & S. gage German silver wire.
Diameter of coil 2.1 centimeters.
Resistance per linear centimeter 694 ohms.

Plot XIV.



Ten thousand ohm coil.
No. 34 B. & S. gage German silver wire.
Diameter of coil 2.7 centimeters.
Resistance per linear centimeter 1330 ohms.

Plot XV.



Standard Ohm C. L., No. 205.
(Coil in flattened receptacle, tested in cooling bath.)
Rogers Laboratory of Physics,
Massachusetts Institute of Technology.
January, 1897.

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

VII.

Received May 20, 1897.

APPLIED MECHANICS.

TIMBER TRUSSES.

TESTS OF THE STRENGTH OF TEN TRIANGULAR TRUSSES OF YELLOW PINE.

THE rafters, and the tie of one (No. 494) of the trusses were each 8″ x 10″ in section, while the rafters and ties of the other nine were each about 6″ x 8″ in section. These nine trusses may be classified, according to the style of framing joint used, into three series, A, B, and C.

Series A consisted of two trusses (Nos. 519 and 533), the inclination of the rafters to the tie being 30° in each.

Series B consisted of three trusses (Nos. 520, 522, and 535), the inclination of the rafters to the tie being 45° in No. 522, and 30° in each of the others.

Series C consisted of four trusses (Nos. 517, 518, 523, and 524), the inclination of the rafters to the tie being 30° in Nos. 517 and 518, and 45° in Nos. 523 and 524.

The detailed dimensions and the style of each joint are shown in the accompanying cuts, and the manner of failure in each case is shown in the photographs of the fractures. In every case the load was applied at the top of the truss, and, except in No. 535, the supports were directly below the intersections of the center lines of the rafters with the center line of the tie.

Inasmuch as the results of these tests do not furnish sufficient data to determine completely the distribution of the stresses in the different members, and as more tests are needed to show even the line of direction of the stress in each rafter, which is, probably, not coincident with the center line of each rafter, it seemed best to figure at present only a few of the stresses, stating the assumptions on which this figuring is based, and bearing in mind that these assumptions may be proved true or false by future experiments.

There are given in each case the total breaking load, the manner of failure, the load causing the second failure (for, in all cases, after certain portions had given away, certain other fastenings came into action), the manner of the second failure; and, in most cases, the shearing resistance per square inch of the timber under the first breaking load (the maximum in the majority of cases). This shearing resistance is figured on the assumptions, 1, that the resultant of the stress in each rafter acts along the center line of the rafter; 2, that the shearing resistance is uniformly distributed over the area sheared; and 3, that the additional fastenings (bolts or straps) did not act until the shearing resistance had been overcome.

Whatever may be shown to be true by future experiments in regard to the first and second assumptions, the behavior of the trusses under test would seem to show that the third is either true in all cases, or at least in most cases.

YELLOW PINE TRUSS, No. 494. Figures 1–4.

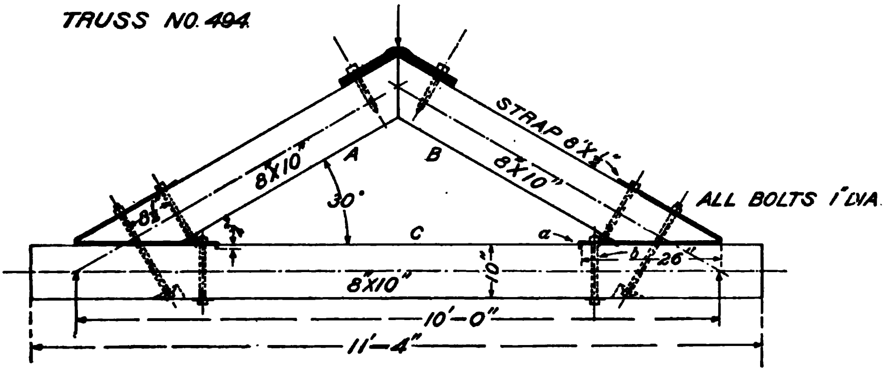


FIG. 1.

At a load of 68,000 pounds the iron began to draw out of the wood at the point marked *a*.

The loading was continued till a maximum was reached at 106,000 pounds.

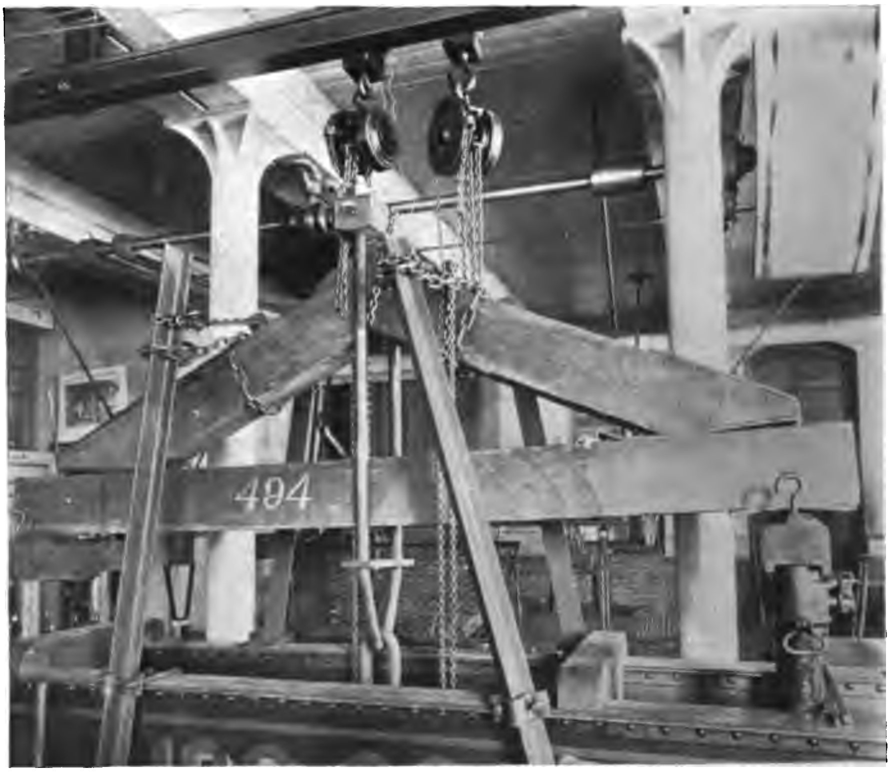


FIG. 2.

For some time before complete failure the bolts had been shearing through the tie; finally the bolt marked (*b*) broke by tension and bending.

Maximum compression per square inch in rafters	**1,300 lbs.**
Maximum tension per square inch in tie	**1,150 lbs.**

FIG. 3.

FIG. 4.

HARD PINE TRUSS, No. 519. SERIES A. Figures 5 and 6.

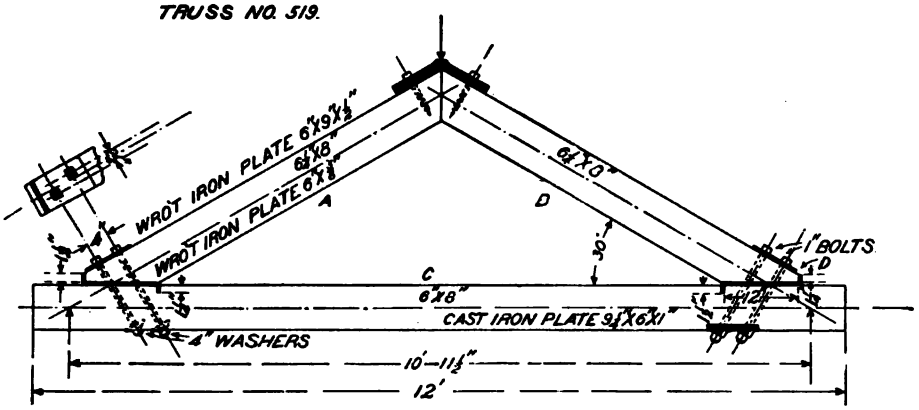


FIG. 5.

In this test downward deflections of the tie were noted for each 5,000 pounds increase of load.

Load.	Deflection.	Load.	Deflection.
5,000	....	35,000	....
10,000	.024″	40,000	.021″
15,000	.019″	45,000	.021″
20,000	.016″	50,000	.027″
25,000	.016″	55,000	.033″
30,000	.017″	60,000	.035″
35,000	.018″	65,000	.045″

The maximum load was	80,000 lbs.
Maximum compression per square inch in rafters	1,600 lbs.
Maximum tension per square inch in tie	1,390 lbs.

The truss failed by the crushing of the foot of the rafter where it bore against the vertical lip of the iron shoe, and by the breaking of the through bolts. The cut does not show the manner of failure very clearly.

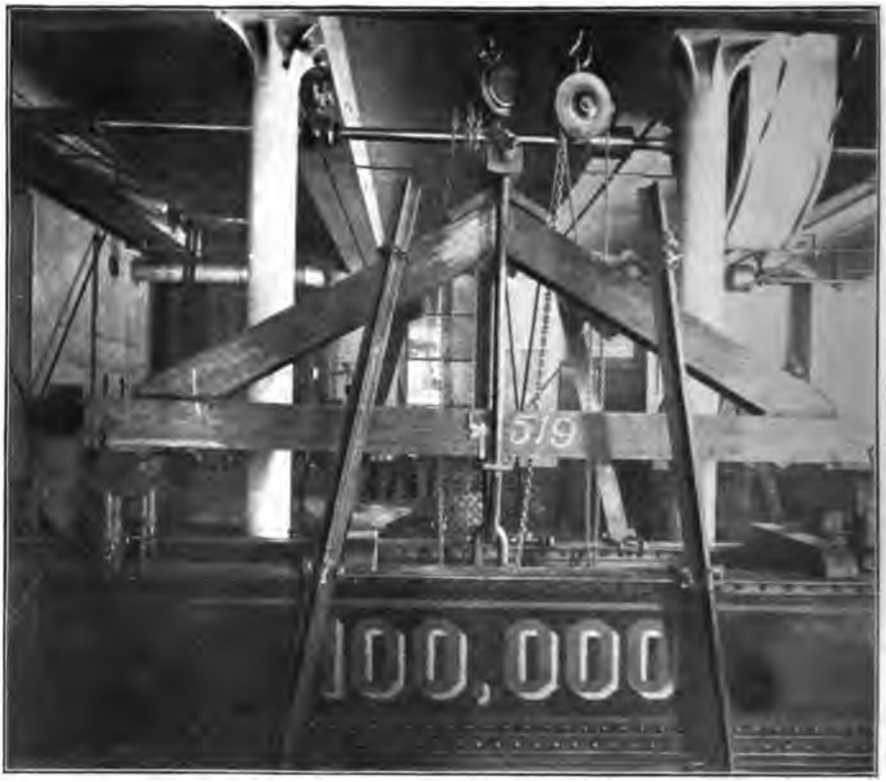


Fig. 6.

HARD PINE TRUSS, No. 533. SERIES A. Figures 7 and 8.

FIG. 7.

This truss is practically the same as that shown by the cut of No. 519. The total length of the bottom tie is $\frac{3}{4}''$ greater than in 519, and the distance between the supports is $1''$ less than in 519. The supports were placed at the intersection of the center lines through the members.

The maximum load on truss was	82,900 lbs.
Maximum compression per square inch in rafters	1,730 lbs.
Maximum tension per square inch in tie	1,500 lbs.

FIG. 8.

HARD PINE TRUSS, No. 520. SERIES B. Figures 9–11.

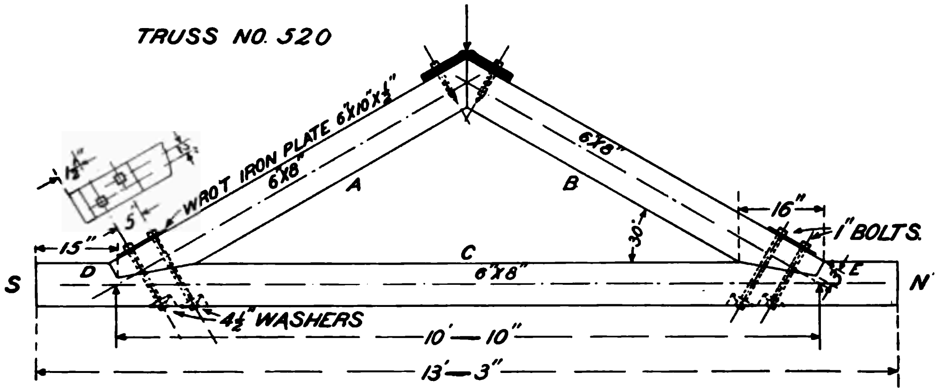


FIG. 9.

At a load of 48,400 pounds the tie sheared at *D*.

At a load of 49,255 pounds the tie sheared at *E*.

At a load of 53,625 pounds the inner bolt at *N* end broke. The outer bolt at this end gave way at a load of 47,085 pounds on the truss.

Maximum compression per square inch in rafters	1,130 lbs.
Maximum tension per square inch in tie	980 lbs.
Neglecting bolts, the maximum shear per square inch at end *D* . .	470 lbs.
Neglecting bolts, the maximum shear per square inch at end *E* . .	480 lbs.

Fig. 10. North end.

FIG. 11. South end.

HARD PINE TRUSS NO. 522. SERIES B. Figures 12–15.

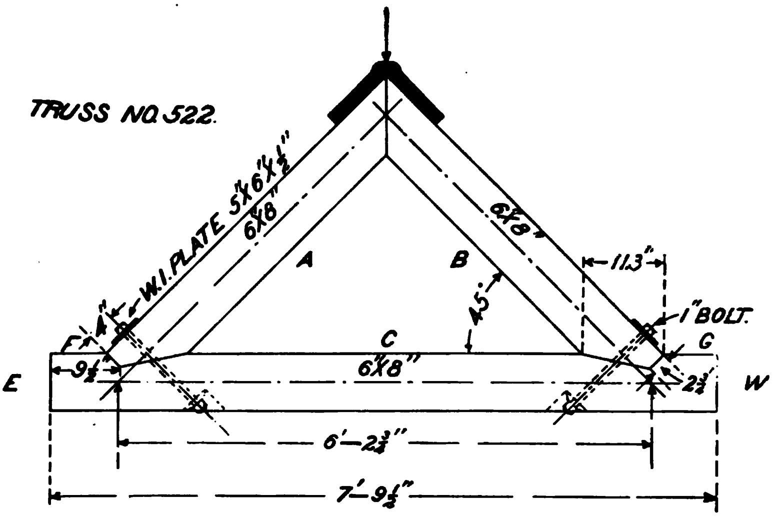


FIG. 12.

At a load of 102,300 pounds the tie sheared at *W* end. The tie then cracked by tension at this end, where the section was reduced by the recess made to take iron washer.

At 105,800 the east end of the tie sheared, and the bolt at this end gave way.

Maximum compression per square inch in rafters	1,560 lbs.
Maximum tension per square inch in tie	1,100 lbs.
Neglecting bolts, shearing force per square inch at time tie sheared at *W* end	900 lbs.
Neglecting bolts, shearing force per square inch at time tie sheared at *E* end	930 lbs.

FIG. 13.

FIG. 14.

FIG. 15.

HARD PINE TRUSS No. 535. SERIES B. Figures 16 and 17.

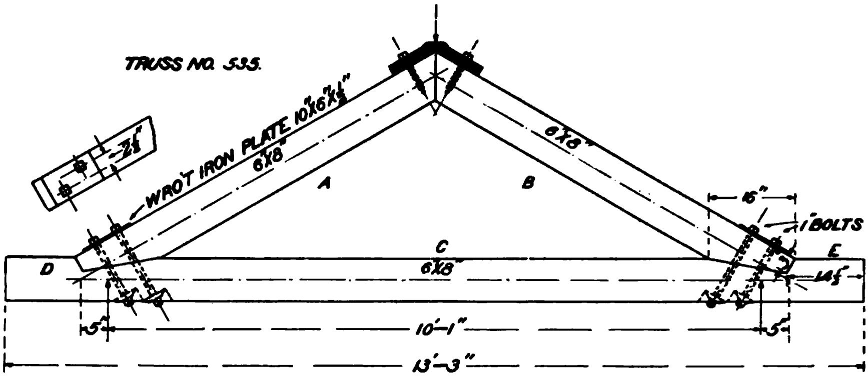


FIG. 16.

At a load of 47,900 pounds tie sheared at end marked *D*.
At 56,600 pounds both bolts at this end gave way.

Maximum compression per square inch in rafters	1,180 lbs.
Maximum tension per square inch in tie	1,020 lbs.
Neglecting bolts, maximum shear per square inch at *D* at time of shear	480 lbs.

It will be noticed that the supports were not at the intersection of the center lines of the members.

FIG. 17. Truss No. 535.

HARD PINE TRUSS, No. 517. SERIES C. Figures 18 and 19.

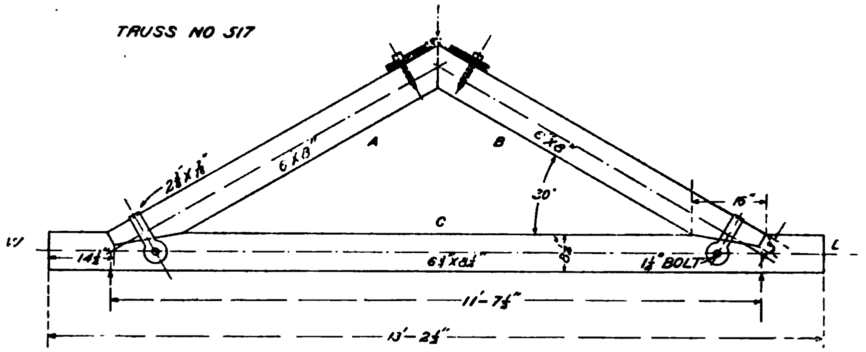


FIG. 18.

At a load of 56,700 pounds tie sheared at *E* end, causing load to drop off considerably. The loading was continued till at 37,650 pounds the strap at the *E* end gave way at both corners.

Maximum compression per square inch in rafters	1,180 lbs.
Maximum tension per square inch in tie	1,040 lbs.
Neglecting strap, maximum shear per square inch in tie at time of shear	570 lbs.

FIG. 19.

HARD PINE TRUSS, No. 518. SERIES C. **Figure 20.**

FIG. 20. Truss No. 518.

This truss was an exact duplicate of No. 517.

At a load of 55,800 pounds the tie sheared at *E* end, as in No. 517. The loading was continued after this shear, but did not again reach 55,800 pounds. At 49,300 the strap at the end which had sheared gave way at one corner.

Maximum compression per square inch in rafters	1,160 lbs.
Maximum tension per square inch in tie	1,010 lbs.
Neglecting strap, maximum shear per square inch in tie at time of shearing	540 lbs

HARD PINE TRUSS, No. 523. SERIES C. Figures 21–24.

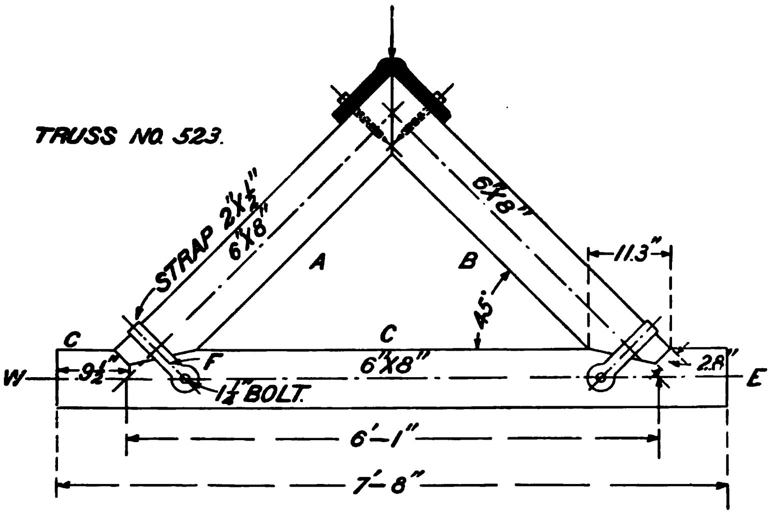


FIG. 21.

At a load of 93,600 pounds tie sheared at *C*. After the shear, continued loading till the strap at this end gave way at 79,200 pounds.

Maximum compression per square inch in rafters	1,380 lbs.
Maximum tension per square inch in tie	900 lbs.
Neglecting strap, maximum shear per square inch in tie at time of shearing	820 lbs.

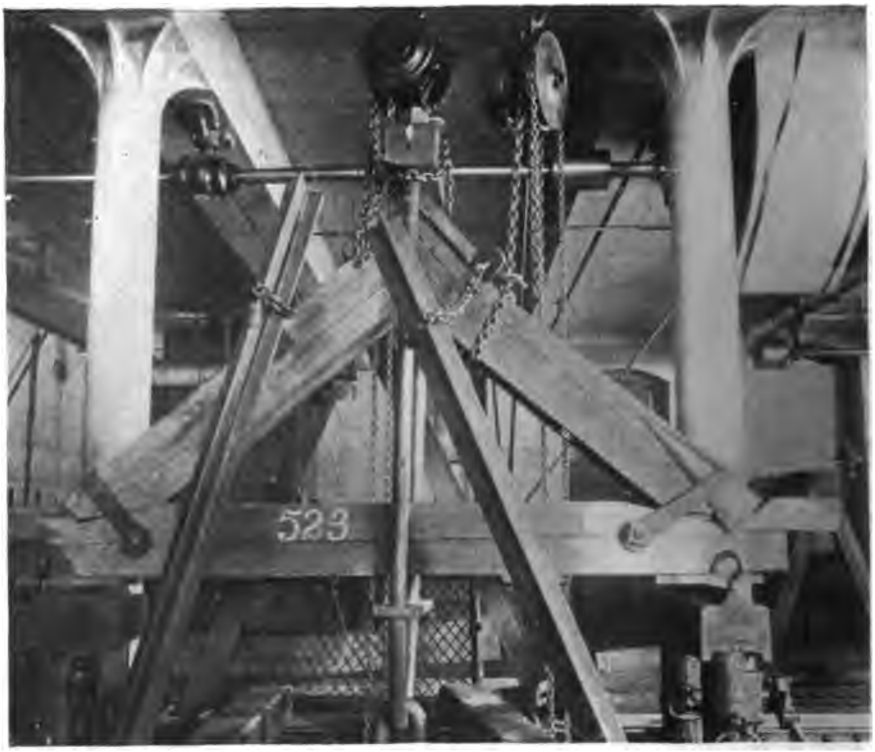


FIG. 22.

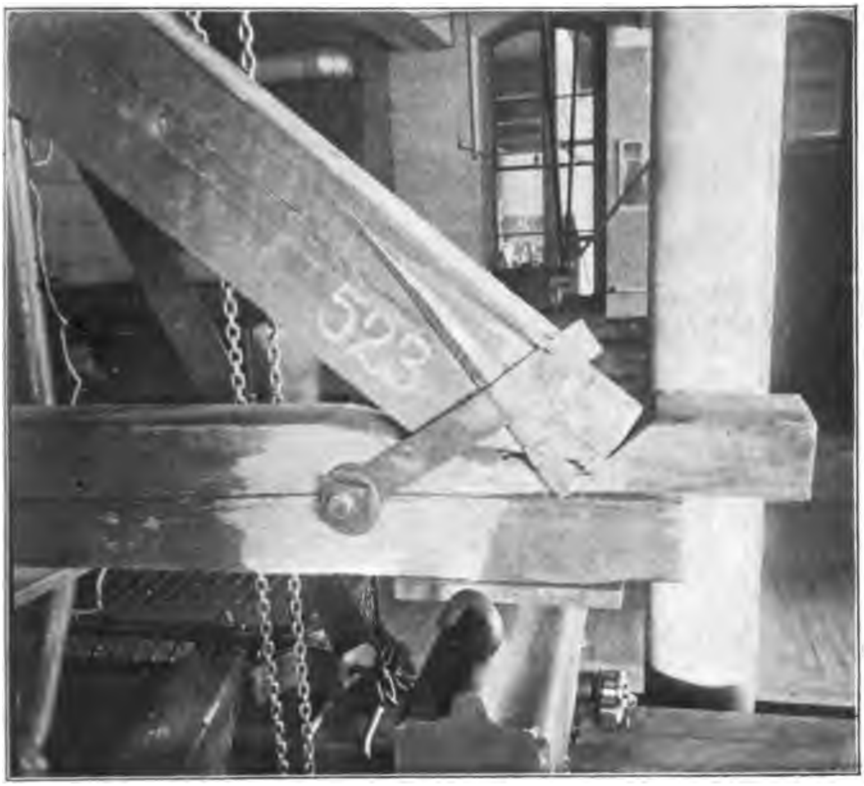


FIG. 23.

FIG. 24.

HARD PINE TRUSS, No. 524. SERIES C. Figures 25 and 26.

FIG. 25.

This truss was exactly the same as truss No. 523. At a load of 105,900 pounds tie sheared at *W* end. After shear, continued loading till strap at *W* end gave way at 87,100 pounds.

Maximum compression per square inch in rafters	1,560 lbs.
Maximum tension per square inch in tie	1,100 lbs.
Maximum shear per square inch in tie at time of shear	930 lbs.

Fig. 26.

TESTS OF HARD PINE TIMBER HEADERS.

The object of this investigation was to find the strength of timber headers loaded through tail-beams framed into the headers by tusk and tenon joints.

As the test was to be one of the headers and not of the tail-beams, these were made quite short. In some of the tests the headers were framed to the trimmers by a double tenon, and held by a joint bolt; in others the headers were held by a stirrup iron and joint bolt.

I beams were used to distribute the load equally between the tail-beams. The upward pull on the top I beam was taken by the weighing system of the testing machine. By screwing up the jacks on which the trimmers rested, loads were applied. The tusk and tenon joints were all the same as those shown by Figure 27*a*.

Cuts of Nos. 482, 483, 484, 490, and 500 show the arrangement by means of which the loads were distributed between the tail-beams.

HARD PINE FRAMED HEADERS, No. 482. **Figures 27 and 28.**

Size of header 6" x 12", 6'– 8" long. Number of tail-beams, (4) 16" on centers.

At a load of 30,380 pounds the north header gave way, starting at the lower tenon at the trimmer on east side (see Fig. 28).

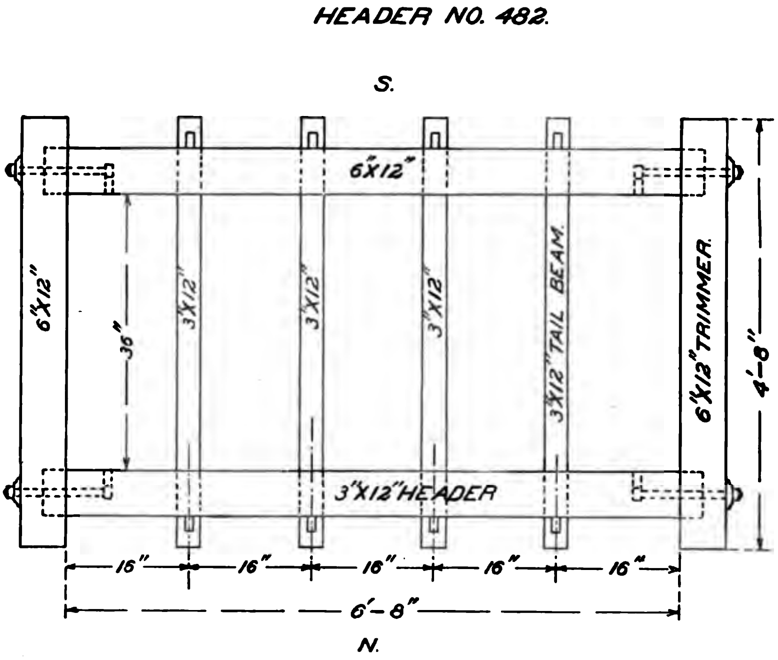
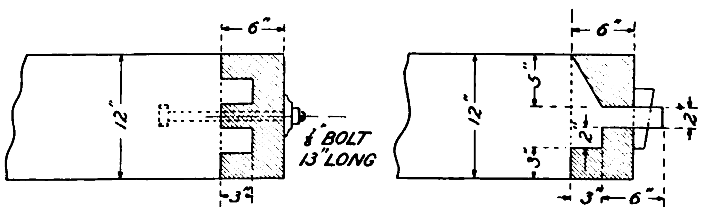


FIG. 27.



JOINT OF HEADER IN TRIMMER. JOINT OF TAIL BEAM IN HEADER

FIG. 27*a*.

Fig. 28.

HARD PINE FRAMED HEADERS, No. 483. Figure 29.

FIG. 29.

The frame of this header was the same as No. 482, with broken north header and west tail-beam replaced by sound sticks. At 40,380 the north header gave way, failing as in the previous joint.

HARD PINE FRAMED HEADER, No. 484. Figure 30.

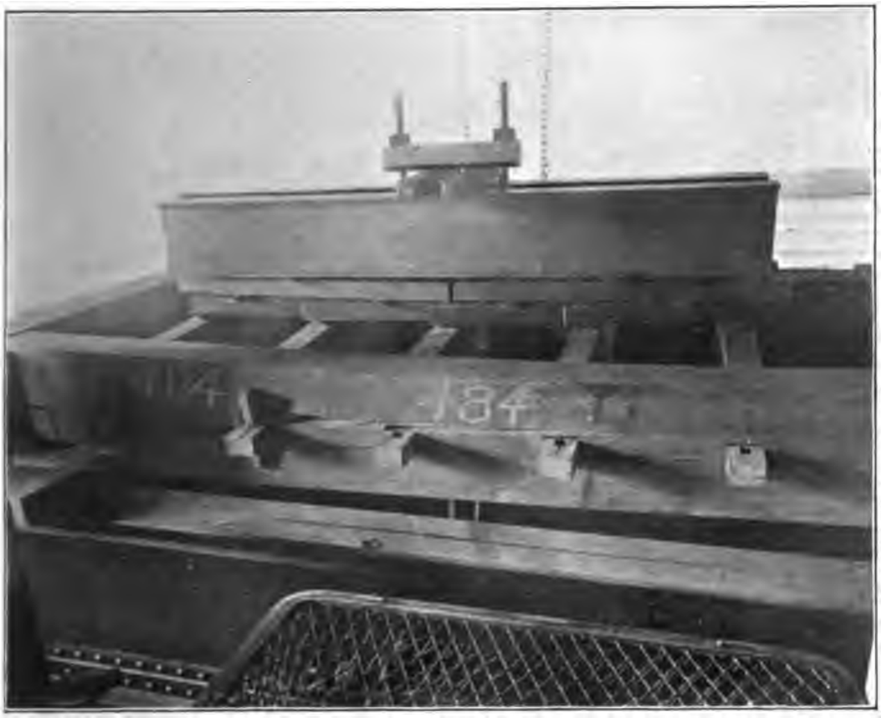


FIG. 30.

Five tail-beams 16″ centers used in this case. Header 6″ x 12″, 8′ – 0″ long. Failed at south header at load of 29,740 pounds.

HARD PINE FRAMED HEADERS, No. 485. Figure 31.

FIG. 31.

This was an exact duplicate of No. 484. Failed at north header at a load of 31,300 pounds on scales, making, including the weights of the I beams used for loading, 32,090 pounds.

HARD PINE FRAMED HEADERS, No. 486. Figure 32.

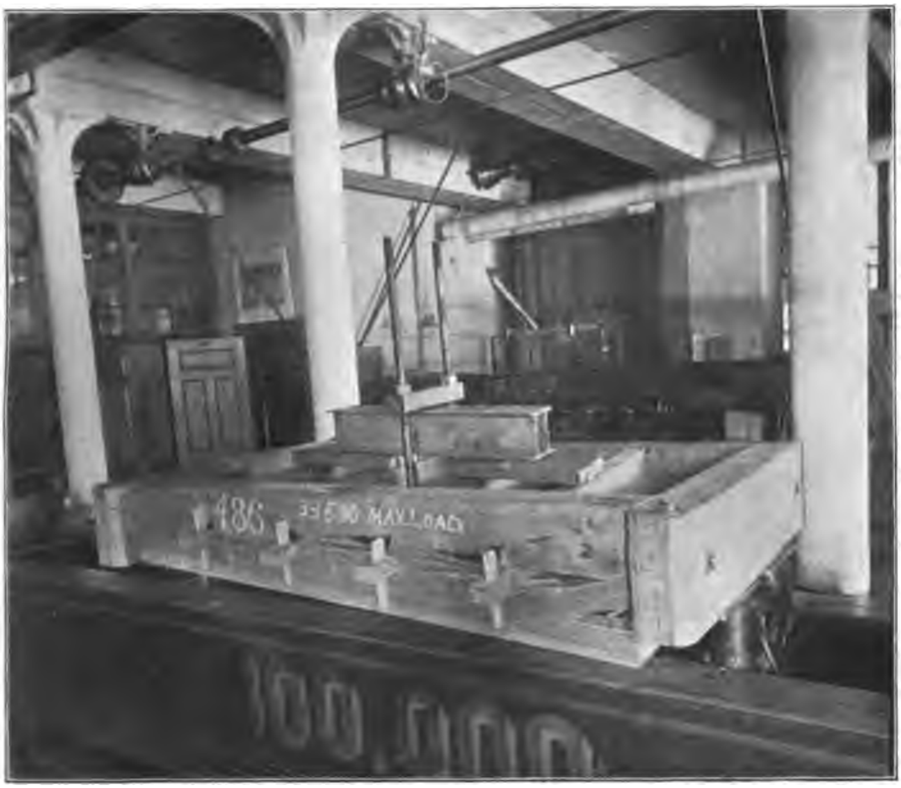


FIG. 32.

Same general frame as No. 483, with north header of 483 replaced by sound stick. At 33,500 pounds on scales or 33,850 on tail-beams, the north header gave way.

HARD PINE TIMBER HEADERS, No. 487. Figure 33.

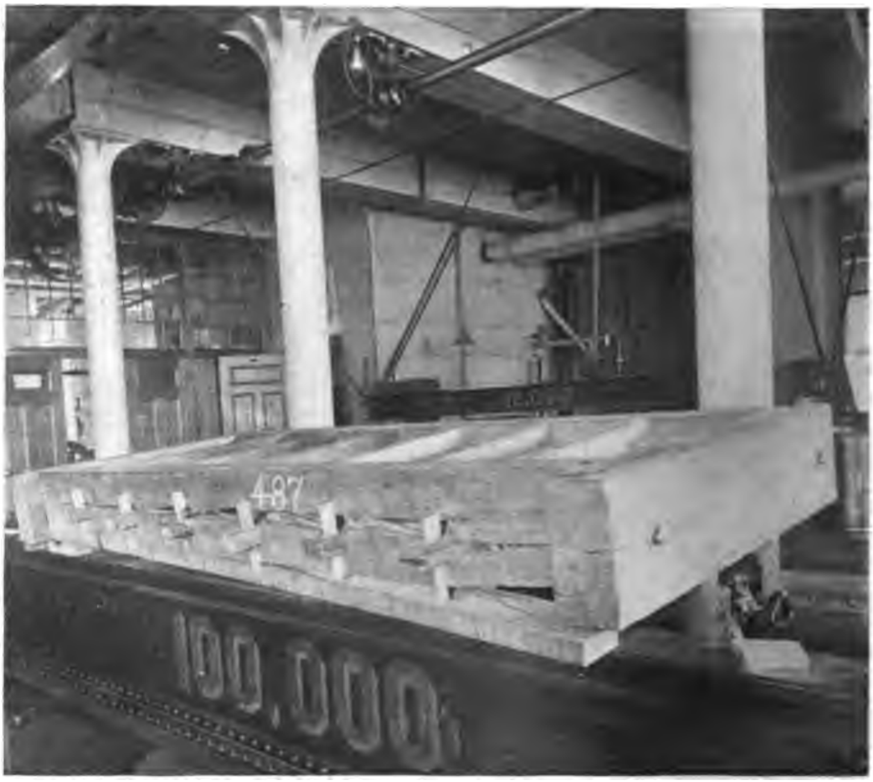


FIG. 33.

Headers were 6″ x 12″ 9′-4″ long. There were six tail-beams spaced 16″ on centers. The load was distributed by an arrangement of the I beams similar to that shown in the cut of No. 493.

At a load of 37,220 pounds, the south header failed throughout its entire length.

HARD PINE TIMBER HEADERS, No. 490. Figures 34 and 35.

Fig. 34. North.

Headers were 6″ x 12″, 10′ – 8″ long. There were seven tail-beams spaced 16″ centers. At 27,810 pounds the north header failed, followed almost immediately by the south header.

Fig. 35. South.

HARD PINE TIMBER HEADERS, No. 492. **Figures 36 and 37**

FIG. 36. North.

Headers Nos. 492, 493, and 500 were held to the trimmers by stirrup irons instead of by double tenons and joint bolts. Header No. 492 was of the same general dimensions as Nos. 483 and 486. The headers were 6″ x 12″, 6′ - 8″ long.

There were four tail-beams 16″ on centers. At 25,590 pounds the south header failed, soon followed by the north header.

FIG. 37. South.

HARD PINE TIMBER HEADERS, No. 493. Fig. 38.

Fig. 38.

Same general dimensions as No. 487. Header 6″ x 12″, 9′ – 4″ long, held to trimmer by stirrup irons. At a load of 26,020 pounds, the north header failed completely.

HARD PINE TIMBER HEADERS, No. 500. Fig. 39.

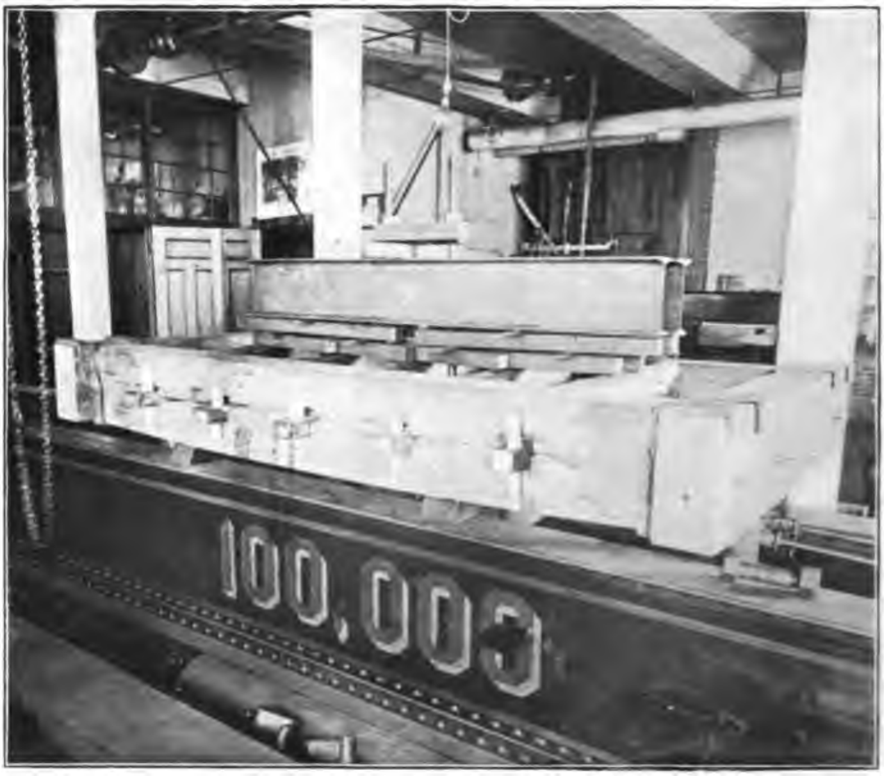


Fig. 39. Header No. 500.

Same general dimensions as Nos. 484 and 485. Headers were 6″ x 12″, 8′ – 0″ long, held to trimmers by stirrup irons. Five tail beams spaced 16″ on centers. Maximum load at failure, 32,740 pounds. Failed at the north header as shown by the cut.

CAST IRON WATER PIPE.

Summary of Tests.

No. of test.	Size of pipe.	Average inside diameter.	Average length.	Average thickness.	Maximum load.	Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends.	REMARKS.
	Ins.	Ins.	Ins.	Ins.	Lbs.	Lbs. per sq. in.	
1	10	9.97	40	.54	19,000	12,800	Broke at A and A′.
2	12	11.96	42	.62	25,000	14,600	Broke at A and A′.
3	10	0.98	42	.54	22,500	14,500	Spigot end. Broke at A′.
4	48	48.14	29	1.14	18,100	17,800	Break started at A.
5	12	12.02	42⅜	.61	24,300	14,600	Spigot end. Break started at A′.
6	12	11.96	36¼	.69	32,500	17,900	Spigot end. Broke at A.
7	10	9.93	36⅝	.64	41,000	21,600	Spigot end. Broke at A′.
8	16	16.00	36	.79	35,000	19,600	Broke at A.
9	16	16.06	35⅞	.80	35,700	19,700	Broke at A′.
10	16	16 06	35[illegible]	.75	35,300	22,300	Broke at A′.
11	20	19.88	37	.82	28,500	17,800	Broke at A.
12	20	19.91	36	.95	38,100	18,300	Broke at A′.
13	20	19.79	36⅝	.80	40,000	26,300	Broke at A′.
14	24	23.84	39[illegible]	.90	33,800	19,600	Broke at A′.
15	24	23.95	41[illegible]	.87	30,700	18,200	Broke at A.
16	24	23.89	40[illegible]	.90	33,600	19,200	Broke at A.
17	30	29.84	34[illegible]	1.15	36,300	18,700	Broke at A.
18	6	6.10	21[illegible]	.49	26,500	25,800	Broke at A.
19	8	7.96	20[illegible]	.58	27,700	26,000	Broke at A.
20	6	6.07	21[illegible]	.48	20,500	20,300	Broke at A and B.
21	8	7.94	21[illegible]	.59	27,900	23,700	Broke at A′.
22	6	6.08	22[illegible]	.50	25,800	23,000	Broke at A′.
23	8	7.90	21[illegible]	.63	30,100	22,600	Broke at A′.
24	6	6.09	21[illegible]	.49	27,000	26,000	Broke at A.
25	8	7.93	24⅜	.59	21,900	16,200	Broke at A.
26	6	6.09	36⅜	.49	38,700	21,600	Spigot end. Broke at A′.
27	8	7.89	36⅝	.62	40,300	18,300	Spigot end. Broke at B.
28	48	47.95	25	1.46	25,800	17,900	Spigot end. Broke at A.
29	36	36.05	34	1.07	24,200	17,300	Broke at A.
30	48	48.02	32¼	1.43	32,300	18,200	Spigot end. Broke at A.
31	48	47.90	34	1.25	24,500	17,000	Spigot end. Broke at A′.

In tests Nos. 1, 2, 3, 4, 5, 6, 28 the load was applied on a space of 15″ in the middle of the length of the pipes.

In remaining tests the load was applied on the entire length of the specimens. In all of the tests the loads were applied to the specimens through iron platforms. As these platforms were rigid, the load was applied along an element.

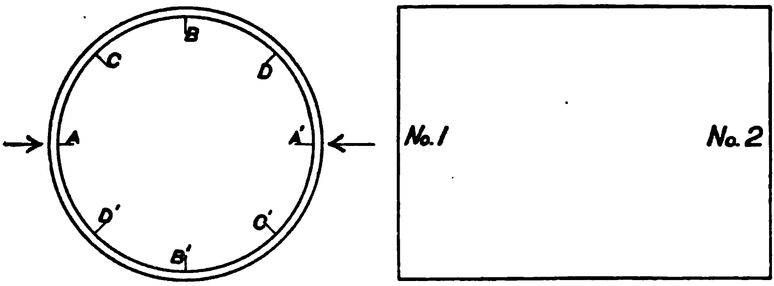


FIG. 40. DIAGRAMS OF CAST IRON WATER PIPE, TRANSVERSE AND LONGITUDINAL SECTIONS. The arrows indicate the direction of pressure; the letters *A A'*, *B B'*, etc., the diameters upon which the deflection was measured.

No. 4. TEST ON CAST IRON WATER PIPE.

March 14, 1897.

	THICKNESS.		INSIDE DIAMETER.		LENGTH.
	End No. 1.		End No. 1.	End No. 2.	
A	1.20				29"
B	1.12	AA'	48.06	48.13	
C	1.19				
D	1.09	BB'	48.19	48.19	
A'	1.12				
B'	1.16				
C'	1.14				
D'	1.11				

DEFLECTION MEASUREMENTS.

LOADS.	END NO. 1.				END NO. 2.				AVERAGE DIFFERENCE.			
	AA'.	BB'.	CC'.	DD'.	AA'.	BB'.	CC'.	DD'.	AA'.	BB'.	CC'.	DD'.
0	1.08	1.00	.98	.97	.90	.96	.99	.99	......	....	....	....
5,000	.87	1.24	1.01	1.01	.67	1.21	1.05	1.03	—.220	.245	.045	.040
10,000	.60	1.50	1.03	1.03	.44	1.42	1.05	1.04	—.250	.235	.010	.015
15,000	.26	1.80	1.06	1.04	.09	1.74	1.09	1.05	—.345	.310	.035	.010
18,100	Maximum load. Cracked along A'A'.											

Size of pipe	48"
Average inside diameter	48.14"
Average length	29"
Average thickness	1.14"

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 17,800 lbs.

REMARKS.

Spigot end.
Load applied on space of 15" along center of length.
Lip on End No. 2 about ¾" wide and 1⅛" thick.
Nick at C End No. 1. Length at nick 28". Length at A'A' 29".

No. 8. TEST ON CAST IRON WATER PIPE.

March 18, 1897.

	Thickness.		Inside Diameter.	Length.
	End No. 1.	End No. 2.		
A	.75	.74	16.00″	36″
B	.76	.73	......	....
A′	.86	.83	......	....
B′	.87	.81	......	....

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	16.70	16.68	16.60	17.14	......	....
5,000	16.67	16.71	16.60	17.13	—.015	.010
10,000	16.66	16.73	16.58	17.15	—.015	.020
15,000	16.65	16.76	16.56	17.17	—.015	.025
20,000	16.60	16.79	16.54	17.20	—.035	.030
25,000	16.58	16.81	16.51	17.20	—.025	.010
30,000	16 55	16.83	16.47	17.23	—.035	.025
35,000	Maximum load.	Break started at A, End No. 1, cracked nearly whole length of pipe. Second break started at A′A′ and B′B′ simultaneously.				

Size of pipe	16″
Average inside diameter	16.00″
Average length	36″
Average thickness	.79″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe is a beam fixed at the ends . . . . 19,600 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 9. TEST ON CAST IRON WATER PIPE.

March 19, 1897.

	Thickness. End No. 1.	Inside Diameter.		Length.
A	.79	16.06	BB	35¾"
B	.74	.....	B'B'	36 "
A'	.79	.....		
B'	.87	.....		

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA'.	BB'.	AA'.	BB'.	AA'.	BB'.
0	16.74	16.84	16.49	16.41	......	....
5,000	16.71	16.86	16.47	16.45	—.025	.030
10,000	16.69	16.90	16.42	16.46	—.035	.025
15,000	16.66	16 92	16.39	16.50	—.030	.030
20,000	16.63	16.94	16.39	16.51	—.015	.015
25,000	16.59	16.98	16.35	16.55	—.040	.040
35,700	Maximum Load. Cracked the whole length at A'A'; then broke at AA; then broke at B'B'; then broke at BB.					

Size of pipe	16"
Average inside diameter	16.06"
Average length	35⅞"
Average thickness	.80"

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 19,700 lbs.

REMARKS.

Spigot end.
Load applied along whole length of specimen.
Lip on End No. 2 about ⅝" wide and 1" thick.

No. 10. TEST ON CAST IRON WATER PIPE.
March 20, 1897.

	Thickness.			Inside Diameter.		Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.	
A	.71	.75				35½″
B	.72	.73	AA′	16.11	16.08	
A′	.77	.78				
B′	.81	.74	BB′	16.03	16.03	

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	16.74	17.00	16.74	16.44	......	....
5,000	16.73	17 02	16.72	16.48	—.015	.030
10,000	16.70	17.05	16.68	16.50	—.035	.025
15,000	16 66	17.10	16.65	16.54	—.035	.045
20,000	16.62	17.12	16.62	16.56	—.035	.020
25,000	16.60	17.14	16.60	16.59	—.020	.025
30,000	16.56	17.18	16.56	16.61	—.040	.030
35,300	Maximum load. Broke along A′A′; then broke along AA.					

Size of pipe	16″	Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 22,300 lbs.
Average inside diameter	16.06″	
Average length	35½″	
Average thickness	.75″	

REMARKS.
Load applied along whole length of specimen.

No. 11. TEST ON CAST IRON WATER PIPE.
March 22, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.81	.76				AA	37¼″
B	.85	.84	AA′	19.89	19.86	BB	37¼″
A′	.83	.84				AA′	36¾″
B′	.85	.80	BB′	19.86	19.89	BB′	36¾″

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	20.22	20.34	20.40	20.63	......	...
5,000	20.20	20.38	20.34	20.68	—.040	.045
10,000	20.17	20.40	20.27	20.74	—.050	.040
15,000	20.12	20.45	20.14	20.81	—.090	.060
28,500	Maximum load. Broke at AA; then broke at A′A′.					
18,000	Broke at B′B′ and BB.					

Size of pipe	20″	Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 17,800 lbs.
Average inside diameter	19.88″	
Average length	37″	
Average thickness	.82″	

REMARKS.
Load applied along whole length of specimen.

No. 12. TEST ON CAST IRON WATER PIPE.
March 23, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	1.00	1.01				AA	36 "
B	.96	.94	AA'	19.91	19.95	BB	35¾"
A'	.93	.90				A'A'	36¼"
B'	97	.90	BB'	19.88	19.92	B'B'	36¼"

DEFLECTION MEASUREMENTS.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA'.	BB'.	AA'.	BB'.	AA'.	BB'.
0	20.13	20.57	20.20	20.54	......	....
5,000	20.10	20.58	20.18	20.57	—.025	.020
10,000	20.06	20.62	20.14	20.59	—.040	.030
15,000	20.03	20.65	20.12	20.61	—.025	.025
20,000	20.00	20.67	20.09	20.63	—.030	.020
38,100	Maximum load. Broke on A'A'. Second break on AA and BB.					

Size of pipe . . . . 20"
Average inside diameter . . . . 19.91"
Average length . . . . 36"
Average thickness . . . . .95"

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 18,300 lbs.

REMARKS.
Load applied along whole length of specimen.

No. 13. TEST ON CAST IRON WATER PIPE.
March 24, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.81	.83				AA	36½"
B	.81	.76	AA'	19.75	19.80	BB	36½"
A'	.85	.73				A'A'	37¼"
B'	.80	.78	BB'	19.80	19.80	B'B'	37"

DEFLECTION MEASUREMENTS.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA'.	BB'.	AA'.	BB'.	AA'.	BB'.
0	20.88	20.55	20.23	20.75	......	....
5,000	20.84	20.58	20.20	20.76	—.035	.020
10,000	20.79	20.61	20.16	20.80	—.045	.035
15,000	20.76	20.65	20.12	20.83	—.035	.035
20,000	20.72	20.69	20.09	20.87	—.035	.040
40,000	Maximum load. Broke at A'A'; next broke at AA.					
26,800	Broke at BB.					

Size of pipe . . . . 20"
Average inside diameter . . . . 19.79"
Average length . . . . 36¾"
Average thickness . . . . .80"

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 26,300 lbs.

REMARKS.
Load applied along whole length of specimen.

No. 14. TEST ON CAST IRON WATER PIPE.
March 25, 1897.

	THICKNESS.			INSIDE DIAMETER.			LENGTH.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.87	.90				AA	40″
B	.89	.85	AA′	23.92	23.84	BB	39″
A′.	.84	.93				A′A′	39½″
B′.	.99	.93	BB′	23.78	23.81	B′B′	39½″

DEFLECTION MEASUREMENTS.

LOADS.	END No. 1.		END No. 2.		AVERAGE DIFFERENCE.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	24.94	24.52	24.87	24.72	......	....
5,000	24.93	24.54	24.83	24.78	—.025	.040
10,000	24.90	24.57	24.76	24.83	—.050	.040
15,000	24.86	24.62	24.69	24.89	—.055	.055
33,800	Maximum load.	Broke on A′A′; next broke on AA.				
20,000		Broke on BB and B′B′.				

Size of pipe	24″
Average inside diameter	23.84″
Average length	39½″
Average thickness	.90″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 19,600 lbs.

REMARKS.
Load applied along whole length of specimen.

No. 15. TEST ON CAST IRON WATER PIPE.
March 26, 1897.

	THICKNESS.			INSIDE DIAMETER.			LENGTH.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.84	.82				AA	41⅜″
B	.84	.84	AA′.	23.84	23.98	BB	41½″
A′.	.94	.86				A′A′	41 ″
B′.	.92	.88	BB′.	23.95	24.02	B′B′	41¼″

DEFLECTION MEASUREMENTS.

LOADS.	END No. 1.		END No. 2.		AVERAGE DIFFERENCE.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	24.74	24.69	24.63	24.58	......	....
5,000	24.71	24.72	24.56	24.64	—.050	.045
10,000	24.67	24.76	24.50	24.70	—.050	.050
15,000	24.63	24.81	24.43	24.76	—.055	.055
20,000	24.57	24.87	24 35	24.84	—.070	.070
30,700	Maximum load.	Broke at AA, beginning at End No. 1.				
28,400		Broke at A′A′.				
20,800		Broke at BB and B′B′.				

Size of pipe	24″
Average inside diameter	23.95″
Average length	41¼″
Average thickness	.87″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 18,200 lbs.

REMARKS.
Load applied along whole length of specimen.

No. 16. TEST ON CAST IRON WATER PIPE.

March 29, 1897.

	THICKNESS.			INSIDE DIAMETER.			LENGTH.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	.93	.87				AA	40¼″
B	.88	.84	AA′	23:83	23.91	BB	40¼″
A′.	.92	.91				A′A′	40¼″
B′.	.94	.88	BB′	23.86	23.97	B′B′	40¼″

DEFLECTION MEASUREMENTS.

LOADS.	END No. 1.		END No. 2.		AVERAGE DIFFERENCE.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	24.46	24.66	24.47	24.66	. . . . . .	. . . .
5,000	24.43	24.70	24.41	24.71	—.045	.045
10,000	24.40	24.73	24.37	24.76	—.035	.040
15,000	24.34	24.77	24.29	24.83	—.070	.055
20,000	24.29	24.80	24.25	24.88	—.045	.040
33,600	Maximum load.	Broke on AA, whole length.				
28,600		Broke on A′A′.				
20,700		Broke on B′B′ and BB.				

Size of pipe . . . . 24″
Average inside diameter . . . . . . 23.89″
Average length . . . . 40¼″
Average thickness . . . . .90″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 19,200 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 17. TEST ON CAST IRON WATER PIPE.

March 30, 1897.

	THICKNESS.			INSIDE DIAMETER.			LENGTH.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	1.10	1.13				AA	34½″
B	1.20	1.16	AA′	30.03	30.02	BB	34½″
A′.	1.13	1.15				A′A′	34½″
B′.	1.16	1.17	BB′	29.31	30.00	B′B′	34½″

DEFLECTION MEASUREMENTS.

LOADS.	END No. 1.		END No. 2.		AVERAGE DIFFERENCE.	
	AA′.	BB′.	AA′.	BB′.	AA′.	BB′.
0	30.97	30.38	30.45	30.89	. . . . . .	. . . .
5,000	30.93	30.41	30.38	30.94	—.055	.040
10,000	30.87	30.47	30.31	30.99	—.065	.055
15,000	30.80	30.52	30.26	31.06	—.060	.060
20,000	30.75	30.58	30.17	31.13	—.070	.065
36,300	Maximum load.	Broke at AA, whole length.				
33,900		Broke at A′A′.				
27,400		Broke at BB.				

Size of pipe . . . . 30″
Average inside diameter . . . . . . 29.84″
Average length . . . . 34½″
Average thickness . . . . 1.15″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 18,700 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 28. TEST ON CAST IRON WATER PIPE.

April 15, 1897.

	Thickness.		Inside Diameter.			Length.
	End No. 1.		End No. 1.	End No. 2.		
A	1.37				AA	25⅛"
B	1.43	AA'	48.08	48.04	BB	25⅛"
C	1.40				CC	25 "
D	1.48	BB'	47.86	47.77	DD	25 "
A'	1.52				A'A'	24⅞"
B'	1.50	CC'	48.02	47.91	B'B'	25 "
C'	1.52				C'C'	24⅞"
D'	1.45	DD'	47.91	47.97	D'D'	25 "

Deflection Measurements.

Loads.	End No. 1.				End No. 2.				Average Difference.			
	AA'.	BB'.	CC'.	DD'.	AA'.	BB'.	CC'.	DD'.	AA'.	BB'.	CC'.	DD'.
0	48.26	48.15	48.26	48.10	48.37	48.07	48.13	48.20	......	....	....	....
5,000	48.11	48.29	48.27	48.11	48.21	48.20	48.13	48.21	—.160	.135	.005	.010
10,000	47.94	48.47	48.30	48.10	48 03	48.39	48.16	48.21	—.175	.185	.030	—.005
15,000	47.64	48.64	48.33	48.11	47.86	48.55	48.16	48.21	—.235	.165	.015	.005
25,800	Maximum load. Broke at AA, whole length.											
22,800	Broke at A'A' and B'B'.											

Size of pipe	48"
Average inside diameter	47.95"
Average length	25"
Average thickness	1.46"

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 17,900 lbs.

REMARKS.

Spigot end.
Lip on End No. 2 about ¾" wide and 1⅛" thick.
Load applied on space of 15" along center of length of specimen.

No. 29. TEST ON CAST IRON WATER PIPE.

April 17, 1897.

	Thickness.			Inside Diameter.			Length.
	End No. 1.	End No. 2.		End No. 1.	End No. 2.		
A	1.02	1.04				AA	34 "
B	1.05	1.12	AA'	36.05	36.00	BB	33⅞"
A'	1.09	1.07				A'A'	34 "
B'	1.09	1.10	BB'	36.08	36.03	B'B'	34 "

Deflection Measurements.

Loads.	End No. 1.		End No. 2.		Average Difference.	
	AA'.	BB'.	AA'.	BB'.	AA'.	BB'.
0	36.31	36.25	36.22	36.25	......	....
5,000	36.22	36.36	36.13	36.40	—.090	.130
10,000	36.10	36.43	35.97	36.50	—.130	.085
15,000	35.99	36.54	35.85	36.64	—.115	.125
20,000	35.84	36.64	35.72	36.80	—.140	.130
24,200	Maximum load. Broke on AA, whole length.					
18,600	Broke on A'A', whole length.					
16,300	Broke on BB, whole length.					
8,300	Broke on B'B', whole length.					

Size of pipe	36"
Average inside diameter	36.05"
Average length	34"
Average thickness	1.07"

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 17,300 lbs.

REMARKS.

Load applied along whole length of specimen.

No. 30. TEST ON CAST IRON WATER PIPE.

April 22, 1897.

	THICKNESS.		INSIDE DIAMETER.			LENGTH.
	End No. 1.		End No. 1.	End No. 2.		
A	1.46				AA	32¼"
B	1.46	AA'	48.14	48.14	BB	32¼"
C	1.47				CC	32 "
D	1.37	BB'	47.81	48.06	DD	32⅛"
A'	1.34				AA'	32¼"
B'	1.45	CC'	48.02	48.14	BB'	32¼"
C'	1.41				CC'	32¼"
D'	1.47	DD'	47.83	48.02	DD'	32⅜"

DEFLECTION MEASUREMENTS.

LOADS.	END NO. 1.				END NO. 2.				AVERAGE DIFFERENCE.			
	AA'.	BB'.	CC'.	DD'.	AA'.	BB'.	CC'.	DD'.	AA'.	BB'.	CC'.	DD'.
(1) 0	48.44	48.22	.....	.....	48 52	48.02	.....	.....	......	....	....	....
(2) 0	48.41	48.28	48.38	48 28	48.48	48.07	48.24	48.22	—.035	.055	....	....
5,000	48.31	48.36	48.37	48.28	48.33	48.20	48.25	48 24	—.125	.105	.000	.010
10,000	48.19	48.47	48.38	48.28	48.20	48.31	48.24	48 25	—.125	.110	.000	.005
15,000	48.04	48.57	48.38	48.27	48.06	48.43	48.24	48.24	—.145	.110	.000	—.010
32,300	Maximum load. Broke on AA.											
27,900	Broke on CC and C'C'. (Break at C'C 'about 6" way from marks, toward AA.)											

Size of pipe	48"	Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 18,200 lbs.
Average inside diameter	48.02"	
Average length	32¼"	
Average thickness	1.43"	

REMARKS.

Spigot end.

Lip on End No. 2 about 1" wide and 1¾" thick.

Load applied along whole length of specimen.

(1) Pipe resting on B'B'.

(2) Pipe suspended from BB.

No. 31. TEST ON CAST IRON WATER PIPE.

April 27, 1897.

	THICKNESS.		INSIDE DIAMETER.			LENGTH.
	End No. 1.		End No. 1.	End No. 2.		
A	1.28				AA	33⅞″
B	1.22	AA′	47.84	47.95	BB	34″
D	1.20				CC	34″
A′	1.13	BB′	47.78	48.05	DD	34″
B′	1.33				AA′	34″
D′	1.34	CC′	47.83	47.97	BB′	33⅞″
					CC′	34⅛″
		DD′	47.84	47.97	DD′	33⅞″

DEFLECTION MEASUREMENTS.

LOADS.	END NO. 1.				END NO. 2.				AVERAGE DIFFERENCE.			
	AA′.	BB′.	CC′.	DD′.	AA′.	BB′.	CC′.	DD′.	AA′.	BB′.	CC′.	DD′.
(1) 0	48.19	48.07	48.19	48.09	48.40	48.30	48.33	48.24	......	....	......	....
(2) 0	48.16	48.10	48.18	48.08	48.37	48.36	48.34	48.25	—.030	.045	.000	.000
5,000	47.99	48.24	48.18	48.08	48.25	48.50	48.35	48.24	—.145	.140	—.005	.005
10,000	47.82	48.40	48.18	48.08	48.07	48.64	48.36	48.24	—.175	.150	.000	.005
15,000	47.60	48.57	48.18	48.07	48.85	48.81	48.37	48.27	—.220	.170	.000	.005
24,500	Maximum load. Broke on A′A′ through whole length.											
20,300	Broke on AA.											

Size of pipe	48″
Average inside diameter	47.90″
Average length	34″
Average thickness	1.25″

Maximum outside fiber stress calculated from maximum load, assuming each half of pipe as a beam fixed at the ends . . . . 17,000 lbs.

REMARKS.

Spigot end.

Lip on End No. 2 about 1″ wide and 1⅜″ thick.

Load applied along whole length of specimen.

(1) Resting on B′B′.

(2) Suspended from BB.

SUMMARY OF TRANSVERSE TESTS ON BARS CUT FROM CAST IRON WATER PIPE.

No. of specimen.	Width.	Depth.	Length of span.	Maximum load.	Deflection at maximum load.	Modulus of rupture.
	Ins.	Ins.	Ins.	Lbs.	Ins.	Lbs. per sq. in.
1	1.99	.50	20	570	.370	34,400
1	2.00	.50	20	635	.443	38,100
2	2.00	.48	20	625	.440	40,700
2	1.99	.50	20	655	.518	39,500
3	2.01	.57	20	720	.345	33,100
3	1.99	.56	20	855	.470	40,500
4	2.02	1.08	24	2,035	.305	31,100
5	2.02	.56	20	700	.520	33,100
5	1.99	.51	20	710	.503	41,200
6	2.01	.73	24	1,170	.594	39,300
7	2.00	.62	20	975	.538	38,100
8	2.00	.79	24	1,315	538	37,900
8	2.00	.79	20	1,665	.420	39,900
9	2.01	.71	24	1,110	.610	39,400
9	2.01	.71	20	1,115	.395	33,000
10	2.01	.74	24	1,350	.680	44,200
10	2.00	.73	20	1,510	.485	42,500
11	2.01	.76	24	1,205	.580	37,400
11	2.00	.73	20	1,250	.360	35,200
12	2.01	.90	24	1,352	.340	29,900
12	2.00	.87	20	1,655	.270	32,800
13	2.02	.71	24	1,455	.515	51,400
13	2.00	.74	20	1,650	.431	45,200
14	2.01	.89	24	1,645	.447	37,200
14	2.00	.86	20	1,830	.296	37,100
15	2.00	.77	24	1,275	.450	38,700
15	2.00	.81	20	1,810	.348	41,400
16	2.02	.91	24	1,644	.442	37,500
16	2.00	.88	20	1,785	.305	34,600
17	2.01	1.11	24	2,272	.395	33,000
17	2.00	1.13	20	2,745	.285	32,200
18	2.01	.56	20	770	.619	36,600
19	2.01	.61	20	930	....	37,300
20	2.00	.50	20	645	.460	38,700
21	2 00	.59	20	880	.540	37,900
22	2.01	.51	20	735	.640	42,200
23	2.01	.71	20	1,240	.560	36,700
24	2.00	.53	20	725	.482	38,700
25	2.01	.64	20	1,020	.549	37,200
26	2.01	.50	20	595	.670	35,500
26	2 00	.46	20	560	.783	39,700
27	2.02	.56	20	600	.360	28,400
27	2.02	.55	20	660	.410	32,400
28	2.00	1.41	24	3,685	.342	33,400
29	2.01	1.02	24	1,820	.395	31,300
29	2.00	.96	20	2,235	.266	36,400
30	2.03	1.37	24	3,445	.308	32,600
31	2.00	1.24	24	2,492	.244	29,200
31	2.00	1.22	20	3,215	.205	32,400

NOTE. — These bars were cut from the broken specimens of the water pipe, the numbers indicating the pipes from which the samples were cut.

INDEX TO THE RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES. PARTS I TO VI.[1]

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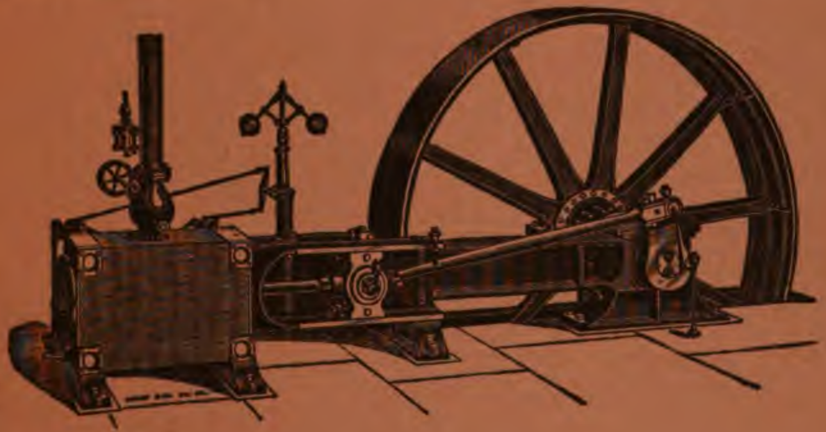
[1] Published in TECHNOLOGY QUARTERLY, Vols. VII to IX (1894 to 1896). The Roman numerals in the index refer to the volume of the QUARTERLY. The numerals in parentheses indicate the part of the *Tests*.



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·TECHNOLOGY· ·QUARTERLY· ·AND·PROCEEDINGS·OF·THE· ·SOCIETY OF ARTS·

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EDWARD·T·HAPGOOD·ARCH'T·
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FIG. I. ACTUN CEH, BENADO. (*Cave of the Deer.*)

In the Sierra de Yucatan, about two and a half leagues westward from Opichen. The immense underground room, reached after a long clamber in the darkness, is lit from above through a skylight in the middle of its ceiling. The roots of alamo trees on the right hang downward from the brink of this luminous chasm to the cave floor, from which remarkable stalagmitic forms, tinted by contact of light and air, rise on all sides. Several of the prominent surfaces have been inscribed by the ancient cave visitors with dots and circles suggesting the human eyes, nose, and mouth, and the outlines of animals resembling deer.

TECHNOLOGY QUARTERLY

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PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. X. DECEMBER, 1897. NO. 4.

CAVE HUNTING IN YUCATAN.

BY HENRY C. MERCER.

Read December 10, 1896.

INTRODUCTION.

CAVE HUNTING EXPLAINED.

Two years ago the Corwith expedition of the University of Pennsylvania (under the kind auspices of Dr. S. Weir Mitchell, and named after its generous donor, Mr. John W. Corwith, of Chicago) set out at rather short notice to open, it seemed, a new field of archæological research in Yucatan. We were going to hunt in caves for evidence of man's antiquity. We asked how long man had inhabited Yucatan, and under what circumstances he had first arrived there. Not that the question had not been asked before by Stephens, Waldeck, Charnay, and other explorers, who had speculated upon the age of the ruins of Central America; but we thought that we were possessed of a way of getting at the question that was quicker, surer, and more conclusive than theirs. We were going to test the antiquity of the man that built the wonderful ruins, and gauge his original state of culture, not by the ruins themselves, but by the traces of his presence left by him in caves; and we were the more confident of success from the fact that the caves, abundant as they were in the region, had never before been searched. We were the first upon the field — the first to attempt to translate their hidden contents.

But why search caves? Why go under ground? Why leave the daylight and all the beauty and wonder of the ruins to delve in damp, dark holes, where at most we proposed to find a few broken pieces of pottery, a few fragments of bone or chips of flint upon which the visitor at a museum might scarcely bestow a glance.

On the answer to this question hangs the whole justification of our attempt, and that answer is, that science has shown that if you want to get to the bottom, to the beginning of the human story, you must hunt in a cave. Science has shown that most if not all primitive peoples, when confronted by caves which were accessible, light and dry, at some time or other entered them. When they did it has appeared that they built fires on their floors and scattered the bones of cooked animals near by, until caked deposits of rubbish were trodden down upon the foothold, and until these, when interbedded with bands of loam or leaves or stalagmite, proving intervals of time when the cave was vacant, presented us with a series of epoch-denoting layers resting upon the cave floor, one upon another, the oldest on the bottom and the latest on the top. Science has thus shown that before artificial houses were built, man entered these natural houses prepared for him by an ancient geological process before his coming, and outlasting his day, and that there, where the rock walls and the limit of light and darkness compelled all cave visitors to inhabit the same area, the whole problem of sequence, of who came first and who came last, layer upon layer was buried at one spot. For these reasons a great number of caves were excavated in England, Belgium, France, and Germany, and a large amount of evidence collected, which over and over again repeated the same story.

Where does the word prehistoric gain its significance? What signifies this classification in ages and epochs of man's culture in the last fifty years? What justifies us in saying that during a series of millenniums before Herodotus and Pliny, before the dawn of history, man had bronze before he had iron; that older than bronze was po ished stone; and that older than polished stone was chipped sto that with bronze and polished stone man had domestic animal at with chipped stone, none; that during the bronze and polished one time animals were recent, while during the older chipped ston och they were of species now extinct? Let it be said again, in er to these questions, that nothing has so well established us in this new knowledge, now not over fifty years old, as the investigation of layers in caves.

No doubt that these cave layers are often missing. No doubt that they are often disturbed, and that there is often much confusion in the record; but as far as Europe is concerned, that man was present and left his footprints in available caves, there can be no doubt. From the man of history to the man with bronze, from the man with bronze to the man with stone, from the recent man to the fossil man, as far as Europe is concerned, all have left their traces in caverns and rock shelters. Now, if science has shown this in Europe, what shall it show for America? When we come to look shall we find that the same rule of superposed epoch-denoting culture layers holds good here? Can we dig down into the subterranean floors and find fossil man here as we found him there? These are questions which I began to ask four years ago, and am still asking, and all that I have yet to present is a narrative of how, in one way or another, I have found the evidence in American caves scanty and shallow, and of how up to date I have failed to find fossil man.

What if we continue to fail to find him? What if we find that he does not exist anywhere in the caves of America? What if we go down the Ohio and Kanawha and Delaware and Susquehanna, as I have done for the last three years, preferring the great waterways and passes where savages would have crossed the Appalachian barrier from east to west, or west to east, and find that this earlier fossil savage, who should have been a contemporary of the extinct animals, is always missing? What if as against all the culture layers of Europe we here find only one — always find the Indian and nothing but the Indian, represented by a characteristic rubbish band composed of familiar arrowheads, potsherds, and bone needles on the floors of all these caves; and what if beneath this in the ancient red or yellow cave earth we dig again and again to the mother rock, to find sometimes the bones of bats or rabbits, or the remains of snails, sometimes the vertebræ of the great sloth, the teeth of the tapir, or the jaws of the mylodon or peccary, but never a trace of humanity?

Such is the kind of evidence thus far gleaned by us from the American caves; but before trying to draw a conclusion from it, it remains to be asked, have we gone far enough? Have we searched enough caves to warrant us banishing fossil man from the eastern region or setting a geological limit to human existence in the New World? Have we investigated regions where we might expect to find man older than elsewhere? And our expedition to Yucatan was a reply to this by pushing the research into a district where it seemed that man should have been old if he was old anywhere on the continent.

YUCATAN PROMISES TO SOLVE THE AMERICAN PROBLEM.

Judged by the test of written language, the old inhabitants of Yucatan might reasonably be placed at the head of all the people found by Columbus in the New World. The Peruvians had *quipus*, tally-knots on thongs or strings, by which something previously learned by heart was suggested to the expert reader. The Mexicans had picture writings more or less symbolic. But the Mayas whom the Spaniards found in Yucatan used hieroglyphics where a symbol comes to stand for the object, and the mind prepares itself to invent an alphabet. The Peruvians were master masons in the massiveness of long and high walls built of immense hewn blocks. The Mexicans were lofty mound builders, and the people of the Ohio valley constructors of such great and elaborate earthworks as you see at Marietta, or at that poetically beautiful fair ground at Newark; but the carved palaces of the Mayas, overloaded with mysterious symbolism whose ruins still astonish the traveler in the forest of Yucatan, exceeded everything. We had a notion of a sort of civilization older than that of Mexico buried away in the wilderness, of something that even the Indians had themselves forgotten when the Spaniards came, of something more ancient, more elaborate, more marvelous in Yucatan than anywhere else from Behring Straits to Patagonia; and when we learned from Professor Heilprin that in the very midst of all these awe-inspiring ruins described by Stephens and Waldeck, by Charnay and Maler, there were abundant dry and spacious caverns which none of these travelers had explored, it seemed as if we had the question of man's antiquity in America presented to us in a nutshell. There where man had reached the highe point of semi-civilization or barbarism in the new hemisphere seemed as if all the doubts as to his antiquity could once and f be set at rest. If he was old anywhere he was old there. ne American problem could be settled anywhere it could be se in Yucatan.

THE AMERICAN PROBLEM.

But what is the American problem, and why settle it? Has it not been settled before? Do we not know how old the Indians are? Have we not the Calaveras skull and pestles and mortars excavated from the bottom of gold mines? Have we not the Trenton "turtle backs" chipped by human hands and gathered from a bank of gravel on the Delaware River, which, by the last of the geological time estimates, should be about 32,000 years old? Dr. Koch's spear-heads, with mastodon remains, chipped blades from the beds of fossil lakes, and a dozen other evidences of man's great antiquity — do they not prove that long before the Indian as we know him, we may look back into the geological past and behold humanity here as in Europe, a contemporary of the mammoth and the mastodon, the saber-toothed tiger, and the fossil horse? Let it be answered that in spite of all thus far presented on the subject, we are still in doubt if not darkness. Let him who supposes that all these things described and recapitulated in the introductions of recent text-books and histories are proved and settled, try to investigate them for himself. When he does he finds that what he had regarded as well-fixed facts fade away like stories of ghosts and haunted houses at near approach. He learns that while in Europe it is an easy matter for you or me to step upon a railway train and go to any one of a score of sites where human remains can be found at short notice with the bones of extinct animals, here, on the other hand, we may assert that no explorer will venture to lead us to-morrow or next week by a journey long or short (which some of us would willingly take) to any point whatsoever east of the Mississippi, where he can guarantee us a sight of fossil man or of one of his implements in place. As far as America is concerned, *homo fossilis* is desperately hard to find.

This, then, is the problem of man's antiquity in America; we do not know how long man was here. The red man was found here, but we have not yet accounted for him. Let alone the question of the Indian's predecessor if he had one, we do not know where the Indian came from. We cannot say whether his development of language, of architecture, and varying customs, whether his dissemination of maize, his apparent domestication of the dog and the llama, whether all this is an affair, geologically speaking, of modern times, or of a longer epoch; of the time represented by the forest loam under our feet that grows western wheat without manure, of the present existing plants and animals, and of the outlines of the country as we now know them, or of a time denoted by a race of animals that is extinct and measured, according to Spencer's late work at Niagara Falls, by a lapse of 32,000 years. This is the question at the bottom of American archæology. This is the question that we went to Yucatan to settle, and to settle by means of hunting in caves.

Marvelous as were the ruins, interesting as were the Indians themselves, the descendants of the builders of the ruins, we turned away from them to dig under ground, for there we ventured to believe that the truth might be demonstrated for the first time. Somewhere, very deep in the cave earth under the crusts of refuse left by the builders of Uxmal and Labna, we must find the trace of fossil man if he had existed in the region. Well might the sites of the known ruins excavated to their full depth fail to reveal his presence, but here, if his footsteps had ever trod the peninsula, he could not escape us.

Such, then, was the promised glimpse of a new knowledge hidden in a dark chamber of which we had the key, that thrilled us with excitement as we set sail for Yucatan. And this is the only consideration, perhaps, that warrants me in coming here to describe our journey as a thing at all memorable, or different from the ordinary experience of travelers who visit the mysterious and little-known land of which I shall speak.

THE PEOPLE OF YUCATAN.

So hurried had been our packing up and departure that we had hardly had time to imagine the kind of people and country that we were to see. We knew that there was a semi-tropical forest, and we imagined orchids and birds of gay plumage. We knew of the marvelous ruins hidden in thickets, where, as in the fairy tale of the "Sleeping Beauty," you cut passages with axes to see deserted palaces that lie concealed only a few yards away. We had been warned against snakes; and to wade through the jungle, as we imagined it, we had taken leather leggins made nearly waist high, and I was prepared to invent better ones and cooler, of fine wire netting, that I thought seriously of having patented. We had heard stories of treachery, and that it would be unsafe to wander away alone with Indians. Hence pistols

FIG. 2. CAVE OF LOLTUN. (*Rock of Flowers.*)

Probably the most beautiful cavern in Yucatan. Situated in a forest solitude near the hacienda of Tabi. Its several spacious rotundas connected by dark passages are lit from above by skylights fringed with forest. Below colored stalactites a graceful underground vegetation charms the eye, and there, water, ever precious in the parched land, drips from shadowy ceilings into ancient dishes of stone. In the charcoal-blackened floors the sought-for proof of human presence was found, which, it is believed, has thrown for the first time the light of reasonable surety upon the antiquity and culture of the ancient peoples of Yucatan; setting limits to future speculation, and preparing the way for a just interpretation of the grotesque ruins, the strange mural decorations, and the hieroglyphs, still unread, that Stephens and Waldeck described to astonished hearers half a century ago. The view is taken in the second or largest rotunda. The Indians are sitting on the edge of trench No. 1, beyond which the dark passage on the right leads to the entrance.

were a necessity. In the rock pools beset with bacteria we were warned not to bathe, much less dared we drink the water, full of fever germs as it was, without previously boiling it. But the first sight of Yucatan suggested another danger against which we had taken precautions in the form of a supply of quinine — namely, fever.

The water rippled by a gentle wind looked green where we lay at anchor one morning, after a seven days' sail from New York, and the shore three miles away seemed yellow and very low. At one spot there were outlines of buildings, and some palm trees raised their graceful fronds through a stratum of vapor. Mr. Armour, whose yacht lay near, and who kindly helped us through the custom house, came aboard and warned us against the feverish place, Progresso by name, advising us to lose no time in leaving it for Merida, forty miles inland. His expedition had been confronted with danger and difficulty. Uxmal was certain malaria ; Tuloom was held by hostile Indians who had just murdered the Spanish governor; members of his party had been driven to desperation by wood lice, and their botanist was ill. The prospect looked discouraging; but once ashore, the responsibility of our long list of bags and boxes, the novel and reassuring look of the place and people, drove doubts to the dogs.

And it was these Maya people who first and last attracted us, while, indeed, a great deal depended on them. If they were to be dirty, surly, cheating, avaricious, or treacherous, if they were to refuse us permission to dig into the remains of their ancestors, we were at their mercy. But in all respects we were most agreeably disappointed with them; and in the first place, I think I may say that they gave the impression of being the cleanest people I ever saw, my own countrymen not excepted.

The white muslin that dazzled the eye in the sun seemed always white ; faces, often smooth-shaven in the Spanish fashion, were clean, and hair well brushed and cut. Where the water came from for the ablutions was a mystery, in a land where it was so scarce. But in this respect our cook, Pastor Leal, put us to shame. On sweltering days, after long walks through the woods when we looked and felt like repulsive vagabonds, he in his white muslin jacket was apt to present the appearance of a very elaborate bartender at some very luxurious hostelry, with a rose in his buttonhole.

No stabbing in the back in Yucatan. No muffled figures lurking around corners with *machetes* as in other parts of Mexico and Cuba.

An overseer told me, strange to relate, that when the Indians fought, they fought with their fists. So we put away our pistols as useless things, and when after weeks of experience with open doors, and with our rooms scattered with valuables that were never found missing but once, we were ready to admit the truth of Professor Heilprin's expression, that the only thief he had met in Yucatan had come from Philadelphia.

But how was this to be explained? Who were these people? Why were they so much more attractive and gentle than any one else? Why different from the Cubans or Mexicans? Were they not Spanish with a little Indian blood in their veins? The answer to these questions seemed to lie in the important fact that they were rather Indians with a little Spanish blood in their veins. A very few of the important families were pure Castilians. All the rest were mixed, and the darker they were, it seemed the kindlier, the cleaner, and the more good-natured.

What an important fact to realize, that the Maya people, who built the great ruins of Central America, have not been stamped out of existence like our Eastern Indians. There they are still to be studied, and I will add, liked by any one who goes to Yucatan. Comprising four-fifths of the present population, they still speak one of the most interesting of the languages of ancient America, and the only one that ever was written. Like many a conquered race, they seem to be absorbing their conquerers.

Their kindness smoothed our way everywhere. The Bishop of Yucatan, to whom we had a letter of introduction from Dr. Brinton, presented us to the large landed proprietor, Señor Escalante, and he to Señor Duarte and to the governor. It so happened that a line of great plantations (*haciendas*) lay along the hills in our way, and we were to travel to and from them. Instead of camping in the forest, we were to sleep under their shelter, and when we found what the forest was on the one hand, and the *haciendas* on the other, we thanked our stars.

Not soon shall I forget our first impression of a *hacienda* at Chalcetok. A tram car awaited us at a wild little spot called San Bernardo, and piling our baggage upon it, a single mule whisked us at a run through the evening air. Across broad fields of the hemp cactus called Hennequin (*Agave sisalensis*) we rattled. Then came a smoke stack in the distance, then a village of thatched huts built of mud and

Fig. 3. Meztiza Girl.

wattle, where at each door you saw half-naked children, figures in white dress, against the characteristic outline of the swinging hammock, and at last the court surrounded by graceful buildings and round arches supported on pillars. By these picturesque galleries under the palm trees, white-robed figures came and went. From a chapel near by a bell rang, and we heard the sing-song of children's voices repeating a prayer. Then the overseer received us, and going in, our party of five, Mr. Corwith and myself, with our secretary, assistant, and two cooks, took possession of three large bare rooms, one of which was a kitchen. While the hammocks were being hung on hammock pegs I walked out on the terrace and looked about. Somehow the scene reminded me of Egypt. The walls, the palm trees, the blue scarves in the twilight were oriental, but the forest seemed strange. I saw it beyond upon the hills, and it stretched away into the horizon, surrounding us with mystery, and shutting off the spot from the nineteenth century and the world. Behind the hemp mill there were gardens, beautiful orange groves hanging heavy with fruit, and birds that sang all day. There were large water tanks and channels of masonry where artificial streams flowed as you see them in gardens in the Levant. After the coming of night and by the rise of the moon, we desired but little to go to bed and lose sight of a reality stranger than fiction. Rather might we have sat up all night imagining ourselves in a land of Lotus or some garden of the Arabian Nights.

Tabi was another *hacienda*, and Yokat another even more beautiful, each of which we left with regret, and each of which vied with the other in hospitality. Sometimes villages lay near us, whither, if not too tired, we might walk of an evening to some public entertainment or a *meztiza* dance. In Merida we had been to an opera and seen the "Huguenots," where all the ladies, seated in boxes, considered it their duty to put on their best French dresses and sit through the performance more or less bored to death. What a contrast was the nocturnal scene that confronted us in the open air at Opichen!

Round about us among flickering torches stood little thatched booths where they cooked cocoa in open fires, or made you strange salads and highly seasoned dishes, and where you smoked highly flavored cigars to the echoes of music half Spanish, half Maya, played on fiddles and flageolets. The strains came from a large shed open on the sides and full of dancers. But I must say the dance was a disappointment; that it lacked the action, the spice that I expected. When one of the Meztiza girls so celebrated for attractiveness danced, she danced alone, and to our minds spoiled her appearance by putting on a man's hat. Several times with stiff solemnity her partner circled about her, and then the two separated, she going one way and he the other. I had heard no loud talking in Yucatan, and here, where demonstrative conversation seemed out of fashion, met no exception to the rule. No audience at a temperance lecture could have taken matters more seriously than did these people during the solemn intermissions. But at these times outside the shed the hospitality which we had met with everywhere was clearly shown. We appeared to be guests of the village, and could pay for nothing. Indians that we had never heard of before forced expensive cigars upon us again and again. It was no use to cry "Hold, enough." I went away with my pockets full of costly "puros" done up in lead foil.

In our many wanderings into the woods with the Maya Indians, in our long diggings with them in subterranean depths where we were not rarely at their mercy, we found them faithful, gentle, and kind. Incapable of handling a shovel correctly, they would pile the blades full of earth with their hands, strike absurd blows, and work with the wrong end of the pickaxe. Yet these were laughing matters. They were children always; you could no more scold them than you could beat a delightful puppy who nibbles the corner of a favorite book.

But a dreadful accident that overtook our party at a cave brought us nearer to them, perhaps, than anything else, and I doubt if any civilized people could have behaved with more dignity and refinement when confronted by sudden and tragic death. We were in a deep, well-like rotunda, where for hours we had been at work. Seated on a mossy rock I was writing my notes while the boughs of several trees that grew from the floor through the skylight rustled overhead. In their high tops two barefooted Indians who had followed us were climbing from bough to bough like monkeys, as with their knives they cut green branches for their cattle at home. Throwing these upon the neighboring ledge at the chasm's brink, one of the men stepped across, seized a pile of the twigs and began to tie them into a bundle. He had pulled them together, and kneeling with his head in the leaves was straining with outstretched arms to bring the mass within reach of a string, when, pushing too hard and too far, the brink betrayed him. I heard a great rattle, saw the fluttering boughs, and then the figure in mid-air, dashed in an instant head foremost upon the cruel rocks at my feet. In a few seconds he had ceased breathing, and his comrades, raising him gently, felt his last heart-beats. Till all was over they looked solemnly on. Then one went away to appear in an hour with a band of friends, who, cutting boughs with their knives and tying them into a litter with a blanket stretched across it, laid upon it the body which we had meanwhile lifted from the cavern with a rope. Last of all one of them descended the chasm, and carving a cross upon the tree, scattered earth upon the fatal stains. This done we marched away in solemn procession to reach home at nightfall, when piteous wailings echoed through the village of Yokat, and we learned that the night which followed had witnessed a wake, a *baloria* differing a little from the weird ceremony so familiar in Ireland.

I believe it would be so easy to become fascinated with the ruins of Yucatan and an investigation of its past glories, as to look with too great unfriendliness upon the influence brought to bear by Europeans upon the Indians, and for that reason I cannot agree with Stephens, who continually refers to the present Mayas as a lost, degraded, and ruined race. Our observations, I admit, were superficial, and we made no careful analysis of the people. But when all is summed up, I imagine that, living as they now live, whether rooted by a sort of vassalage upon the plantations, or revolted and run wild in forests, they are better off in the scale of human development than when, at the head of aboriginal American culture, they were yet ignorant of the more useful metals and domestic animals, and stained with the cruelty of horrible human sacrifices. I would rather believe that they have a future, and are working it out by one of the most potent of all means, namely, blood alliance with the conquering race.

THE FOREST OF YUCATAN.

So much for the people; but what of the conditions of travel in Yucatan? The roads, they were abominable. You jolted over bowlders, rock seams, and ledges, at a run in carts with enormously heavy, tired wheels, squirming in swinging boxes on mattresses of vegetable pollen, and tossed like dice in a dice-box. The food? That we carried with us and cooked ourselves. Black beans; rarely meat when a bull was killed; cocoa, red wine from France, and ham from the United States; rice and potatoes, sometimes delicious fruits that we had never tasted before, and oranges. What would we have done without them to quench our thirst after long tramps, when we rolled bags full of them upon the floors of caves where there was no water? But most of the danger and much of the difficulty of exploration in Yucatan are embodied in one fact, and that fact is the existence of the forest. I had expected to see a luxuriant Amazonian tangle, to stumble over the roots of enormous trees festooned with orchids, to feel the damp touch of succulent leaves where serpents lurked and insects swarmed, to wonder at the color of butterflies and parrots. Instead, I saw a stunted, leafless thicket thickly tangled with thorns, not more striking in appearance than some dry swamp overgrown with alder and blackberry bushes in the United States in December. There were no large trees, no patches of grass, no colors; there was no noise of insects and no superabundance of birds. Under foot lay withered leaves, dry, loose stones, and ledges of yellow rock.

In this wilderness the traveler loses his way. Fever attacks him. The explorer, devoured with wood-lice, fails of heart. And where are you going to dig, among the stones, dead leaves and briers? In certain places where the thin, red soil has collected lie ***haciendas*** with fields of hemp, sugar cane, or maize. But elsewhere from Chiapas to Belize, from the Gulf on the north to the Cordil-dil-lieras on the southwest, this tangled, thirsty thicket covers everything. Revolted Indians hiding away in it, and using it as a bulwark against their enemies, hold their own in its depths. I do not believe the rumors of temples and cities still flourishing in it unknown to white men, but I am sure that Maler has found many structures buried in its recesses that escaped Stephens, Waldeck, and Charnay, and that no one ever heard of before, though those known to us, like Uxmal, Labna, and Chichenitza, are wonderful enough.

Not yet, owing to the difficulty of digging in the stones and briers, or of cutting down the thicket, and building scaffolds so as to even see or photograph them, have they been adequately excavated or studied. And there they stand, rapidly vanishing, it must be said, because of their imperfect construction. And because their walls rest on no true arches, because the joints are not bound nor the stones squared, and because the facing is not linked to the heart, they crumble to pieces more rapidly than the ancient buildings of Egypt and Assyria, Rome and Greece.

Some are easy to reach. You might sail from New York and see Uxmal in ten days, but I am half glad that stories of fever and snakes,

FIG. 4. VIEW FROM THE DWARF'S HOUSE AT UXMAL.

heat and thirst, have frightened away the horde of tourists who, rushing in, would rob the region of its unconscious charm. So let the ruins remain in solitude. Let them disappear in silence surrounded by all the mystery of the forest.

At Uxmal these marvelous structures are set on high mounds and platforms that look like natural hills as you catch glimpses of them from the distant sierra. The so-called House of the Dwarf stands upon the highest mound of all, and you climb to it on a stone face by narrow and steep steps, where a fall would be no less sure death than a slip on the sides of the great Pyramid at Gizeh. The wind blew fiercely when we stood there for the first time, and fortunately for us, heavy clouds drifted across the sky, darkening the strange walls below us, that rose out of the thicket. The wilderness stretched away to the hills. As we had seen it often before from the sierra, it had assumed again that day its tint of deceitful blue. It seemed as if there were cool places where rivers flowed, and where the cloud shadows fell upon it, pleasant lawns and high trees. But these mirage-like allurements were the false wiles of the ever-present forest, here as parched, shadeless, and thirsty as ever.

In the tangle of thorns below, all sign of communication between building and building, all traces of smaller dwellings, of aqueducts or roads, seemed to be lost. But who had yet had the strength or courage to search for these things in this most feverish of places, where at one time even the cattle died; where I was told that Indians did not survive two generations? Hard enough was it to penetrate the curtain of briers and mantle of rubbish about the sides and walls of the great buildings, as Charnay and LePlongeon had done, so as even to photograph or study them. The House of Turtles, the Casa-del-Gubernador, the Nunnery; what significance had these names invented by the Spaniard, as we walked through a false arch into an immense courtyard, and saw walls on every side covered with a symbolism in stone that antedated the coming of the European? Monstrous masks, projections like the trunks of elephants, grotesque tongues, great eyes, rows of teeth, rising suns, phallic signs, and above all the great rattlesnake with plumed human head-dress confronted us with a meaning that was lost. It came upon the mind in a sense of something malevolent; something symbolic of horrible and bloody themes of sacrifice; of torture and awful ceremony in the native manuscripts. It seemed to rise from the forest and haunt the memory of our journey in the wilds. Were we in the nineteenth century? Were we looking at things that had existed, or were we wandering in a land of dreams? In these strange impressions, never known before, we felt the fascination of ancient America so potent to encompass the searcher in the *tierra caliente* and lead him astray. So often had it betrayed him with strange fancies, that counting up the names of well-known explorers who have become disturbed or distressed in this study, which I pray you to excuse me from doing here, the French have invented a phrase of sinister meaning when they say: *Toutes les Americanistes devant fous.* All the students of ancient America go mad.

CAVES.

But what of the caves which had occupied our thoughts continuously from the first? Did we succeed in exploring them, or the chief group of them that lay scattered among and between the ruined cities? Were they what we expected, and did they contain the evidence we sought? In answer to which questions let me say that our first look at the caves brought disappointment. Instead of being what I had expected to find them, they were unlike any caves I had ever seen before. Caves that contain the remains of men or animals in the United States or Europe generally open into the sides of cliffs or escarpments of rock. But these yawned down into the ground like wells, sloping inward like the sides of an ink-bottle. The fact was, there were no cliffs in Yucatan. No rivers had cut across beds of rock, thus laying bare caves in cross section. But erosion had proceeded directly downward till holes opened in the cave ceiling. Sometimes piles of stones had fallen into these skylights, almost reaching their overhanging edge. Often trees grew up to their brink. But you generally had to climb down on rude sapling ladders made by Indians, on trees or by ropes, and so difficult was it to get into many of these caverns, that they would have been ruled out of an explorer's consideration in other countries. Savage peoples preferring more accessible shelters would have avoided them, and so doubtful was it that many of them would contain all or any considerable part of the evidence we sought, that it seemed as though our expedition had already failed; as if, as far as cave hunting was concerned, we had come to Yucatan in vain. And for a time the prospect was discouraging in the extreme, until an overlooked consideration restored the caves to all their importance. It was the consideration embodied in the word *agua*, water, one of the first and last words a traveler hears in Yucatan. Broadly speaking, the peninsula is waterless. A few exceptions confront us in the muddy, stagnant pools called *aguadas*, and a few stony channels on the northeast coast only active in the rainy season. But with these allowed for, there are no streams, springs, or lakes in the region. To get water you must go under ground for it. You must bore wells, or find it in caves where it drops from the roof. The ancient Mayas lived on rain water collected in the rainy seasons, and stored in cemented cisterns which now form one of the most important features of the ruins. But what did they do before the cisterns were built, before they had established themselves in the region and constructed the cities? The important answer to this question is, that the caves supply water, and that since the early immigrants could not bore wells in regions where there were no *aguadas*, they must needs have ransacked the caves for water or perished. And the evidence soon showed that from the time of their first coming they had entered the caves by ladders when necessary, and halted for a while near the refreshing pools or dripping stalactites.

So after all, the whole story of man's life in Yucatan was in our hands and lay buried in the caves. The lowest film of trodden earth, of charcoal, ashes, and pottery, marked the advent of the first comer, the uppermost that of the last, and when once we realized this, our work flourished. But the trouble of it was to get the right cave — a cave where the floor rubbish had not become mixed by sliding, where great blocks had not fallen from the ceiling to obstruct work, where we could dig to the living rock at the bottom without blasting or impossible expense; and at last we found it.

At a wild place in the hills called Oxkintok in the midst of a group of little known ruins, not half a mile from a stone mound that contained a complex series of passages described as a labyrinth, within walking distance of our headquarters at Señor Escalante's *hacienda* of Chalcetok, Mr. Corwith chanced upon a cave, which when we came to examine it promised to answer all our expectations.

Like all the other caves it was entered through an orifice or sky window. But the fallen rocks had so choked the entrance that ingress was easy. And one of the chief desiderata for the exploration of all caves was fulfilled when we found that even then in the midst of the dry season it dripped water, and that ancient stone dishes hollowed from blocks of limestone lay about the floor or stood full of water under the stalactites. More than this, at the base of the skylight which lit the chamber at its farther end, lay a heap of stones which proved to consist largely of dressed blocks, chips, and partly worked water dishes left there by the ancient builders of the ruins, who were thus shown at the first glance to have come to the cave not only to get water, but to get stone. A few small crannies leading away from the spacious room had been walled up by the Indians as blinds for shooting doves. But it was the only room, and its smooth earthen floor presented the only place to dig. As sure as it was that the people of the surrounding ruins had visited this place to get water, so sure was it that proof of their presence in the form of layers of ashes, charcoal, and potsherds, of chips of stone or implements of bone, together with the remains of contemporary animals, lay under foot. No rocks obstructed us, and there was no chance for land sliding or disturbance. Directly in the middle of the chamber in the dim light of the roof window, we had found the place to settle the question of man's antiquity in Yucatan.

It was not light enough where we stood to blow out the candles by whose aid we had come stumbling onward for some distance through the darkness and over loose rocks. The Indians took off their sandals and set down the shovels and pickaxes, and the large round baskets supported by straps across their foreheads. We spread their contents — specimen bags, tape measures, monocular level, India-ink and pens — upon the ground, and then marked with trowels a rectangle to include the area of our trench, about 20 feet long by 4 broad across the middle of the cave floor.

No common curiosity, no desire to unearth beautiful vases, figureines of jade, or ornaments of obsidian, inspired us as the Indians began to dig. All these things lay above ground and around us in the mounds and cisterns, and in the rubbish near the ruins. We were hunting for a few broken potsherds and bones. But they were to tell us more than all the rest. They would answer the unanswered question, how long had man lived in Yucatan? — a question which here in the heart of prehistoric America we proposed to test for the first time, by searching for the earliest footprints of humanity in the earth beneath our feet.

We held the candles downward as the Indians turned up the lumps of earth with the pickaxes, and saw the ground caked thick with potsherds and the bones of the deer. When we had dug a great hole 2 feet deep, we had passed a surface layer of human rubbish which we studied well, to find under it a band of comparatively undisturbed earth. When we had gone 5 feet another subdivision of the rubbish layer was plainly visible, some 15 inches thick, lying still deeper. The discolored earth was full of broken potsherds of various colors and makes, and intermixed with the bones of still existing animals, while in it and below the surface we found no trace of the Spaniard. Very certainly we were working among the leavings of the builders of the ruins, but we soon left the rubbish behind us and dug downward into the unknown. The earth was red and comparatively soft. The pit grew to the depth of 7, 10, and 12 feet. Days passed as we toiled on. At each new digging we clambered down to go over the bottom inch by inch with trowels and candles. We built props against the side so as to scrutinize them in the gloom for traces of layers. The small snail shells and bat bones continued, but the charcoal and ashes had stopped, and with them all traces of man. What would come next?

How shall I describe the intervals when I walked about the cavern as the work went on; while I looked at the colors of the tinted stalactites overhead; while the weird rustling of the banana trees that rose from the cave floor through the skylight, and beat the crusts with their boughs, filled the cave with echoes, or slanting sun gleams fell upon our heap of oranges till they glowed in the twilight like tongues of flame. The fact that we were upon the track of a new knowledge inspired us. If man were to intervene between us and the living rock, he was the predecessor by a long interval of the ruin builder; perhaps a stone chipper ignorant of the art of polishing stone, perhaps an undeveloped or ape-like savage who struggled for existence with the megatherium, the fossil bear, or the formidable saber-toothed tiger of Port Kennedy.

Smeared with clay, weary, full of misgivings of the caving in of the trench or some unexpected obstruction, we toiled on by candlelight; the more thrilled with excitement the deeper we dug, until at last all anxiety ended when the pickaxe clanged on solid rock. We were done. It was over. We had penetrated for the first time this region of discovery to its uttermost limit, and had found, in the thick red interval below the culture layers of the surface, nothing but bats, snails, and rabbits. Here, where the primitive savage must have left his sign if he existed, there was no primitive savage, no trace of humanity. The human evidence began and ended with the layers above. They stood for the builders of the ruins—a people who, judged by the potsherds of the layer, had arrived equipped with the art of making pottery, who had not, therefore, developed their culture in Yucatan, but had brought it with them from somewhere else. They represented an invasion of the peninsula fairly in accord with the Maya annals — something about a thousand or fifteen hundred years old; modern as compared with humanity in Europe, that was all. It had been suspected, but we had presented direct evidence on the subject for the first time.

This, then, was the testimony of the cave at Oxkintok. Let it stand for all the twenty-nine caves explored; since all, one after another, expressed the same fact more or less clearly as they were more or less fit for excavation. For the reasons stated in my book, "The Hill Caves of Yucatan,"[1] we were satisfied; with this proof in our hands the work was done. Defeat would have been to fail to find caves favorable for excavation. But we had found them. We had been eminently successful; and though to make assurance doubly sure we pushed on, and continued to examine caves that always repeated and never contradicted what we had already learned, the work had lost its zest. What remained were glimpses of rare and wondrous beauty that rewarded us at these places; such a sight as we saw at Actun Xpukil (cave of mice), where rotunda after rotunda, lit from above and overgrown with banana groves, opened downward by what seemed subterranean valleys and mountains; as at Xabaka (cave of the coal-black water), where the dark pool lay in the gloom of an immense chamber reached by a chasm overhung with trees and ferns, and yawning from several sunny little recesses haunted by bees; like Xkokikan (the cave of serpents), where Indians told of intertwined masses of snakes writhing at the bottom of a gulf; or like Actun Benado, where the tinted walls of an immense rotunda, lit from above, rose about you like the complex vaultings of a gothic cathedral on whose walls Indians had carved the figures of animals.

But of all the fair sights of Yucatan, fairest of all and last to be forgotten, is beautiful Loltun. Rock of flowers indeed! where, like the

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[1] The Hill Caves of Yucatan; or, A Search for Evidence of Man's Antiquity in the Caverns of Central America. Philadelphia: J. B. Lippincott Co., 1896.

FIG. 5. ACTUN XPUKIL. (*Cave of Mice.*)

Actun Xpukil (*Cave of Mice*) is in the mountains, two miles west of the *hacienda* of Chalcetok, Yucatan, and four miles from the ruined city of Oxkintok; one of the largest and most beautiful caverns in Yucatan, containing fifty-nine stone water-dishes and many relics of the builders of the neighboring ruins. View from the first rotunda into the second rotunda, showing the effect of the skylight upon vegetation underground. Palm trees flourish in the cooler air. Alamo roots reach the cave floor from the brink of the skylight eighty to one hundred feet above.

FIG. 6. SKYLIGHT IN THE WATER CAVE OF OXKINTOK.

The banana trees are growing on a heap of fallen limestone fragments, many of which have been hollowed for water-dishes or mortars, or dressed square for wall building by the makers of the neighboring ruins. No trace of the tools was discovered.

enchanted garden that Aladdin saw, doomed to vanish at an ill-chosen word, groves rustled under ground, and by the quiet light of the sky windows fringed with forest, it seemed always afternoon. A bluish reflection made the air appear like liquid. By the great vaults where cool drops fell, we seemed to be walking under the sea at places where enormous fish, not stranger in shape than the stalagmites, might swim from labyrinths of coral. Here we were neither in the heavens above, or on the earth beneath, but by the waters under the earth; and the airs that drew cool through the underground gardens were one of the delights of Paradise upon those scorching days.

When the cavern had yielded its secret after ten days of toil, as we were about to say farewell to it for the last time, its superhuman beauty came irresistibly upon us. Then the great chasms and galleries leading into an unknown blackness had lost their terror. Then stalagmites, that rose in forms of men and beasts from the floor, seemed to wear gentle smiles. In the pleasant air the birds chirped alluringly from about the skylights, while from under the blue arches seemed to come a rustle of leaves that repeated the whisper — here is rest. A vague regret, a confusion of motives stirred us. We felt the power of an enchantment potent to beguile us, like the lotus eaters, to forget the way home.

We have been told that our expedition was a failure because we did not contrive to bring back a store of vases painted with hieroglyphs, remarkable objects of jade, blades of obsidian, or even manuscripts. Forgive us if we did not return laden with these things, if, in the first place, we did not go to Yucatan to find them. Neither did we go there to find fossil man, but the truth. To defend our work from the charge of failure is to say that we have cited for the first time the evidence of caves to set a limit to the speculations of archæologists in Yucatan; that by a newly applied test of much importance we have fixed a reasonable antiquity for the ruins and the builders of the ruins, and that by proof rather than guesswork we have shown that the culture of the Mayas was not developed in Yucatan, but brought from abroad.

As far as the geological antiquity of the human race is concerned, shall we not infer that Yucatan, that center of archæological interest, has been fairly eliminated from the field of search, and that from our labor it may be concluded, not unjustly, that if you would find fossil man you must look for him elsewhere?

RESULTS OF TESTS MADE IN THE ENGINEERING LABORATORIES.

VIII.

Received May 20, 1897.

APPLIED MECHANICS.

TESTS ON BOLTED JOINTS.

THE fourteen tests on bolted joints given in the following summary were planned with the aim of finding the effect on the efficiency of the joint and on the tensile strength of the net section of plate, of increasing the compression per square inch in front of the rivets.

All the specimens were made from the same sheet of boiler plate of a tensile strength of 68,000 pounds per square inch. The bolts were of machine steel of 96,300 pounds tensile strength per square inch. The holes in the plate were drilled and rimmed, and the bolts were turned so as to be an easy driving fit with a machinist's hammer.

Micrometer readings of the stretch of the joints were taken from both the top and the bottom sides, there being two sets of measuring points on each side.

Details and cuts of the first eight joints were printed in the TECHNOLOGY QUARTERLY, Vol. IX, 1896, pages 171–180 (*Results of Tests, V*). Joints 9 and 10 were made with three bolts, joints 11 and 12 with two bolts, and joints 13 and 14 with one bolt.

Joints Nos. 2, 11, 12, 13, and 14 failed by the shearing of the bolts.

The broken joints are shown by the half-tone cuts, Figures 1–5.

SUMMARY OF TESTS.

Number of joint.	Size of bolts.	Pitch.	Thickness of plate.	Width of joint.	Area of net section. (Sq. ins.)	Maximum load.	Maximum tension on net section. (Lbs. per sq. in.)	Maximum shear on bolts. (Lbs. per sq. in.)	Maximum compression. (Lbs. per sq. in.)	Average thickness of plate in front of bolts at fracture.	Reduction of area. (Net section.)	Efficiency of joint.
1	¾"	2 "	.43"	6.01"	1.62	102,000	63,100	38,500	105,400	.49"	31%	58%
2	¾"	2 "	.43"	6.00"	1.61	101,100	62,600	38,100	104,500	.49"	15%	57%
3	⅞"	2 9/16"	.43"	7.69"	2.18	137,000	62,900	38,000	121,000	.51"	28%	61%
4	⅞"	2 9/16"	.43"	7.70"	2.18	136,000	62,300	37,700	120,500	.52"	30%	60%
5	1 "	3¼"	.44"	9.76"	2.97	179,500	60,400	38,100	136,000	.57"	28%	62%
6	1 "	3¼ "	.44"	9.76"	2.97	180,700	60,800	38,300	136,900	.58"	23%	62%
7	1⅛"	4 "	.45"	12.00"	3.88	238,500	61,500	39,900	158,600	.59"	25%	65%
8	1⅛"	4 "	.45"	12.00"	3.88	225,500	58,100	37,600	148,600	.56"	26%	62%
9	1¼"	4⅞ "	.45"	14.64"	4.90	292,000	59,600	39,700	173,100	.68"	25%	65%
10	1¼"	4⅞ "	.45"	14.64"	4.90	292,000	59,600	39,700	173,100	.66"	22%	65%
11	1⅜"	5⅜ "	.45"	11.55"	3.96	194.000	49,000	32,700	156,700	.68"	6%	55%
12	1⅜"	5⅜ "	.45"	11.55"	3.97	197,700	49,800	33,300	160,800	.68"	7%	56%
13	1⅜"	....	.45"	5.54"	1.87	96,300	51,400	32,400	155,600	.66"	10%	57%
14	1⅜"	....	.44"	5.51"	1.82	96,700	53,200	32,600	159,800	.66"	8%	59%

No. 9. TEST ON BOLTED JOINT. (Figure 1.)

Date, February 25, 1897.

Loads.	North Side.				Mean.	Difference.	South Side.				Mean.	Difference.	Average difference.	Total difference.
	Top.		Bottom.				Top.		Bottom.					
	1	2	1	2			1	2	1	2				
5,000	.1314	.1315	.1287	.1287	.1301		.0532	.0532	.0534	.0532	.0532			
25,000	.1367	.1365	.1327	.1326	.1346	.0045	.0532	.0532	.0526	.0526	.0529	.0003	.0021	.0021
45,000	.1420	.1418	.1382	.1380	.1400	.0054	.0525	.0525	.0521	.0521	.0523	.0006	.0024	.0045
65,000	.1502	.1503	.1470	.1470	.1486	.0086	.0523	.0520	.0520	.0520	.0521	.0002	.0042	.0087
Load dropped off for 21 hours.														
65,000	.0491	.0491	.0487	.0487	.0489			.1604		.1566	.1585			
85,000	.0450	.0450	.0450	.0449	.0450	.0039	.1852	.1852	.1819	.1819	.1835	.0250	.0106	.0193
105,000	.0376	.0376	.0376	.0376	.0375	.0075	.2390	.2390	.2352	.2355	.2372	.0537	.0231	.0424
125,000	.0370	.0370	.0383	.0384	.0377	.0002	.2647	.2645	.2619	.2620	.2633	.0261	.0132	.0556
145,000	.0526	.0524	.0577	.0577	.0551	.0174	.3325	.3324	.3352	.3350	.3338	.0705	.0439	.0995
165,000	.0869	.0869	.0912	.0914	.0891	.0340	.3950	.3950	.3948	.3948	.3949	.0611	.0476	.1471
185,000	.1520	.1522	.1552	.1552	.1539	.0648	.4846	.4845	.4832	.4835	.4840	.0891	.0769	.2240
292,000	Maximum load.													

Size of bolts	1¼"	Maximum shear per sq. in. on bolts	39,700 lbs.
Pitch of bolts	4⅞"	Maximum compression per sq. in. on plate	173,100 lbs.
Thickness of plate	.45"	Average thickness of plate in front of bolts at fracture	.68"
Width of plate	14.64"	Reduction of area net section of plate,	25%
Area net section of plate	4.90 sq. in.	Efficiency of joint	65.2%
Maximum tension per sq. in. on net section of plate	59,600 lbs.		

No. 10. TEST ON BOLTED JOINT. (Figure 2.)

Date, March 1, 1897.

Loads.	North Side.				Mean.	Difference.	South Side.				Mean.	Difference.	Average difference.	Total difference.
	Top.		Bottom.				Top.		Bottom.					
	1	2	1	2			1	2	1	2				
5,000	.0367	.0365	.0415	.0418	.0391		.0336	.0333	.0284	.0282	.0309			
25,000	.0373	.0375	.0395	.0392	.0384	.0007	.0426	.0428	.0344	.0343	.0385	.0076	.0035	
45,000	.0379	.0378	.0395	.0393	.0388	.0004	.0517	.0519	.0421	.0420	.0469	.0084	.0044	.0079
65,000	.0343	.0344	.0355	.0357	.0350	.0038	.0621	.0622	.0525	.0526	.0574	.0105	.0034	.0113
85,000	.0341	.0340	.0358	.0357	.0349	.0001	.0724	.0727	.0634	.0633	.0680	.0106	.0053	.0166
							Load dropped off 17 hours.							
35,000	.0204	.0201	.0277	.0279	.0240		.0824	.0823	.0752	.0753	.0788			
105,000	.0268	.0270	.0349	.0348	.0309	.0069	.0953	.0954	.0888	.0890	.0921	.0133	.0101	.0267
115,000	.0199	.0202	.0277	.0278	.0239	.0070	.1470	.1470	.1404	.1405	.1437	.0516	.0223	.0490
125,000	.0207	.0208	.0285	.0286	.0247	.0008	.1487	.1489	.1422	.1423	.1455	.0018	.0013	.0503
135,000	.0198	.0200	.0277	.0278	.0238	.0009	.1583	.1585	.1522	.1523	.1553	.0098	.0045	.0548
145,000	.0169	.0169	.0247	.0247	.0208	.0030	.1790	.1790	.1728	.1730	.1760	.0207	.0089	.0637
155,000	.0108	.0110	.0191	.0192	.0150	.0058	.2141	.2140	.2081	.2082	.2111	.0351	.0147	.0784
165,000	.0075	.0076	.0158	.0157	.0117	.0033	.2400	.2400	.2340	.2342	.2371	.0260	.0114	.0998
175,000	.0045	.0046	.0131	.0129	.0088	.0029	.2676	.2674	.2625	.2625	.2650	.0279	.0125	.1123
							Load dropped off 3 hours.							
175,000	.0851	.0850	.0943	.0943	.0897		.2922	.2919	.2804	.2803	.2862			
185,000	.0850	.0848	.0943	.0940	.0895	.0002	.3160	.3160	.3047	.3047	.3104	.0242	.0120	.1243
195,000	.0845	.0842	.1040	.1042	.0942	.0047	.3526	.3526	.3425	.3425	.3476	.0372	.0220	.1463
292,000	Maximum load.													

Size of bolts	1¼"	Maximum shear per sq. in. on bolts .	39,700 lbs.
Pitch of bolts	4⅞"	Maximum compression per sq. in. on plate	173,100 lbs.
Thickness of plate	.45"	Average thickness of plate in front of bolts at fracture	.66"
Width of plate	14.64"	Reduction of area net section of plate,	22%
Area net section of plate	4.90 sq. in.	Efficiency of joint	65.2%
Maximum tension per sq. in. on net section of plate	59,600 lbs.		

Fig. 1. Bolted Joint No. 9.

Fig. 2. Bolted Joint No. 10.

No. 11. TEST ON BOLTED JOINT. (Figure 3.)

Date, March 3, 1897.

Loads.	North Side.				Mean.	Difference.	South Side.				Mean.	Difference.	Average difference.	Total difference.
	Top.		Bottom.				Top.		Bottom.					
	1	2	1	2			1	2	1	2				
5,000	.2657	.2655	.2713	.2710	.2684		.0972	.0972	.1021	.1019	.0996			
25,000	.2734	.2736	.2785	.2782	.2759	.0075	.1000	.1000	.1041	.1039	.1020	.0034	.0055	.0055
45,000	.2907	.2904	.2939	.2938	.2922	.0163	.0978	.0976	.1011	.1013	.0995	.0025	.0069	.0124
65,000	.3025	.3028	.3127	.3127	.3077	.0155	.0997	.0797	.1030	.1030	.1014	.0019	.0087	.0211
	Load dropped off for 21 hours.													
65,000	.1090	.1093	.1119	.1119	.1105		.3128	.3128	.3148	.3150	.3138			
85,000	.1435	.1431	.1448	.1449	.1441	.0336	.3191	.3194	.3204	.3203	.3198	.0060	.0198	.0409
105,000	.2173	.2173	.2159	.2162	.2167	.0726	.3657	.3657	.3664	.3665	.3661	.0463	.0595	.1004
125,000	.3325	.3325	.3316	.3316	.3321	.1154	.4633	.4635	.4648	.4646	.4391	.0730	.0942	.1946
145,000	.4876	.4876	.4900	.4900	.4888	.1567	.6050	.6050	.6100	.6100	.6075	.1684	.1626	.3572
194,000	Maximum load.													

Size of bolts	1⅜″	Maximum compression per sq. in. on plate	156,700 lbs.
Pitch of bolts	5⅜″	Average thickness of plate in front of bolts at fracture	.68″
Thickness of plate	.45″	Reduction of area net section of plate,	6%
Width of plate	11.55″	Average width of bolt holes at fracture,	1.46″
Area net section of plate	3.96 sq. in.	Average length of bolt holes at fracture,	2.23″
Maximum tension per sq. in. on net section of plate	49,000 lbs.	Efficiency of joint	55%
Maximum shear per sq. in. on bolts	32,700 lbs.		

No. 12. TEST ON BOLTED JOINT. (Figure 4.)

Date, March 9, 1897.

Loads.	North Side.				Mean.	Difference.	South Side.				Mean.	Difference.	Average difference.	Total difference.
	Top.		Bottom.				Top.		Bottom.					
	1	2	1	2			1	2	1	2				
5,000	.1009	.1010	.1837	.1834	.1422		.1075	.1076	.1719	.1719	.1397			
25,000	.1043	.1040	.1807	.1803	.1423	.0001	.1170	.1172	.1761	.1762	.1466	.0069	.0035	.0035
45,000	.1000	.1000	.1738	.1739	.1369	.0054	.1432	.1432	.1995	.1995	.1713	.0247	.0097	.0132
55,000	.0966	.0968	.1695	.1693	.1331	.0038	.1591	.1589	.2149	.2146	.1869	.0156	.0059	.0191
65,000	.0929	.0926	.1648	.1648	.1288	.0043	.1829	.1827	.2376	.2377	.2102	.0233	.0095	.0286
75,000	.0943	.0942	.1655	.1655	.1299	.0011	.1875	.1875	.2403	.2403	.2139	.0037	.0024	.0310
	Load dropped off for 3 hours.													
75,000	.0922	.0923	.1622	.1620	.1272		.1928	.1924	.2408	.2410	.2167			
85,000	.0935	.0937	.1639	.1640	.1288	.0016	.2148	.2150	.2678	.2674	.2413	.0246	.0131	.0441
95,000	.1020	.1021	.1716	.1718	.1369	.0081	.2470	.2470	.2993	.2989	.2730	.0317	.0199	.0640
105,000	.1295	.1296	.1982	.1986	.1640	.0271	.2883	.2879	.3392	.3390	.3136	.0406	.0339	.0979
115,000	.1790	.1790	.2472	.2469	.2130	.0490	.3437	.3441	.3937	.3935	.3688	.0552	.0521	.1500
125,000	.2363	.2345	.3040	.3027	.2693	.0563	.3995	.3980	.4487	.4480	.4235	.0547	.0555	.2055
197,700	Maximum load.													

Size of bolts	$1\frac{3}{8}$''
Pitch of bolts	$5\frac{3}{4}$''
Thickness of plate	.45''
Width of plate	11.55''
Area net section of plate	3.97 sq. in.
Maximum tension per sq. in. on net section of plate	49,800 lbs.
Maximum shear per sq. in. on bolts .	33,300 lbs.
Maximum compression per sq. in. on plate	160,800 lbs.
Average thickness of plate in front of bolts at fracture	.68''
Reduction of area net section of plate,	7%
Average width of bolt holes at fracture,	1.45''
Average length of bolt holes at fracture,	2.27''
Efficiency of joint	56%

FIG. 3. BOLTED JOINT NO. 11.

FIG. 4. BOLTED JOINT NO. 12.

FIG. 5. BOLTED JOINTS NOS. 13 AND 14.

WROUGHT IRON PIPE COLUMNS.

SUMMARY OF TESTS. MARCH, 1896.

DATE OF TEST.	Nominal size of pipe.	Inside diameter.	Outside diameter.	Diameter of flanges.	Length of inside of flanges.	Gauge length.	Maximum load.	Area of cross section.	Maximum load per sq. in.	Compression modulus of elasticity.	$\frac{l}{\rho}$, or ratio of length to radius of gyration.
	In.	In.	In.	In.	In.	In.	Lbs.	Sq. in.	Lbs.		
March 31, 1896	2	2.06	2.37	7	69[illegible]	51	30,000	1.08	27,800	24,300,000	88.8
March 30, 1896	2	2.04	2.39	7	69[illegible]	51	29,800	1.22	24,500	22,200,000	89.1
March 26, 1896	2½	2.50	2.89	8	93[illegible]	86	34,500	1.65	20,900	25,200,000	98.1
March 27, 1896	2½	2.48	2.88	8	93[illegible]	86	37,000	1.68	22,000	25,900,000	98.4
March 10, 1896	3	3.06	3 44	8[illegible]	93[illegible]	86	45,500	1.94	23,500	27,700,000	81.4
March 12, 1896	3	3.09	3.48	8[illegible]	93[illegible]	86	51,000	2.01	25,300	25,100,000	80.5
March 24, 1866	3½	3.60	4.00	9½	105¼	100.5	55,000	2.39	23,000	25,200,000	78.2
March 25, 1896	3½	3.59	3.99	9½	105[illegible]	100.5	65,000	2.39	27,200	24,600,000	78.5
March 16, 1896	4	4.07	4.53	9½	117$\frac{7}{16}$	100 5	80,000	3.11	25,700	25,800,000	77.1
March 20, 1896	4	4.09	4 50	9½	117$\frac{9}{16}$	100.5	69.000	2.76	25,000	24,900,000	77.3

The above ten columns were tested with ordinary cast iron flange couplings screwed on the ends.

SUMMARY OF TESTS. OCTOBER AND NOVEMBER, 1896.

Date of Test.	Nominal size of pipe.	Inside diameter.	Outside diameter.	Length of column.	Gauge length.	Limits of loads used in calculation of modulus of elasticity.	Compression used in calculation of modulus of elasticity.	Maximum load.	Area of cross section.	Maximum load per sq. in.	Compression modulus of elasticity.	$\frac{l}{\rho}$, or ratio of length to radius of gyration.
	Ins.	Ins.	Ins.	Ft. Ins.	Ins.	Lbs.	Ins.	Lbs.	Sq. Ins.	Lbs.		
Nov. 17, 1896	4	4.06	4.50	8, 0	80	5,000- 55,000	.0565	92,000	2.96	31,100	23,900,000	63.4
Nov. 18, 1896	4	4.13	4.52	8, 0	80	5,000- 45,000	.0520	78,000	2.65	29,400	23,300,000	62.7
Nov. 16, 1896	4	4.07	4.51	10, 0$\frac{3}{16}$	100	5,000- 55,000	.0687	85,000	2.97	28,700	24,500,000	79.1
Nov. 19, 1896	4	4.06	4.50	10, 0	100	5,000- 45,000	.0556	81,700	2.96	27,600	24,300,000	79.2
Nov. 2, 1896	4	4.09	4.50	12, 0	120	5,000- 35,000	.0480	75,000	2.77	27,100	27,100,000	94.7
Nov. 20, 1896	4	4.12	4.48	12, 0	120	5,000- 45,000	.0719	77,000	2.43	31,700	27,500,000	94.6
Nov. 10, 1896	5	5.04	5.52	9, 11$\frac{15}{16}$	100	5,000- 65,000	.0578	118,000	3.98	29,600	26,100,000	54.2
Nov. 11, 1896	5	5.05	5.56	10, 0	100	5,000- 65,000	.0538	122,000	4.25	28,700	26,200,000	63.9
Oct. 21, 1896	5	5.03	5.53	12, 0	100	5,000- 65,000	.0545	115,000	4.15	27,700	26,500,000	77.1
Oct. 26, 1896	5	5.18	5.57	12, 0	120	5,000- 65,000	.0800	103,500	3.29	31,400	27,300,000	75.7
Nov. 25, 1896	5	5.11	5.54	12, 0$\frac{1}{16}$	120	0- 80,000	.1083	112,000	3.60	31,100	24,600,000	76.4
Nov. 4, 1896	5	5.10	5.56	14, 10$\frac{9}{16}$	120	5,000- 45,000	.0437	112,000	3.85	29,100	28,500,000	94.7
Nov. 5, 1896	5	5.10	5.57	14, 11$\frac{7}{8}$	120	5,000- 55,000	.0604	116,000	3.94	29,400	25,200,000	95.3
Nov. 9, 1896	6	6.15	6.63	9, 11$\frac{15}{16}$	100	5,000- 85,000	.0588	143,000	4.82	29,700	28,200,000	53.1
Nov. 12, 1896	6	6.17	6.64	10, 0$\frac{1}{16}$	100	5,000-105,000	.0791	145,000	4.73	30,700	26,700,000	53.2
Oct. 22, 1896	6	6.18	6.63	12, 0	120	5,000- 45.000	.0405	......	4.53	......	26,200,000	63.6
Oct. 23, 1896	6	6.13	6 65	12, 0	120	5,000- 65,000	.0542	145,000	5.22	27,800	25,500,000	63.7
Nov. 25, 1896	6	6.17	6.63	12, 0	120	25,000- 85,000	.0618	142,000	4 63	30,700	25,200,000	63.6
Nov. 6, 1896	6	6.23	6.67	15, 0	120	5,000- 85,000	.0814	145,000	4.46	32,500	26,500,000	78.9
Nov. 7, 1896	6	6.19	6.63	15, 0	120	20,000- 70,000	.0525	132,000	4.43	29,800	25,800,000	79.4

The above twenty columns had the ends turned off square in a lathe, and were supported on cast iron caps.

All the above columns were tested in the same manner as the spruce columns already described in TECHNOLOGY QUARTERLY, Vol. VIII, 1895, pp. 219-247.

TORSION TESTS.

TORSION TESTS ON BURDEN'S BEST WROUGHT IRON, 2″ DIAMETER.

Number of test.	Date, 1896–1897.	Diameter of cross section. (Ins.)	Distance between jaws. (Ins.)	Gauged length. (Ins.)	Elastic limit. (In. lbs.)	Outside fiber stress at elastic limit. (Lbs. per sq. in.)	Maximum twisting moment. (In. lbs.)	Apparent outside fiber stress as calculated from maximum twisting moment. (Lbs. per sq. in.)	Limits of loads for calculating shearing modulus of elasticity. In. lbs.)	Angle of twist for difference of loads used in calculating shearing modulus of elasticity. ° ′ ″	Shearing modulus of elasticity. (Lbs. per sq. in.)	Number of turns between jaws at fracture.	Turns per foot between jaws at fracture.	Time of breaking after passing elastic limit. (Min.)
1	Oct. 23	2.01	63.8	40.0	18,000	11,300	85,050	53,300	3,600–18,000	1, 44, 00	11,300,000	9.50	1.79	30
2	Oct. 28	2.01	59.0	40.0	21,600	13,600	86,400	54,200	3,600–21,600	2, 14, 30	11,500,000	8.62	1.76	..
3	Oct. 29	2.01	53.0	36.0	21,600	13,600	84,510	53,000	3,600–21,600	2, 4, 30	11,200,000	6.87	1.56	..
4	Oct. 30	2.00	58.8	40.0	18,000	11,500	87,480	55,700	3,600–18,000	1, 48, 30	11,600,000	8.40	1.71	44
5	Oct. 31	2.00	65.5	40.0	18,000	11,500	85,410	54,400	3,600–14,400	1, 21, 30	11,600,000	8.52	1.56	..
6	Nov. 16	2.01	60.2	40.0	18,000	11,300	85,590	53,700	3,600–14,400	1, 23, 0	11,200,000	8.82	1.75	48
7	Nov. 18	2.02	58.5	36.0	21,600	13,400	85,140	52,600	3,600–14,400	1, 12, 20	11,300,000	8.05	1.65	39
8	Nov. 19	2.00	57.0	36.0	21,600	13,800	82,650	52,600	3,600–14,400	1, 14, 10	11,500,000	7.31	1.54	35
9	Nov. 20	2.02	57.8	40.0	21,600	13,400	86,580	53,500	3,600–14,400	1, 21, 10	11,200,000	8.54	1.77	..
10	Dec. 1	2.02	59.5	40.0	18,000	11,100	86,040	53,200	3,600–14,400	1, 21, 0	11,200,000	8.61	1.74	40
11	Dec. 3	2.02	60.0	40.0	19,800	12,200	87,840	54,300	3,600–14,400	1, 20, 30	11,300,000	8.93	1.79	40
12	Dec. 5	2.02	60.0	40.0	21,600	13,400	88,200	54,400	3,600–14,400	1, 21, 0	11,200,000	8.48	1.70	42
13	Dec. 8	2.01	53.3	36.0	21,600	13,600	87,480	54,900	3,600–14,400	1, 14, 10	11,300,000	7.85	1.77	35
14	Dec. 10	2.01	59.5	40.0	19,800	12,400	83,970	52,700	3,600–14,400	1, 21, 40	11,400,000	8.01	1.62	..
15	Dec. 11	2.01	59.5	40.0	18,000	11,400	84,780	53,200	3,600–14,400	1, 22, 30	11,200,000	8.32	1.68	40
16	Dec. 15	2.03	61.0	40.0	19,800	12,100	83,520	50,900	3,600–14,400	1, 20, 20	11,100,000	8.98	1.77	..
17	Feb. 26	2.00	63.0	40.0	19,800	12,600	84,050	53,500	3,600–14,400	1, 20, 30	11,700,000	9.24	1.76	41
18	Mar. 2	2.02	60.3	40.0	19,800	12,200	85,950	53,100	3,600–14,400	1, 21, 20	11,200,000	7.94	1.58	45
19	Mar. 3	2.01	60.0	40.0	18,000	11,300	84,600	53,100	3,600–14,400	1, 21, 10	11,400.000	8.62	1.72	..
20	Mar. 4	2.02	61.0	40.0	19,800	12,200	83,520	51,600	3,600–14,400	1, 22, 50	11,000,000	8.50	1.67	..
21	Mar. 5	2.00	60.5	40.0	19,800	12,600	86,040	54,000	3,600–14,400	1, 21, 40	11,600,000	8.80	1.75	..
22	Mar. 8	2.01	51.0	36.0	23,400	14,700	85,680	53,700	3,600–14,400	1, 14, 0	11,300,000	7.35	1.73	33
23	Mar. 15	2.01	36.8	40.0	21,600	13,600	87,480	54,900	3,600–14,400	1, 20, 40	11,500,000	8.66	1 83	38.5
24	Mar. 16	2.01	47.8	30.0	21,600	13,600	85,860	53,900	3,600–14,400	1, 1, 30	11,300,000	7.24	1.82	32
25	Mar. 18	2.01	59.4	42.0	19,800	12,400	85,050	53,300	3,600–14,400	1, 25, 0	11,500,000	8.92	1.80	39
26	Mar. 19	2.01	60.9	42.0	21,600	13,600	86,400	54,200	3,600–14,400	1, 26, 20	11,300,000	8.75	1.73	45
27	Mar. 25	2.00	59.5	40.0	21,600	13,800	86,400	55,000	3,600–14,400	1, 21, 10	11,700,000	9.08	1.83	39
28	Apr. 6	2.01	58.5	40.0	23,100	14,500	85,650	53,700	3,600–14,400	1, 20, 40	11,500,000	8.30	1.70	55
29	Apr. 12	2.00	58.5	40.0	19,800	12,600	84,870	54,200	3,600–14,400	1, 19, 50	11,800,000	7.87	1 61	36
30	Apr. 13	2.01	58.3	40.0	21,600	13,600	87,300	54,800	3,600–14,400	1, 20, 40	11,500,000	9.45	1.94	40
31	Apr. 14	2 01	58.4	40.0	21,600	13,600	86,490	54,200	3,600–14,400	1, 18, 10	11,900,000	8.73	1.80	39
32	Apr. 22	2.01	58.4	40.0	21,600	13,600	87,120	54,600	3,600–14,400	1, 19, 50	11,600,000	8 09	1.67	..
33	Apr. 28	2.00	59.8	40.0	19,800	12,600	84,870	54,000	3,600–14,400	1, 20, 50	11,700,000	8.80	1.77	38

NOTES. — After passing the elastic limit the specimens were all fractured in the following uniform manner: For 5 minutes the slowest speed was used, giving the power-end jaw a rotation at the rate of one turn in about 13.5 minutes; for the next five minutes a medium speed was used at the rate of one turn in about 5.5 minutes; then the specimen was fractured under the fastest speed at the rate of one turn in about 3.5 minutes.

After the completion of the first sixteen experiments the testing machine was lined up and carefully readjusted.

Specimen No. 18 broke at the scale-end jaw; No. 29 broke near the middle of the specimen; and all the remaining specimens broke at the power-end jaw.

TORSION TESTS ON HARD BRASS WIRE.

Number of test.	Date, 1896.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Oct. 23	.081	12.0	8.0	3.5	76,700	.29
2	Oct. 23	.081	12.0	9.2	3.5	88,200	.29
3	Oct. 26	.086	12.0	8.7	3.3	69,700	.27
4	Oct. 29	.081	12.0	8.8	3.3	83,700	.27
5	Nov. 2	.083	10.0	9.2	2.5	82,000	.25
6	Nov. 4	.081	12.0	7.8	3.0	74,800	.25

Note. —This wire was of the same grade as that upon which the tension tests were made. (See page 387.)

TORSION TESTS ON COMPOSITION.

Proportions: Copper, 88%; Zinc, 2%; Tin, 10%. ½″ and ⅝″ bars.

Number of test.	Date, 1897.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Apr. 13	.516	9.0	1207	8.63	44,900	.96
2	Apr. 22	.515	9.5	1204	7.54	44,800	.79
3	Apr. 22	.514	9.5	1099	7.61	41,300	.80
4	Apr. 27	.517	9.5	1097	7.14	40,500	.75
5	Apr. 27	.528	9.5	1015	5.72	35,200	.60
6	Apr. 28	.525	9.5	1067	6.62	37,300	.70
7	Apr. 14	.635	9.5	2095	7.79	41,700	.84
8	Apr. 14	.633	9.5	2230	7.88	44,800	.83
9	Apr. 15	.631	9.5	2083	6.88	42,200	.72
10	Apr. 22	.638	9.5	2353	8.80	46,100	.93
11	Apr. 28	.638	9.4	1906	6.68	37,400	.70
12	Apr. 28	.632	9.4	2173	6.82	43,900	.73

TORSION TESTS ON ¼″ ROLLED REFINED IRON.

Number of test.	Date, 1897.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Mar. 1	.253	12.0	196.8	18.50	61,600	1.54
2	Mar. 3	.256	12.0	194.2	18.31	59,200	1.53
3	Mar. 10	.257	12.0	195.0	16.44	58,400	1.37
4	Mar. 11	.254	12.0	199.7	16.94	61,900	1.41
5	Mar. 24	.255	12.0	191.0	16.31	58,000	1.36
6	Mar. 26	.254	12.0	191.0	12.85	59,400	1.07
7	Mar. 26	.254	12.0	205.0	19.00	63,700	1.58
8	Mar. 29	.253	12.0	200.0	19.95	62,600	1.66
9	Apr. 1	.253	12.0	202.0	18.97	63,400	1.58
10	Apr. 5	.254	10.0	205.0	15.00	63,700	1.50
11	Apr. 6	.253	10.0	205.0	16.75	63,700	1.68
12	Apr. 6	.255	10.0	198.0	17.00	60,800	1.70
13	Apr. 7	.259	12.0	190.0	16.05	55,100	1.34

TORSION TESTS ON ⅜″ ROLLED REFINED IRON.

Number of test.	Date, 1897.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Feb. 25	.375	12.0	605	13.25	58,500	1.10
2	Mar. 4	.373	12.0	622	12.85	60,800	1.07
3	Mar. 5	.373	12.0	639	12.60	62,500	1.05
4	Mar. 10	.373	12.0	590	12.50	57,700	1.04
5	Mar. 11	.375	12.0	614	12.06	59,100	1.01
6	Mar. 15	.372	12.0	592	8.91	58,600	.74
7	Mar. 22	.378	12.0	654	9.09	61,700	.76
8	Mar. 23	.369	12.0	606	11.80	60,900	.98
9	Mar. 24	.374	12.0	600	12.80	58,400	1.07
10	Mar. 26	.373	12.0	639	11.85	62,200	.99
11	Mar. 29	.378	12.0	648	12.03	61,200	1.00
12	Apr. 1	.369	12.0	599	13.37	60,900	1.11
13	Apr. 5	.374	10.0	626	9.50	60,900	.95
14	Apr. 6	.377	10.0	625	8.50	59,500	.85
15	Apr. 6	.380	10.0	615	9.50	57,100	.95

TORSION TESTS ON COMMON IRON WIRE.

Length of specimen between jaws, 12.0 inches.

Number of test.	Date, 1896.	Diameter of cross section. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Nov. 4	.194	113.2	41.0	79,200	3.4
2	Nov. 5	.194	103.9	41.3	72,900	3.4
3	Nov. 6	.193	112.5	42.0	80,000	3.5
4	Nov. 11	.192	112.3	43.5	80,800	3.6
5	Nov. 11	.194	116.7	19.5	81,400	1.6
6	Nov. 12	.193	113.1	46.8	80,100	3.9
7	Nov. 13	.193	121.8	38.5	86,300	3.2
8	Nov. 13	.193	112.1	45.5	79,400	3.8
9	Nov. 16	.193	119.1	48.0	84,400	4.0
10	Nov. 16	.193	116.2	45.5	82,300	3.8
11	Nov. 18	.193	108.0	48.3	76,500	4.0
12	Nov. 18	.192	116.5	42.8	83,800	3.6
13	Nov. 18	.193	107.7	41.8	76,300	3.5
14	Nov. 18	.193	119.0	43.5	84,300	3.6
15	Nov. 18	.193	117.3	46.5	83,100	3.9
16	Nov. 18	.193	112.2	46.5	79,500	3.9

TORSION TESTS ON COMMON IRON WIRE.

Annealed at a dull red heat for 8 hours. Length of specimen between jaws, 12.0″.

Number of test.	Date, 1896.	Diameter of cross section. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Nov. 23	.193	110.6	50.0	78,400	4.2
2	Nov. 25	.193	94.6	47.7	67,000	4.0
3	Nov. 25	.194	95.5	53.9	66,600	4.5
4	Nov. 30	.193	95.4	42.3	67,600	3.5
5	Nov. 30	.193	95.8	47.3	67,900	3.9
6	Dec. 1	.194	99.0	38.8	69,000	3.2
7	Dec. 2	.192	96.0	55.3	69,000	4.6
8	Dec. 4	.194	95.2	42.3	66.400	3.5
9	Dec. 5	.194	98.3	57.8	68,600	4.8
10	Dec. 10	.194	97.5	47.0	68,600	3.9

Note.—This wire was from same coil as that from which the tests at top of page were made.

TORSION TESTS ON ¼″ BESSEMER STEEL WIRE, COPPERED FINISH.

Number of test.	Date, 1896–97.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Nov. 24	.250	12.0	242.6	25.0	79,000	2.0
2	Nov. 30	.250	12.0	252.2	22.8	82,200	1.9
3	Nov. 30	.249	12.0	247.5	27.3	81,700	2.3
4	Dec. 1	.249	12.0	238.5	27.5	78,700	2.3
5	Dec. 2	.250	12.0	248.0	25.3	80,800	2.1
6	Dec. 3	.250	12.0	243.6	18.5	79.400	1.5
7	Dec. 4	.249	12.0	243.0	24.0	80,200	2.0
8	Dec. 5	.250	12.0	243.3	24.3	79,300	2.0
9	Dec. 7	.250	12.0	246.0	25.3	80,200	2.1
10	Dec. 10	.249	12.0	246.7	25.0	81,400	2.1
11	Dec. 15	.250	12.0	244.7	26.0	79,800	2.1
12	Dec. 15	.250	12.0	236.6	21.4	77,100	1.8
13	Apr. 7	.250	12.0	249.0	24.1	81,400	2.0
14	Apr. 12	.249	12.0	248.0	29.7	81,800	2.5
15	Apr. 13	.250	9.0	261.0	20.3	85,300	2.3

TORSION TESTS ON ⅜″ BESSEMER STEEL WIRE, COPPERED FINISH.

Length of specimen between jaws, 12.0 inches.

Number of test.	Date, 1897.	Diameter of cross section. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Feb. 25	.376	836.0	21.53	80,000	1.79
2	Feb. 26	.376	769.0	15.00	73,400	1.25
3	Mar. 1	.377	849.0	20.00	81,000	1.67
4	Mar. 3	.375	765.5	12.88	73,800	1.07
5	Mar. 4	.377	810.0	20.60	77,200	1.72
6	Mar. 4	.375	776.0	16.00	74,800	1.34
7	Mar. 5	.375	835.0	12.30	80,500	1.03
8	Mar. 10	.376	773.0	15 40	74,300	1.28
9	Mar. 11	.375	846 0	18.92	82,000	1.58
10	Mar. 15	.377	809.1	17.58	77,000	1.47
11	Mar. 22	.377	811.0	19.15	77,100	1.60
12	Mar. 23	.376	817.0	6.10	78 500	.51
13	Mar. 24	.377	829.0	19.36	78,800	1.61
14	Mar. 24	.375	803.0	21.71	77,300	1.81
15	Mar. 25	.377	843.0	23.78	80,300	1.98

TORSION TESTS ON ¼″ ANNEALED CAST STEEL.

(Usually known as "Tool Steel.")

Number of test.	Date, 1897.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Feb. 25	.246	12.0	288.9	21.15	98,600	1.76
2	Feb. 26	.246	12.0	277.9	24.60	95,500	2.05
3	Mar. 3	.249	12.0	296.7	19.16	97,600	1.60
4	Mar. 4	.245	12.0	290.5	24 08	100,900	2.01
5	Mar. 5	.248	12.0	271.0	17.56	90,300	1.46
6	Mar. 10	.248	12.0	275.1	17.13	92,300	1.43
7	Mar. 11	.247	12.0	327.7	12.90	111,300	1.08
8	Mar. 11	.249	12.0	299.5	19.75	98,300	1.65
9	Mar. 18	.248	13.4	281.9	23.69	94,400	1.77
10	Mar. 23	.244	12.0	267.0	14.00	93,600	1.17
11	Mar. 24	.246	12.0	290.0	23.33	99,000	1.94
12	Mar. 23	.249	12.0	326.0	11.35	109,700	.95
13	Mar. 26	.248	12.0	292.0	14.37	97,000	1.20
14	Mar. 29	.247	12.0	276.0	18.04	93,700	1.50
15	Apr. 1	.244	12.0	293.0	15.25	102,700	1.27

TORSION TESTS ON STUBBS' STEEL WIRE.

Number of test.	Date, 1896–97.	Diameter of cross section. (Ins.)	Length of specimen between jaws. (Ins.)	Maximum twisting moment. (In. lbs.)	Number of turns between jaws at fracture.	Apparent maximum outside fiber stress. (Lbs. per sq. in.)	Average number of turns per inch.
1	Nov. 24	.1840	6.0	93.2	6.8	72,600	1.1
2	Nov. 30	.1848	6.0	120.0	3.3	96,800	.6
3	Nov. 30	.1839	6.0	106.8	2.8	87,300	.5
4	Dec. 1	.1842	6.0	121.5	7.5	99,000	1.3
5	Dec. 2	.1841	6.0	105.0	7.3	85,600	1.2
6	Dec. 3	.1839	6.0	101.3	6.4	82,800	1.1
7	Dec. 4	.1851	6.0	121.0	3.8	97,000	.6
8	Dec. 5	.1840	6.0	115.7	6.5	94,600	1.1
9	Dec. 7	.1840	6.0	116.8	8.8	95,500	1.5
10	Dec. 7	.1840	6.0	115.1	6.3	94,100	1.1
11	Dec. 10	.1842	6.0	119.9	4.1	97,700	.7
12	Apr. 7	.1852	6.5	113.5	3.6	91,000	.6
13	Apr. 12	.1836	6.0	113.0	3.9	93,000	.7

TENSION TESTS ON REFINED IRON.

Number of test.	Date, 1896–97.	SPECIMEN.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Elastic limit. (Lbs.)
1	Nov. 9	Refined iron.	1.02	.817	10.0	1,000–13,000	.0054	27,200,000	26,000
2	Nov. 10	Refined iron.	1.01	.801	10.0	1,000–13,000	.0054	27,700,000	26,000
3	Nov. 12	Refined iron.	1.01	.801	10.0	1,000–13,000	.0053	28,300,000	24,000
4	Nov. 23	Refined iron.	1.02	.817	10.0	1,000– 9,000	.0037	26,500,000	26,000
5	Nov. 30	Refined iron.	1.01	.801	10.0	1,000–13,000	.0056	26,800,000	24,000
6	Dec. 2	Refined iron.	1.02	.817	10.0	1,000–13,000	.0056	26,200,000	24,000
7	Dec. 7	Refined iron.	1.01	.801	10.0	1,000–13,000	.0053	28,300,000	24,000
8	Feb. 26	Refined iron.	1.02	.817	10.0	1,000–13,000	.0052	28,200,000	......
9	Mar. 1	Refined iron.	1.02	.817	10.0	1,000–13,000	.0054	27,200,000	26,000
10	Apr. 17	Refined iron.	1.01	.801	10.0	1,000– 9,000	.0036	27,700,000	24,000
11	Apr. 28	Refined iron.	1.01	.801	10.0	1,000–13,000	.0058	25,800,000	24,000
12	Oct. 23	Refined iron.	.77	.466	10.0	500– 6,500	.0046	28,000,000	12,000
13	Oct. 24	Refined iron.	.74	.430	10.0	500– 6,500	.0047	29,700,000	12,000
14	Nov. 6	Refined iron.	.74	.430	10.0	500– 6,500	.0047	29,700,000	11,000
15	Nov. 9	Refined iron.	.76	.454	10.0				12,000
16	Nov. 25	Refined iron.	.76	.454	10.0	500– 6,500	.0048	27,600,000	14,000

TENSION TESTS ON REFINED IRON.—*Concluded.*

Number of test.	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. ins.)	Reduction of area. (Per cent.)	Ultimate extension in gauged length. (Ins.)	Ultimate extension in gauged length. (Per cent.)	REMARKS.
1	31,800	41,100	50,300	.679	16.9	1.28	12.8	Broke in upper jaw, outside of gauged length.
2	32,500	37,650	47,000	.636	20.6	.75	7.5	Broke at flaw.
3	30,000	40,400	50,400	.595	25.8	1.74	17.4	Broke at punch marks.
4	31,800	40,560	49,600	.622	23.9	1.74	17.4	Broke at punch marks.
5	30,000	40,220	50,200	.541	32.5	1.05	10.5	
6	29,400	41,230	50,500	.568	30.6	2.12	21.2	Broke at punch marks.
7	30,000	41,190	51,400	.568	29.2	1.81	18.1	Broke at punch marks.
8	......	41,180	50,400	.650	20.4	1.31	13.1	Broke outside of gauged length.
9	31,800	42,000	50,200	.694	15.1	1.28	12.8	
10	30,000	38,550	48,100	.541	32.5	1.27	12.7	Broke outside of gauged length at a flaw.
11	30,000	40,560	50,600	.581	27.5	1.69	16.9	Broke at punch marks.
12	25,800	22,630	48,600	.221	52.6	2.65	26.5	
13	27,000	23,250	53,900	.264	38.6	2.57	25.7	
14	25,600	23,230	54,000	.353	18.0	1.59	15.9	Broke at lower punch marks.
15	26,400	22,470	49,500	.264	41.8	2.62	26.2	
16	30,900	24,280	53,500	.302	33.4	2.41	24.1	

TENSION TESTS ON BESSEMER STEEL WIRE.

Number of test.	Date, 1897.	SPECIMEN.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. ins.)	Reduction of area. (Per cent.)	REMARKS.
1	Mar. 8	Bessemer steel wire.	.1290	.01307	50.00	50–350	.....	30,000,000	...	......	1,013	77,500	.00466	64.4	This wire was of the same grade as that used in the torsion tests on ¼" and ⅜" Bessemer steel wire, coppered finish.
2	Mar. 8	Bessemer steel wire.	.1280	.01287	50.00	50–350	.0383	30,400,000	850	66,100	1,021	79,400	.00568	55.9	
3	Mar. 9	Bessemer steel wire.	.1288	.01303	50.00	50–350	.0373	30,900,000	890	68,300	1,010	77,500	.00503	61.4	
4	Mar. 11	Bessemer steel wire.	.1291	.01309	50.00	50–350	.0382	30,000,000	880	67,200	970	74,100	.00478	63.5	The specimens buckled so badly when the rebound at fracture occurred, that it was not possible to measure the ultimate extension with accuracy. In tests 3, 4, and 5, the extension in 36" was measured as carefully as possible and found to be 1.1, 1.1, and .7 per cent. respectively.
5	Mar. 11	Bessemer steel wire.	.1283	.01293	50.00	50–350	.0394	29,500,000	860	66,500	996	77,000	.00554	57.1	
6	Mar. 25	Bessemer steel wire.	.1283	.01293	50.00	50–350	.0387	30,000,000	900	69,600	1,021	79,000	.00554	57.1	
7	Mar. 29	Bessemer steel wire.	.1289	.01306	50.00	50–350	.0369	31,200,000	910	69,700	1,005	77,000	.00515	60.5	
8	Mar. 29	Bessemer steel wire.	.1281	.01289	50.00	50–350	.0398	29,200,000	920	71,400	1,043	80,900	.00466	63.9	
9	Mar. 31	Bessemer steel wire.	.1283	.01293	50.00	50–350	.0378	30,700,000	850	65,800	1,004	77,700	.00484	62.6	
10	Mar. 30	Bessemer steel wire.	.1286	.01299	50.00	50–350	.0373	31,000,000	890	68,500	1,000	77,000	.00478	63.2	

TENSION TESTS ON BESSEMER STEEL WIRE. (Coppered finish.)

Number of test.	Date, 1896-97.	SPECIMEN.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used for calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. ins.)	Reduction of area of cross section. (Per cent.)	REMARKS.
1	Dec. 2	Bessemer steel wire.	.1048	.00863	50.0	100–300	.0404	28,700,000	700	81,200	853.0	98,900	.00353	59.1	Broke outside of gauged length, at clamp.
2	Dec. 4	Bessemer steel wire.	.1047	.00861	50.0	50–350	.0629	27,700,000	740	86,000	795.0	92,300	.00363	57.8	This wire was of the same grade as that used in the torsion tests on ¼" and ⅜" Bessemer steel wire, coppered finish.
3	Dec. 7	Bessemer steel wire.	.1045	.00858	50.0	50–350	.0617	28,400,000	710	82,600	830.0	96,700	.00553	41.4	
4	Dec. 8	Bessemer steel wire.	.1045	.00858	50.0	50–350	.0617	28,400,000	700	81,600	807.5	94,200	.00385	55.1	
5	Dec. 8	Bessemer steel wire.	.1040	.00849	50.0	50–350	.0612	28,900,000	760	89,500	834.0	98,000	.00374	56.0	Inasmuch as the elastic limit was so near the maximum load and the reduction at the fracture was so short, it was not possible to measure the ultimate extension with accuracy.
6	Feb. 26	Bessemer steel wire.	.1050	.00866	50.0	50–350	.0642	27,000,000	690	79,700	815.0	94,120	.60442	49.0	
7	Mar. 1	Bessemer steel wire.	.1055	.00874	50.0	30–350	.0617	27,800,000	760	86,900	805.0	92,100	.00385	56.0	
8	Mar. 3	Bessemer steel wire.	.1050	.00866	50.0	50–350	.0593	29,200,000	740	85,500	807.0	93,200	.00396	54.3	
9	Mar. 4	Bessemer steel wire.	.1041	.00851	50.0	50–350	.0610	28,900,000	710	83,400	808.0	94,900	.00353	58.6	
10	Mar. 5	Bessemer steel wire.	.1049	.00864	50.0	50–350	.0614	28,300,000	750	86,800	796.0	92,100	.00374	56.7	
11	Mar. 18	Bessemer steel wire.	.1059	.00881	50.0	50–350	.0602	28,300,000	690	78,300	807.0	91,600	.00363	59.0	
12	Mar. 20	Bessemer steel wire.	.1048	.00863	50.0	50–350	.0609	28,600,000	690	80,000	787.0	91,200	.00363	57.9	
13	Mar. 25	Bessemer steel wire.	10.53	.00871	50.0	50–550	.0608	28,300,000	690	79,200	803.0	92,200	.00342	60.7	
14	Apr. 28	Bessemer steel wire.	10.41	.00851	50.0	50–350	.0593	29,700,000	710	83,400	795.0	93,400	.00363	57.3	

TENSION TESTS ON HARD BRASS WIRE.

Number of test.	Date, 1896.	Specimen.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Elastic elongation for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. in.)	Reduction of area of cross sectiot. (Per cent.)	Remarks.
1	Oct. 30	Hard brass wire.	.081	.00515	100 0	38–266	.3638	12,100,000	266	51,500	465.5	90,100	.00204	60.5	The elastic limit was not clearly defined in this kind of wire, hence it could only be roughly estimated from the stretch readings.
2	Oct. 31	Hard brass wire.	.081	.00515	100.0	38–228	.2663	13,800,000	228	44,100	465 5	90,100	.00283	45.3	
3	Nov. 16	Hard brass wire.	.081	.00515	100.0	38–228	.2834	13,000,000	228	44,200	460.0	89,300	.00255	50.5	
4	Nov. 16	Hard brass wire.	.081	.00515	100.0	38–228	.2838	13,000,000	228	44,200	458.5	89,000	.00255	50.5	
5	Nov. 17	Hard brass wire.	.081	.00515	100.0	40–240	.3091	12,600,000	280	54,300	457.0	88,700	.00204	60.4	
6	Nov. 19	Hard brass wire.	.081	.00515	100.0	40–240	.2997	13,000,000	240	46,600	474.5	92,100	.00246	52.2	
7	Nov. 20	Hard brass wire.	.081	.00515	100.0	40–240	.3045	12,800,000	240	46,600	471.0	91,400	.00292	43.3	
8	Nov. 21	Hard brass wire.	.081	.00515	100.0	40–240	.3007	12,900,000	240	46,600	472.0	91,600	.00237	53.9	
9	Nov. 23	Hard brass wire.	.081	.00515	100.0	40–200	.2137	14,500,000	200	38,800	471.5	91,500	.00246	52.2	
10	Nov. 23	Hard brass wire.	.081	.00515	100.0	40–240	.2989	13,000,000	240	46,600	456.0	88,500	.00221	57.2	
11	Nov. 25	Hard brass wire.	.081	00.515	100.0	40–200	.2382	13,000,000	200	38,800	473.0	91,800	.00174	66.3	
12	Nov. 30	Hard brass wire.	.081	.00515	100.0	40–240	.2911	13,300,000	240	46,600	469.0	91,000	.00221	57.2	

TENSION TESTS ON COLD-DRAWN STEEL WIRE, ELECTRICALLY WELDED.

Number of test.	Date, 1897.	Diameter of cross section. (Ins.)	Diameter of fractured section. (Ins.)	Area of original section. (Sq. ins.)	Area of fractured section. (Sq. ins.)	Reduction of area of cross section. (Per cent.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Description of Specimen.	Location of Fracture.
1	Mar. 29	.1197	.071	.01125	.00396	64.8	1,006	89,400	Plain wire.	Near center.
2	Apr. 13	.1198	.077	.01127	.00466	58.7	972	86,230	Plain wire.	Near center.
3	Apr. 18	.1199	.075	.01129	.00442	60.9	956	84,670	Plain wire.	Near center.
4	Apr. 27	.1196	.085	.01124	.00568	49.5	997	88,750	Cross wire electrically welded at right angles.	Outside of weld.
5	Apr. 27	.1197	.075	.01125	.00442	60.7	993	88,240	Cross wire electrically welded at right angles.	Outside of weld.
6	Apr. 27	.1196	.075	.01124	.00442	60.7	993	88,380	Cross wire electrically welded at right angles.	Outside of weld.
7	Apr. 9	.1473	.103	.01704	.00833	51.1	1,792	105,200	Plain wire.	Near center.
8	Apr. 13	.1475	.112	.01709	.00985	42.3	1,900	111,200	Plain wire.	Near center.
9	Apr. 27	.1475	.105	.01709	.00866	49.3	1,875	109,700	Electrically welded butt joint.	Outside of weld.
10	Apr. 27	.1479	.095	.01718	.00709	58.7	1,650	96,040	Electrically welded butt joint.	Outside of weld.
11	Apr. 27	.1477	.111	.01713	.00968	43.8	1,860	108,600	Cross wire electrically welded at right angles.	Outside of weld.
12	Apr. 27	.1476	.108	.01711	.00916	46.5	1,875	109,600	Cross wire electrically welded at right angles.	Outside of weld.
13	Apr. 27	.1480	.094	.01720	.00694	59.7	1,765	102,600	Cross wire electrically welded at right angles.	Outside of weld.
14	Apr. 13	.1061	.073	.00884	.00419	52.7	982	111,100	Plain wire.	Near center.
15	Apr. 17	.1066	....	.00893	......	....	892	99,940	Cross wire electrically welded at right angles.	At weld.
16	Apr. 17	.1063	.069	.00888	.00374	57.9	954	107,500	Cross wire electrically welded at right angles.	Outside of weld.
17	Apr. 17	.1066	....	.00893	......	....	657	73,610	Cross wire electrically welded at right angles.	At weld.
18	Apr. 7	.1063	.052	.00888	.00212	76.1	482	54,300	Plain wire, annealed.	Near center.
19	Apr. 18	.1057	.061	.00878	.00292	66.7	493	56,180	Plain wire, annealed.	Near center.
20	Apr. 17	.1064	.050	.00889	.00196	77.9	486	54,660	Annealed wire with electrically welded cross wire.	Outside of weld.

Notes. — These specimens were welded by a patented process.
None of the specimens except Nos. 15 and 17 broke at the weld, and No. 15 nearly reached its ultimate strength before giving away. The other fractures took place at least 2″ from the weld in each case.
The length of specimen between jaws of testing machine was about 8″.

MISCELLANEOUS TENSION TESTS ON METALS.

·Number of test.	Date, 1896–97.	Specimen.	Diameter of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Gauged length. (Ins.)	Limits of loads used in calculation of modulus of elasticity. (Lbs.)	Average elastic elongation per 1,000 lbs. between limits used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)
1	Mar. 2	Stay bolt iron.	.86	.581	10.0	1,000-15,000	.00058	29,700,000
2	Mar. 3	Stay bolt iron.	.82	.528	10.0	....	......	....
3	Mar. 4	Stay bolt iron.	.74	.430	10.0	1,000-12,000	.00080	29,100,000
4	Mar. 4	Stay bolt iron.	.74	.430	10.0	1,000-11,000	.00079	29,400,000
5	Mar. 5	Stay bolt iron.	1.00	.785	10.0	1,000-22,000	.00044	28,900,000
1	Mar. 9	Open hearth steel.	.87	.595	10.0	1,000-13,000	.00059	28,500,000
2	Mar. 11	Open hearth steel.	.73	.419	10.0	1,000- 9,000	.00080	29,900.000
3	Mar. 16	Open hearth steel.	.72	.407	10.0	1,000- 9,000	.00084	29,200.000
4	Mar. 18	Open hearth steel.	.60	.283	10 0	500- 7,000	.00115	30,800.000
5	Mar. 20	Open hearth steel.	.60	.283	10.0	500- 7,000	.00118	30,000,000
1	Mar. 30	Soft Bessemer steel.	.73	.419	10.0	1,000-12,000	.00081	29,500,000
2	Apr. 2	Soft Bessemer steel.	.86	.581	10.0	1,000-12,000	.00063	27,300,000
3	Apr. 13	Soft Bessemer steel.	.61	.292	10.0	3,000- 7,000	.00123	27,900,000
4	Mar. 22	Soft Bessemer steel.	.73	.419	10.0	1,000- 7,000	.00085	28,100,000
5	Mar. 24	Soft Bessemer steel.	.60	.283	10.0	500- 8,000	.00120	29,500,000
1	Mar. 31	Hull rivet steel.	.74	.431	10.0	1,000-12,000	.00088	26,400,000
2	Apr. 1	Hull rivet steel.	.72	.407	10.0	1,000-13,000	.00087	28,300,000
3	Apr. 7	Hull rivet steel.	.85	.568	10.0	2,000-15,000	.00060	29,400,000
4	Apr. 13	Hull rivet steel.	.85	.568	10.0	2,000-16,000	.00060	29,400,000
1	Oct. 21	Burden best wrought iron.	.76	.454	10.0	500- 6,500	.00073	30,060,000
2	Oct. 22	Burden best wrought iron.	.76	.454	10.0	500- 6,500	.00078	28,140,000
3	Dec. 4	Burden best wrought iron.	.77	.466	10.0	500- 6,500	.00082	26,300,000
4	Dec. 7	Burden best wrought iron.	.76	.454	10.0	500- 6,500	.00073	30,060,000
1	Apr. 27	Composition.	.762	.456	8.00	....	......	....
2	Apr. 27	Composition.	.772	.468	8 00	....	......	....
3	Apr. 27	Composition.	.764	.458	8.00	....	......	....
4	Apr. 27	Composition.	.756	.449	8.00	....	......	....

MISCELLANEOUS TENSION TESTS ON METALS. — *Concluded.*

Number of test.	Elastic limit. (Lbs.)	Elastic limit. (Lbs. per sq. in.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Area of fractured section. (Sq. ins.)	Reduction in area. (Per cent.)	Ultimate extension in gauged length. (Ins.)	Ultimate extension in gauged length. (Per ct.)	REMARKS.
1	15,000	25,800	30,000	51,700	.363	37.5	2.27	22.7	
2	14,000	26,500	26,500	50,200	.273	48.2	2.41	24.1	
3	12,000	27,900	23,100	53,700	.238	44.8	2.47	24.7	
4	11,000	25,600	21,470	49,900	.302	29 8	1.44	14 4	Broke at a flaw.
5	22,000	28,000	39,540	50,300	.417	46.6	2.88	28.8	
1	13,000	21,900	25,730	43,300	.145	75.6	3.59	35.9	
2	9,000	21,500	18,810	44,900	.102	75.7	3.44	34.4	
3	9,000	22,100	18,840	46,300	.105	73.6	3.42	34.2	
4	7,000	24,800	13,230	46.800	.076	73.3	3.27	32.7	
5	7,000	24,800	13,200	46,700	.071	75.0	3.50	35.0	
1	12,000	28,700	23,510	56,200	.132	68.5	2.77	27.7	
2	17,000	29,300	32,940	56,700	.204	64.8	3.03	30.3	
3	9,000	30,800	17,941	61,400	.104	64.4	2.53	25.3	
4	12,000	28,700	23,650	56,500	.126	70.0	3.03	30.3	
5	8,000	28,300	17,830	63,100	.102	64.0	2.67	26.7	
1	12,000	27,900	24,380	56,680	.139	67.8	2.96	29.6	
2	13,000	31,900	24,700	60,700	.139	66.0	3.25	32.5	
3	17,000	30,000	33,180	58,500	.196	65 4	2.92	29.2	
4	16,000	28,200	33,370	58,800	.189	66.8	3.01	30.1	
1	12,000	26,400	22,060	48,600	.212	53.2	2.84	28.4	
2	11,000	24,300	22,230	49,000	.209	55.0	2.75	27.5	
3	12,000	25,800	22,550	48,400	.238	49.0	2.94	29.4	
4	12,000	26,400	22,100	48,700	.221	51.4	2.88	28.8	
1	.....	......	13,340	29,250	.332	27.2	1.75	21.9	Broke at a flaw. These composition specimens were made up as follows: copper, 88%, zinc, 2%, tin, 10%. The same material was tried in the torsion tests.
2	......	......	14,470	30,910	.302	35.5	2.30	28.8	
3	......	......	13,650	29,780	.292	36 2	2.00	25.0	
4	......	......	13,910	30,970	.292	34.9	2.22	27.8	

ROPE TESTS.

This series of tests upon rope had for its object, first, to determine the relative holding power of various forms of knots; and second, to ascertain the average stretch of new rope under the application of a steadily increasing load. The tests of each kind were all made upon specimens taken from one coil. The length of specimen between fastenings was in all cases about 5 feet. The average strength of the rope used in calculating the efficiency of the knots was taken as the average of the breaking loads of a number of spliced specimens which gave away at the center. The knots used are shown by the accompanying cuts (Figures 7 to 12), and the stretches by the curves on the plot (Figure 6).

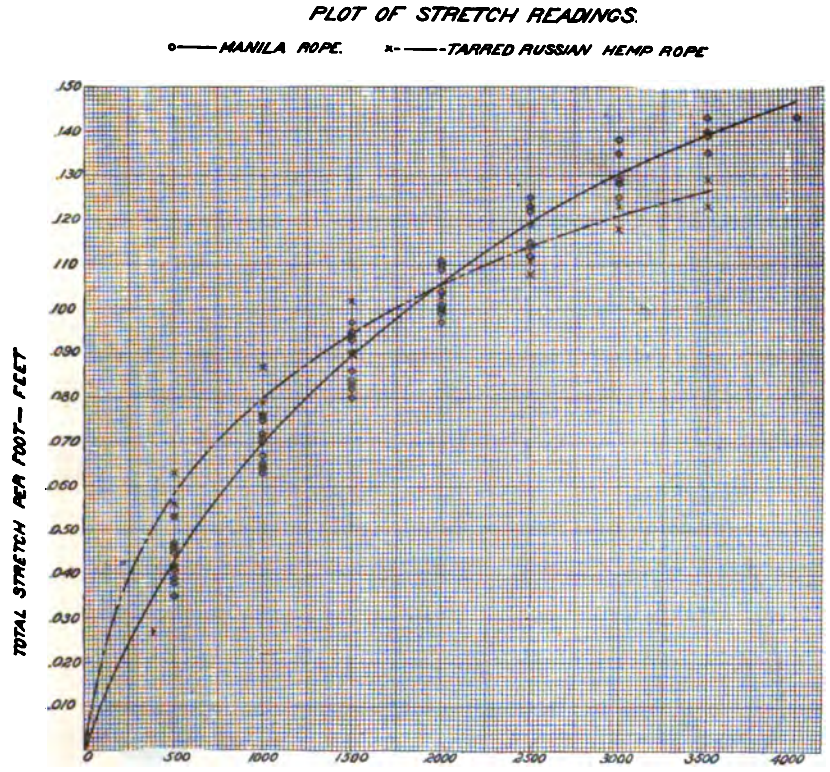

FIG. 6.

FIG. 7.
PLAIN SLIP KNOT.

FIG. 8.
FLEMISH LOOP.

FIG. 9.
TIMBER HITCH.

FIG. 10.
BOWLINE.

FIG. 11.
DOUBLE HALF HITCH.

FIG. 12.
EYE SPLICE.

TENSION TESTS ON 2½″ MANILA ROPE. (Three strands.)

Number of test.	Date, 1896–97.	Number of feet per pound.	Number of turns of one strand per foot.	Condition.	Location of Break.	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot or splice. (Per cent.)	Method of Holding.
1	Nov. 11	5.0	5⅓	Splices wet. Center portion of rope dry.	At center.	5,390	5,420	100	Spliced eyes over iron eyes.
2	Nov. 11	5.0	5⅓		At center.	5,300			
3	Nov. 25	5.0	5⅓		At center.	5,540			
4	Dec. 1	5.0	5⅓		At center.	5,440			
5	Mar. 13	5.6	5⅔	Dry.	At lower knot.	4,430	4,280	79	Held at each end by a timber hitch knot over a 2″ pipe coupling.
6	Mar. 15	5.3	5⅔		At upper knot.	4,270			
7	Mar. 15	5.3	5⅔		At lower knot.	4,150			
8	Mar 17	5.9	5⅓	Dry.	At upper knot.	3,820	3,750	69	Held at each end by a double half hitch knot over a 2″ pipe coupling.
9	Mar. 18	5.5	5⅓		At upper knot.	3,690			
10	Mar. 18	5.5	5⅓		At lower knot.	3,740			
11	Dec. 10	5.1	5	Dry.	At lower knot.	3,560	3,520	65	Held at each end by a slip knot over a 2″ pipe coupling.
12	Mar. 17	5.3	5⅔		At lower knot.	3,470			
13	Mar. 19	5.5	5⅓		At upper knot.	3,530			
14	Mar. 4	5.1	5⅔	Dry.	At lower knot.	2,950	2,880	53	Bowline knots over iron eyes.
15	Mar. 4	5.2	5⅔		At lower knot.	2,900			
16	Mar. 10	5.6	5		At lower knot.	2,800			
17	Mar. 10	5.5	5	Dry.	At lower knot.	2,430	2,500	46	Flemish loops over iron eyes.
18	Mar. 11	5.5	5⅓		At lower knot.	2.530			
19	Mar. 11	5.5	5⅔		At lower knot.	2,540			

TENSION TESTS ON 2¼″ RUSSIAN HEMP ROPE. (Three strands.)

Number of test.	Date, 1896–97.	Number of feet per pound.	Number of turns of one strand per foot.	CONDITION.	LOCATION OF BREAK.	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot or splice. (Per cent.)	METHOD OF HOLDING.
1	Nov. 4, '95.*	...	5⅜	Splices wet. Center portion of rope dry.	At center.	7,020	6,580	100	Spliced eyes over iron eyes.
2	Nov. 22, '95.*	5	5⅛		At center.	6,880			
3	Mar. 20, '95.*	...	5		At center.	6,660			
4	Apr. 2, '95.*	5.5	5⅓		At center.	6,290			
5	Apr. 5	5.5	5⅛		At center.	6,030			
6	Mar. 31	5.3	5⅜	Dry.	At lower knot.	5,320	5,100	78	Timber hitches over 2″ pipe couplings.
7	Apr. 5	4.4	5⅛		At lower knot.	5,030			
8	Apr. 5	4.4	5⅛		At upper knot.	4,970			
9	Nov. 23	5.1	5⅓	Dry.	At lower knot.	5,260	5,020	76	Slip knots over 2″ pipe couplings.
10	Dec. 7	5.0	5		At upper knot.	4,680			
11	Dec. 9	5.0	5		At lower knot.	5,130			
12	Nov. 13	5.0	5	Dry.	At upper knot.	4,190	3,920	60	Bowline knots over iron eyes.
13	Nov. 13	5.0	5		At lower knot.	3,870			
14	Nov. 25	5.0	5⅛		At upper knot.	3,590			
15	Apr. 6	5.3	5⅛		At lower knot.	4,010			
16	Nov. 13	5.0	5	Dry.	At upper knot.	3,230	3,550	54	Flemish loops over iron eyes.
17	Nov. 18	5.0	5		At lower knot.	4,030			
18	Nov. 23	5.1	5⅛		At upper knot.	3,700			
19	Mar. 31	5.2	5⅜		At upper knot.	3,250			

* These tests have been published before, and are quoted here for reference.

TENSION TESTS ON 2½″ TARRED RUSSIAN HEMP ROPE. (Three strands.)

Number of test.	Date, 1896–97.	Number of feet per pound.	Number of turns of one strand per foot.	CONDITION.	LOCATION OF BREAK.	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot or splice. (Per cent.)	METHOD OF HOLDING.
1	Nov. 6, '95.*	...	5½	Splices wet. Center portion of rope dry.	Near center.	5,250	5,250	100	Spliced eyes over iron eyes
2	Nov. 22, '95.*	4.3	6		Near center.	4,700			
3	Mar. 10, '96.*	4.5	5½		Near center.	5,790			
4	Apr. 12	4.4	6	Dry.	At upper knot.	3,780	3,790	72	Timber hitches over 2″ pipe couplings.
5	Apr. 12	4.4	6		At lower knot.	3,880			
6	Apr. 14	4.2	6		At upper knot.	3,700			
7	Dec. 2	4.0	5½	Dry.	At upper knot.	4,250	4,140	79	Slip knots over 2″ pipe couplings.
8	Dec. 3	5.1	6		At upper knot.	3,670			
9	Apr. 14	4.2	6		At upper knot.	4,490			
10	Dec. 2	4.3	6	Dry.	At upper knot.	3,260	2,980	57	Bowline knots over iron eyes.
11	Dec. 4	4.3	5½		At lower knot.	2,810			
12	Dec. 4	4.3	5½		At upper knot.	2,860			
13	Dec. 2	4.3	6	Dry.	At upper knot.	3,020	2,810	54	Flemish loops over iron eyes.
14	Dec. 2	4.3	6		At upper knot.	2,900			
15	Dec. 3	5.1	6		At lower knot.	2,510			

* These tests have been published before, and are quoted here for reference.

TENSION TESTS ON 2½″ TARRED AMERICAN HEMP ROPE. (Three strands.)

Number of test.	Date, 1896–97.	Number of feet per pound.	Number of turns of one strand per foot.	CONDITION.	LOCATION OF BREAK.	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot or splice. (Per cent.)	METHOD OF HOLDING.
1	Nov. 2	4.7	5½	Splices wet. Center portion of rope dry.	Near lower splice.	5,400	5,070	100	Spliced eyes over iron eyes.
2	Nov. 4	4.5	5⅝		Near lower splice.	5,080			
3	Nov. 4	4.4	5		Near upper splice.	5,070			
4	Nov. 4	4.5	5½		Near upper splice.	4,980			
5	Apr. 27	4.6	3⅞		At center.	4,820			
6	Apr. 15	4.6	5½	Dry.	At upper knot.	4,490	4,250	84	Timber hitches over 2″ pipe couplings.
7	Apr. 15	4.7	5⅝		At lower knot.	3,920			
8	Apr. 28	4.7	5⅝		At lower knot.	4,340			
9	Nov. 9	4.5	5	Dry.	At lower knot.	4 490	4,560	90	Double half hitches over 2″ pipe couplings.
10	Nov. 9	4.5	5		At upper knot.	4,630			
11	Nov. 7	4.3	5½	Dry.	At lower knot.	4,760	4,650	92	Slip knots over 2″ pipe couplings.
12	Nov. 7	4.3	5⅝		At knot.	4,530			
13	Nov. 4	4.4	5	Dry.	At lower knot.	4,030	4,070	80	Bowline knots over iron eyes.
14	Nov. 6	...	5		At upper knot.	4,460			
15	Dec. 10	4 6	5⅝		At upper knot.	3,730			
16	Nov. 6	...	5	Dry.	At lower knot.	3,640	3,860	76	Flemish loops over iron eyes.
17	Nov. 7	4 3	5½		At upper knot.	3,950			
18	Dec. 15	4 8	..		At lower knot.	3,980			

TENSION TESTS ON NO. 10 JUTE TWINE. (Three strands.)

Number of test.	Date, 1896.	Number of feet per ounce.	Maximum load. (Lbs.)	Location of Break.	Method of Holding.
1	Oct. 24	88.6	38 5	3" above lower clamp.	The cord was held by Proctor twine clamps in this series of tests.
2	Oct. 24	88.6	34 5	2" below upper clamp.	
3	Oct. 28	79.5	34.5	At center.	
4	Oct. 28	76.7	33.5	Near lower clamp.	
5	Oct. 28	76.7	34.0	At center.	
6	Oct. 29	78.1	41.0	Near center.	
7	Oct. 30	78 1	35.0	Near lower clamp.	
8	Oct. 30	76.8	41.0	At center.	
9	Oct. 31	84.1	32.4	Near center.	
10	Oct. 31	82.9	37.8	At center.	
11	Oct. 31	84.1	34.3	Near lower clamp.	
12	Nov. 2	75.2	40.0	At center.	
13	Nov. 2	85.8	40.0	At center.	
14	Nov. 16	81.0	35.0	At center.	
15	Nov 16	81.0	43.5	At center.	
16	Nov. 16	76.6	37.6	At center.	

Note. — The length of specimen between clamps was about 18". All these tests were made upon dry material.

TENSION TESTS ON NO. 48 JUTE TWINE. (Four strands.)

Number of test.	Date, 1896–97.	Number of feet per ounce.	Maximum load. (Lbs.)	Total stretch to fracture. (Per cent.)	Location of Break.	Method of Holding.
1	Nov. 26	29.8	102 6	2.4	4" below upper clamp.	The cord was held by Proctor twine clamps in this series of tests.
2	Nov. 25	28.8	124.0	2.7	4" above lower clamp.	
3	Dec. 2	31.4	97.0	2.8	In lower clamp.	
4	Dec. 2	27.2	97.0	2.5	Near middle.	
5	Dec. 2	27.2	96.0	2.7	At lower clamp.	
6	Dec. 7	29 8	101.0	3.7	Near center.	
7	Dec. 8	31.2	103.5	2.5	Near center.	
8	Dec. 8	31.2	99.5	2.6	Near center.	
9	Mar. 9	27.6	91.0	...	At center.	
10	Mar. 9	32.8	118.3	...	At center.	
11	Mar. 11	32.7	103.8	...	At upper clamp.	
12	Mar. 11	25.7	95.0	...	Near upper clamp.	
13	Mar. 18	29.7	98.5	...	2" below upper clamp.	

Note. — The stretch was measured in a gauged length of 8" or 10". The length of specimen between clamps was about 18". These tests were made upon dry material.

TENSION TESTS ON NO. 16 FLAX BOOT THREAD. (Six strands.)

Number of test.	Date, 1896.	Number of feet per ounce.	Maximum load. (Lbs.)	Location of Break.	Method of Holding.
1	Nov. 16	140.4	49.0	At lower clamp.	The cord was held by Proctor twine clamps in this series of tests.
2	Nov. 16	140.4	43.3	4″ above lower clamp.	
3	Nov. 16	135.2	45.7	At center.	
4	Nov. 17	136.8	48.0	Near center.	
5	Nov. 17	128.7	43.6	Near center.	
6	Nov. 17	136.8	40.0	Near lower clamp.	
7	Nov. 17	136.8	39.3	At center.	
8	Nov. 17	136.8	40.1	At lower clamp.	
9	Nov. 17	136.8	40.0	Near lower clamp.	
10	Nov. 17	136.8	40.5	Near center.	
11	Nov. 17	125.0	44.0	At lower clamp.	
12	Nov. 19	136.7	40.3	At center.	
13	Nov. 19	136.7	40.0	At center.	
14	Nov. 19	141.1	46.2	At center.	
15	Nov. 19	118.2	39.6	At center.	
16	Nov. 19	136.7	39.7	At center.	
17	Nov. 19	136.7	38.7	At center.	
18	Nov. 19	118.2	42.7	At center.	
19	Nov. 25	133.6	37.9	Near center.	
20	Nov. 30	134.3	42.0	Just below upper clamp.	
21	Nov. 30	134.6	47.0	Near center.	
22	Nov. 30	128.7	45.3	Near center.	
23	Nov. 30	128.7	40.0	At center.	
24	Nov. 30	134.6	44.0	Near center.	

NOTE. — The length of specimen between clamps was about 28″. These tests were made upon dry material.

TENSION TESTS ON NO. 3½ BRAIDED CURTAIN CORD.

Number of test.	Date, 1897.	Number of feet per ounce.	Maximum load. (Lbs.)	Location of Break.	Method of Holding.
1	Feb. 15	10.7	109.0	2″ below upper clamp.	The cord was held by Proctor twine clamps in this series of tests.
2	Feb. 26	10.8	107.5	Near lower clamp.	
3	Feb. 26	....	107.5	Near lower clamp.	
4	Mar. 1	10.9	110.0	Near center.	
5	Mar. 3	9.8	114.9	At center.	
6	Mar. 4	10.8	99.0	Just below upper clamp.	
7	Mar. 5	10.9	116.9	At center.	
8	Mar. 5	10.7	105.6	At upper clamp.	
9	Mar. 9	....	105.0	At center.	
10	Mar. 9	10.9	103.4	At center.	
11	Mar. 11	10.7	108.3	At center.	
12	Mar. 11	10.7	102.5	Near center.	
13	Mar. 11	11.0	98.7	Near lower clamp.	
14	Mar. 18	10.7	108.5	In lower clamp.	
15	Mar. 18	10.3	112.2	Near lower clamp.	

NOTES. — This cord was made of white braided cotton. It was composed of nine strands, each of four threads, braided over a core of four threads.

The length between clamps was about 18″.

These tests were made upon dry material.

TENSION TESTS ON No. 8 SAMSON BRAIDED SASH CORD.

Number of test.	Date, 1897.	Number of feet per ounce.	Maximum load. (Lbs.)	LOCATION OF BREAK.	METHOD OF HOLDING.
1	Feb. 19	2.32	284.0	4″ below upper clamp.	In tests No. 1 to 13 inclusive the cord was held by Proctor twine clamps.
2	Feb. 26	2.28	280.0	Near center.	
3	Mar. 1	2.33	282.0	Near center.	
4	Mar. 3	2.30	298.0	At center.	
5	Mar. 4	2.32	282.0	Just below upper clamp.	
6	Mar. 5	2.35	280.0	At center.	
7	Mar. 5	2.33	299.5	In upper clamp.	
8	Mar. 11	2.35	292.0	At center.	
9	Mar. 18	2.25	303.5	At center.	
10	Mar. 20	2.32	304.0	Near center.	
11	Mar. 25	2.33	286.5	At center.	
12	Mar. 25	2.33	291.0	Near upper clamp.	
13	Mar. 29	2.32	285.8	At upper clamp.	
14	Mar. 29	2.31	291.0	Near upper knot.	Timber hitch knots.
15	Mar. 29	2.32	281.0	In upper knot.	Slip knots.
16	Mar. 29	2.32	271.0	In upper knot.	Bowline knots.
17	Mar. 29	2.34	229.0	In upper knot.	Flemish loop knots.

NOTES. — This cord was made of drab braided cotton. It was composed of twelve strands, each of nine threads, braided over a core of ten threads.

The knot holdings were made over Proctor clamps, which were 2⅛″ in diameter. The last four tests may be compared with similar ones upon rope, to show the relative efficiency of the knots used.

The length of cord between clamps was 18″.

All the tests were made upon dry material.

TENSION TESTS ON No. 9 SAMSON BRAIDED SASH CORD.

Number of test.	Date, 1897.	Number of feet per ounce.	Method of Holding	Maximum load. (Lbs.)	Average strength. (Lbs.)	Efficiency of knot or holding as compared with total strength of specimen. (Per cent.)	Location of Break.
1	Apr. 9	2.21	Proctor clamps.	351	350	100	At center.
2	Apr. 13	2.03	Proctor clamps.	344			At center.
3	Apr. 17	2.20	Proctor clamps.	359			Near lower clamp.
4	Apr. 27	2.23	Timber hitches.	356			Near center.
5	Apr. 27	2.28	Timber hitches.	350			At center.
6	Apr. 27	2.14	Timber hitches.	348			Near lower knot.
7	Apr. 28	2.26	Timber hitches.	342			Near center.
8	Apr. 13	2.22	Bowline knots.	300	309	88	Lower knot.
9	Apr. 13	2.23	Bowline knots.	295			Lower knot.
10	Apr. 17	2.11	Bowline knots.	320			Lower knot.
11	Apr. 27	2.23	Bowline knots.	320			Lower knot.
12	Apr. 9	2.23	Flemish loop knots.	276	280	80	Lower knot.
13	Apr. 17	2.02	Flemish loop knots.	278			Lower knot.
14	Apr. 27	2.28	Flemish loop knots.	285			Lower knot.
15	Apr. 27	2.22	Timber hitches with square knot at center of specimen.	291	290	83	In square knot.
16	Apr. 27	....		290.			In square knot.
17	Apr. 27	2.29		290			In square knot.
18	Apr. 27	2.21	Timber hitches and open-hand knot at center of specimen.	258	268	77	At open-hand knot.
19	Apr. 27	2.22		259			At open-hand knot.
20	Apr. 28	2.43		289			At open-hand knot.

Notes. — The length of specimen between clamps was 18″.

This cord was made of drab braided cotton, and consisted of fifteen strands of eight threads each, braided over a core of ten threads.

The knots were tied over a Proctor clamp which was 2¼″ in diameter.

These tests were made upon dry material.

TENSION TESTS ON $\frac{5}{16}$″ FABER LINEN SASH CORD.

Number of test.	Date, 1897.	Number of feet per ounce.	Maximum lead. (Lbs.)	Location of Break.	Method of Holding.
1	Feb. 19	1.70	671	2″ above lower clamp.	The cord was held by Proctor clamps in this series of tests.
2	Feb. 26	1 70	582	In upper clamp.	
3	Mar. 1	1.71	625	In upper clamp.	
4	Mar. 3	1.71	639	Near lower clamp.	
5	Mar. 4	....	606	In upper clamp.	
6	Mar. 5	1.71	685	In upper clamp.	
7	Mar. 10	1 68	690	In upper clamp.	
8	Mar. 13	1.72	660	At lower clamp.	The cord was dry in this series of tests.
9	Mar. 25	1.73	713	At center.	
10	Mar. 26	1.69	613	At lower clamp.	
11	Mar. 29	1.91	687	At center.	

Notes — The length of specimen between clamps was 18″.

This cord was made of twisted linen, and consisted of four strands of three threads each, twisted around a core of six threads.

The core was of Russian hemp.

The number of twists of one strand was about twelve per foot.

The Proctor clamp did not prove as good a holding for this as for the smaller cord, since most of the specimens broke in or near the clamp.

TENSION TESTS ON ⅜" BELT LACINGS.

Number of test.	Date, 1896–97.	Weight per yard. (Ounces.)	Gauged length. (Ins.)	Maximum load. (Lbs.)	Ultimate extension in gauged length. (Ins.)	Ultimate extension in gauged length. (Per cent.)
1	Nov. 20	.78	8.00	224	2.52	31.5
2	Nov. 21	.49	8.00	177	2.18	27.3
3	Nov. 21	1.23	8.00	245	2.10	26.3
4	Nov. 23	.73	8.00	207	1.58	19.8
5	Nov. 23	.67	8.00	215	3.00	37.5
6	Nov. 23	.50	8.00	203	1.78	22.2
7	Nov. 23	.71	8.00	221	2.25	28.1
8	Dec. 15	.53	8.00	185	1.25	15.6
9	Dec. 15	.77	8.00	220	1.40	17.5
10	Mar. 30	.69	....	205	....	....
11	Mar. 30	.72	....	274	....	....
12	Mar. 31	.61	....	237	....	....
13	Mar. 31	.74	....	210	....	....
14	Apr. 7	.47	....	162	....	....

Note. — The lacings were held by Proctor twine clamps. The material was ordinary "split raw hide."

TENSION TESTS ON LEATHER BELTS.

Number of test.	Date, 1897.	Dimensions of cross section. (Ins.)	Area of cross section. (Sq. ins.)	Maximum load. (Lbs.)	Maximum load. (Lbs. per sq. in.)	Gauged length. (Ins.)	Ultimate extension in gauged length. (Ins.)	Ultimate extension in gauged length. (Per cent.)	Kind of Belt.
1	Mar. 17	.32 x 2.96	.947	6,440	6,800	6.00	1.58	26.3	Indian tanned leather.
2	Mar. 17	.34 x 2.50	.850	3,400	4,000	2.00	.31	15.5	Schieren electric.
3	Mar. 17	.34 x 2.53	.860	3,250	3,780	....	....	....	Schieren electric.
4	Mar. 17	.34 x 2.48	.843	3,700	4,390	2.00	.31	15.5	Schieren electric.
5	Mar. 17	.34 x 2.42	.823	4,050	4,920	2.00	.31	15.5	Schieren electric.

TRANSVERSE STRENGTH OF SPRUCE BEAMS.

Load applied at middle of span.

Number of test.	Width and depth. (Ins.)	Distance between supports. (Feet.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Deflection for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Breaking load. (Lbs.)	Weight of beam. (Lbs.)	Modulus of rupture. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	MANNER OF BREAKING.	REMARKS.
536	3⅞ x 12	14	500-3,500	.4306	1,233,000	10,005	150	4,550	164	Tension.	
537	4 x 12	13	500-4,500	.4865	1,129,000	10,475	150	4,290	166	Tension.	
538	3¾ x 12	14	500-5,000	.6604	1,247,000	10,615	140	4,990	179	Tension.	
539	3¾ x 11⅞	14	500-2,000	.4082	691,000	3,315	155	1,610	58	Tension.	Very poor quality.
540	4 x 11⅞	14	500-3,500	.4661	1,139,000	8,565	150	3,860	138	Tension.	
541	3⅞ x 12	17	500-3,000	.6768	1,171,000	6,165	200	3,440	103	Tension and crushing.	
543	3¾ x 12	8	500-6,500	.2125	964,000	17,815	90	4,760	298	Longitudinal shear.	Part of beam No. 541.
544	3⅞ x 11⅞	13	500-3,500	.5106	859,000	4,440	160	1,940	75	Tension.	Poor quality.
545	3⅞ x 12	14	500-5,000	.6107	1,305,000	11,815	150	5,370	193	Longitudinal shear.	
546	4⅛ x 12	13	500-3,500	.3122	1,279,000	9,915	150	3,940	153	Longitudinal shear.	
572	3⅞ x 12	12	500-4,500	.4165	1,071,000	10,525	125	4,100	172	Longitudinal shear.	
573	3⅞ x 11½	10½	500-6,500	.3503	1,457,000	19,325	115	7,150	327	Longitudinal shear and tension.	Old, well seasoned. Used as plank in laboratory.
574	2 x 11½	11	500-4,500	.5244	1,471,000	9,960	60	7,480	327	Tension.	
575	3⅞ x 12	11	500-6,500	.3715	1,426,000	13,740	160	4,900	225	Tension.	
576	3¾ x 12	11	1,000-7,000	.3987	1,336,000	13,850	150	5,110	233	Tension.	
577	4 x 12	11	1,000-7,000	.4650	1,073,000	13,315	125	4,600	210	Tension.	
579	3⅞ x 12	11	500-4,500	.2910	1,180,000	13,750	130	4,900	224	Longitudinal shear and tension.	

TRANSVERSE STRENGTH OF SPRUCE BEAMS.

Load equally distributed over two points equally spaced between supports dividing span into thirds.

Number of test.	Width and depth. (Ins.)	Distance between supports. (Feet.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Deflection for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Breaking load. (Lbs.)	Weight of beam. (Lbs.)	Modulus of rupture. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	MANNER OF BREAKING.	REMARKS.
547	$3\frac{3}{4} \times 12$	14	500–6,500	.7162	1,305,000	12,210	155	3,840	206	Tension.	
548	$3\frac{7}{8} \times 11\frac{7}{8}$	13	500–6,500	.7329	1,020,000	14,130	130	4,060	232	Tension.	
549	$3\frac{7}{8} \times 12$	12	500–4,500	.4209	882,000	12,125	140	3,160	198	Tension.	
550	$3\frac{7}{8} \times 12\frac{1}{8}$	12	500–4,500	.3752	960,000	12,280	140	3,130	198	Tension.	
551	4×12	12	500–6,500	.4227	1,276,000	19,455	130	4,890	306	Tension.	
552	$3\frac{7}{8} \times 12\frac{1}{8}$	12	500–6,500	.5598	965,000	12,080	140	3,080	195	Tension.	
553	$4 \times 11\frac{7}{8}$	14	500–6,500	.6944	1,302,000	15,280	165	4,590	244	Tension.	
554	4×12	12	500–4,500	.3592	1,001,000	11,780	140	2,970	186	Longitudinal shear.	
555	$3\frac{11}{16} \times 12$	12	1,500–6,500	.4493	1,086,000	15,605	125	4,260	267	Tension.	Broke at knot.
557	$4 \times 11\frac{3}{4}$	12	500–3,500	.2296	1,166,000	12,675	130	2,920	204	Longitudinal shear and tension.	In this beam the load was applied at two points $2\frac{1}{2}$ feet each side of center.

TRANSVERSE STRENGTH OF SPRUCE BEAMS.

Load equally distributed over four points equally spaced between supports dividing span into fifths.

Number of test.	Width and depth. (Ins.)	Distance between supports. (Feet.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Deflection for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Breaking load. (Lbs.)	Weight of beam. (Lbs.)	Modulus of rupture. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	MANNER OF BREAKING.	REMARKS.
556	3¾ x 11⅞	12	500–6,500	.3483	1,551,000	22,930	125	5,640	388	Tension.	
558	3¾ x 11¾	12	500–6,500	.3717	1,497,000	27,240	120	6,840	466	Tension.	
559	3¾ x 11⅞	14	500–6,500	.5940	1,442,000	17,375	130	5,000	295	Longitudinal shear.	
560	4 12	12	500–6,500	.3005	1,631,000	34,125	130	7,700	535	Longitudinal shear.	
561	4 x 12	11	500–6,500	.2826	1,336,000	20,450	140	4,240	322	Longitudinal shear and tension.	
562	3⅞ x 11¾	12	500–6,500	.4833	1,115,000	14,125	125	3,450	235	Longitudinal shear and tension.	Poor quality.
563	4⅛ x 12	11½	500–6,500	.5154	812,000	9,340	90	2,260	149	Tension.	Very poor quality.
564	3⅞ x 11¾	11	500–6,500	.2951	1,557,000	21,800	115	5,380	399	Longitudinal shear.	
565	3¾ x 12	12½	500–6,500	.5727	1,032,000	14,145	130	3,560	238	Tension.	
566	3⅞ x 12	12	500–6,500	.4035	1,254,000	23,085	135	5,390	374	Tension.	
567	3⅞ x 12	11	500–6,500	.2841	1,371,000	28,975	130	6,190	469	Tension.	
568	4 x 12	12	500–6,500	.5172	947,000	13,860	140	3,900	219	Tension.	
569	4 x 12	12	500–6,500	.3543	1,383,000	19,650	140	4,450	309	Tension.	
570	4 x 12	11	500–4,500	.3223	780,000	7,450	120	1,560	118	Tension.	Very poor quality.
571	3½ x 12	12	500–6,500	.3910	1,432,000	20,550	120	5,310	369	Tension.	

TRANSVERSE STRENGTH OF YELLOW PINE.

Load applied at middle of span.

Number of test.	Width and depth. (Ins.)	Distance between supports. (Feet.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Deflection for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Breaking load. (Lbs.)	Weight of beam. (Lbs.)	Modulus of rupture. (Lbs. per sq. in.)	Maximum intensity of longitudinal shear. (Lbs. per sq. in.)	MANNER OF BREAKING.	REMARKS.
503	8 x 10	19	500–4,000	.5000	2,300,000	26.120	...	8,890	244	Tension crushing and shearing.	
542	7⅞ x 10	10	500–9,500	.2426	2,035,000	42,795	250	9,810	410	Longitudinal shear.	

TRANSVERSE STRENGTH OF COMPOSITION BARS.

Load applied at middle of span.

Number of test.	Width and depth. (Ins.)	Distance between supports. (Feet.)	Limits of loads for calculation of modulus of elasticity. (Lbs.)	Deflection for difference of loads used in calculation of modulus of elasticity. (Ins.)	Modulus of elasticity. (Lbs. per sq. in.)	Breaking load. (Lbs.)	Weight of beam. (Lbs.)	Modulus of rupture. (Lbs. per sq. in.)	REMARKS.
535*a*	1.45 x 1.45	2.5	50– 550	.0633	12,100,000	.....	23	......	85% copper, 7% zinc, 8% tin.
535*b*	1.43 x 1.45	2.5	100– 600	.0680	11,400,000	1,380	22	21,000	65% copper, 35% zinc.
535*c*	1.46 x 1 46	2.5	100–1,000	.1081	12,300,000	2,120	23	31,300	85% copper, 7% zinc, 8% tin.

NOTE. — Tensile tests of this composition are given in Vol. V, pages 202, 203.

NEAT CEMENT. (Tension.)

Date of Test.	Kind of Cement.	Brand.	Per cent. of water used in mixing.	Time of set. (Days.)	Breaking strength.
Nov. 16, 1896 . . .	Rosendale.	Hoffman.	30	7	99
Nov. 16, 1896 . . .	Rosendale.	Hoffman.	30	7	119
Nov. 16, 1896 . . .	Rosendale.	Hoffman.	30	7	128
Nov. 16, 1896 . . .	Rosendale.	Hoffman.	30	7	132
Nov. 17, 1896 . . .	Rosendale.	Hoffman.	30	7	93
Nov. 17, 1896 . . .	Rosendale.	Hoffman.	30	7	102
Nov. 18, 1896 . . .	Rosendale.	Hoffman.	30	7	92
Nov. 18, 1896 . . .	Rosendale.	Hoffman.	30	7	93
Nov. 18, 1896 . . .	Rosendale.	Hoffman.	30	7	95
Nov. 18, 1896 . . .	Rosendale.	Hoffman.	30	7	103
Nov. 30, 1896 . . .	Rosendale.	Hoffman.	30	7	95
Dec. 1, 1896 . . .	Rosendale.	Hoffman.	30	7	101
Dec. 1, 1896 . . .	Rosendale.	Hoffman.	30	7	109
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	383	780
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	383	780
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	383	864
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	384	832
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	384	855
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	384	856
Nov. 13, 1896 . . .	Portland.	B. S. & Co.	25	384	858
Dec. 2, 1896 . . .	Portland.	B. S. & Co.	25	411	788
Dec. 2, 1896 . . .	Portland.	B. S. & Co.	25	411	814
Dec. 2, 1896 . . .	Portland.	B. S. & Co.	25	411	874
Dec. 8, 1896 . . .	Portland.	B. S. & Co.	25	417	816
Dec. 9, 1896 . . .	Portland.	B. S. & Co.	25	417	832
Dec. 8, 1896 . . .	Portland.	B. S. & Co.	25	418	827
Nov. 4, 1896 . . .	Portland.	Anchor.	24	5	406
Nov. 4, 1896 . . .	Portland.	Anchor.	24	5	411
Nov. 4, 1896 . . .	Portland.	Anchor.	24	5	408
Nov. 4, 1896 . . .	Portland.	Anchor.	24	5	440
Oct. 28, 1896 . . .	Portland.	Anchor.	25	7	482
Oct. 29, 1896 . . .	Portland.	Anchor.	23	7	450
Oct. 30, 1896 . . .	Portland.	Anchor.	24	7	474
Oct. 30, 1896 . . .	Portland.	Anchor.	24	7	489
Nov. 2, 1896 . . .	Portland.	Anchor.	24	7	500
Nov. 4, 1896 . . .	Portland.	Anchor.	24	7	540
Nov. 13, 1896 . . .	Portland.	Anchor.	24	7	460
Nov. 13, 1896 . . .	Portland.	Anchor.	24	7	465
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	462
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	472
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	480
Mar, 8, 1897 . . .	Portland.	Anchor.	24	7	488
Mar. 4, 1897 . . .	Portland.	Anchor.	24	7	474
Mar. 4, 1897 . . .	Portland.	Anchor.	24	7	510

NEAT CEMENT. (Tension.) — *Concluded.*

Date of Test.	Kind of Cement.	Brand.	Per cent. of water used in mixing.	Time of set. (Days.)	Breaking strength.
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	520
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	536
Mar. 8, 1897 . .	Portland.	Anchor.	24	7	542
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	578
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	607
Mar. 8, 1897 . . .	Portland.	Anchor.	24	7	502
Mar. 9, 1897 . . .	Portland.	Anchor.	24	7	495
Mar. 9, 1897 . . .	Portland.	Anchor.	24	7	571
Mar. 9, 1897 . . .	Portland.	Anchor.	24	7	580
Mar. 10, 1897 . . .	Portland.	Anchor.	24	7	482
Mar. 10, 1897 . . .	Portland.	Anchor.	24	7	484
Mar. 10, 1897 . . .	Portland.	Anchor.	24	7	550
Mar. 10, 1897 . . .	Portland.	Anchor.	24	7	492
Mar. 10. 1897 . . .	Portland.	Anchor.	24	7	566
Mar. 11, 1897 . . .	Portland.	Anchor.	24	7	484
Mar. 29, 1897 . . .	Portland.	Anchor.	24	27	642
Mar. 29, 1897 . . .	Portland.	Anchor.	24	27	680
Mar. 29, 1897 . . .	Portland.	Anchor.	24	27	680
Apr. 8, 1897 . . .	Portland.	Anchor.	24	35	660
Apr. 8, 1897 . . .	Portland.	Anchor.	24	35	728
Apr. 15, 1897 . . .	Portland.	Anchor.	24	42	686
Apr. 13, 1897 . . .	Portland.	Atlas.	18	1	191
Apr. 13, 1897 . . .	Portland.	Atlas.	18	1	192
Apr. 15, 1897 . . .	Portland.	Atlas.	18	3	308
Apr. 15, 1897 . . .	Portland.	Atlas.	18	3	338
Mar. 24, 1897 . . .	Portland.	Atlas.	18	7	530
Mar. 24, 1897 . . .	Portland.	Atlas.	18	7	552
Mar. 24, 1897 . . .	Portland.	Atlas.	18	7	530
Mar. 25, 1897 . . .	Portland.	Atlas.	18	7	540
Mar. 25, 1897 . . .	Portland.	Atlas.	18	7	548
Mar. 25, 1897 . . .	Portland.	Atlas.	18	7	583
Mar. 25, 1897 . . .	Portland.	Atlas.	18	7	667
Mar. 29, 1897 . . .	Portland.	Atlas.	18	7	560
Apr. 22, 1897 . . .	Portland.	Atlas.	15	7	565
Apr. 22, 1897 . . .	Portland.	Atlas.	15	7	710
Apr. 22, 1897 . . .	Portland.	Atlas.	18	7	768
Apr. 22, 1897 . . .	Portland.	Atlas.	18	7	815
Apr. 22, 1897 . . .	Portland.	Atlas.	18	7	756
Apr. 22, 1897 . . .	Portland.	Atlas.	18	7	785
Apr. 28, 1897 . . .	Portland.	Atlas.	18	15	960
Apr. 12, 1897 . . .	Portland.	Atlas.	18	27	800
Apr. 12, 1897 . . .	Portland.	Atlas.	18	27	800
Apr. 12, 1897 . . .	Portland.	Atlas.	18	27	840

SAND TESTS. (Tension.)

Date of Test.	Kind of Cement.	Brand.	Parts sand to one part cement.	Per cent. of water used in mixing.	Number of days set.	Breaking strength.
Oct. 28, 1896 . . .	Portland.	Anchor.	2	8	7	190
Oct. 29, 1896 . . .	Portland.	Anchor.	2	10	7	153
Oct. 29, 1896 . . .	Portland.	Anchor.	2	10	7	168
Oct. 30, 1896 . . .	Portland.	Anchor.	2	10	7	159
Oct. 30, 1896 . . .	Portland.	Anchor.	2	10	7	188
Oct. 30, 1896 . . .	Portland.	Anchor.	2	10	7	214
Nov. 2, 1896 . . .	Portland.	Anchor.	2	8	7	167
Nov. 4, 1896 . . .	Portland.	Anchor.	2	8	7	175
Nov. 4, 1896 . . .	Portland.	Anchor.	2	8	7	182

SAND TESTS. (Compression.)

Date of Test.	Kind of Cement.	Brand.	Parts sand to one part cement.	Per cent. of water used in mixing.	Number of days set.	Breaking strength.
Oct. 28, 1896 . . .	Portland.	Anchor.	2	8	7	9,600
Oct. 28, 1896 . . .	Portland.	Anchor.	2	8	7	12,100
Oct. 29, 1896 . . .	Portland.	Anchor.	2	10	7	9,700
Oct. 30, 1896 . . .	Portland.	Anchor.	2	10	7	9,470
Oct. 30, 1896 . . .	Portland.	Anchor.	2	10	7	9,570
Oct. 30, 1896 . . .	Portland.	Anchor.	2	10	7	9,840
Nov. 2, 1896 . . .	Portland.	Anchor.	2	8	7	9,150
Nov. 4, 1896 . . .	Portland.	Anchor.	2	10	5	7,940
Nov. 4. 1896 . . .	Portland.	Anchor.	2	10	5	8,440

NOTES. — Sand used in these tests was common building sand.
These tests were on 2-inch cubes.

NEAT CEMENT. (Compression.)

Date of Test.	Kind of Cement.	Brand.	Per cent. of water used in mixing.	Time of set. (Days.)	Breaking strength.
Nov. 16, 1896	Rosendale.	Hoffman.	30	7	2,600
Nov. 16, 1896	Rosendale.	Hoffman.	30	7	2,755
Nov. 16, 1896	Rosendale.	Hoffman.	30	7	2,900
Nov. 16, 1896	Rosendale.	Hoffman.	30	7	2,970
Nov. 17, 1896	Rosendale.	Hoffman.	30	7	2,280
Nov. 17, 1896	Rosendale.	Hoffman.	30	7	2,440
Nov. 18, 1896	Rosendale.	Hoffman.	30	7	2,490
Nov. 18, 1896	Rosendale.	Hoffman.	30	7	2,520
Nov. 18, 1896	Rosendale.	Hoffman.	30	7	2,590
Nov. 30, 1896	Rosendale.	Hoffman.	30	7	2,300
Nov. 30, 1896	Rosendale.	Hoffman.	30	7	2,580
Nov. 30. 1896	Rosendale.	Hoffman.	30	7	2,700
Nov. 30, 1896	Rosendale.	Hoffman.	30	7	3,010
Dec. 1, 1896	Rosendale.	Hoffman.	30	7	2,230
Dec. 1, 1896	Rosendale.	Hoffman.	30	7	2,320
Dec. 1, 1896	Rosendale.	Hoffman.	30	7	2,390
Dec. 1, 1896	Rosendale.	Hoffman.	30	7	2,450
Dec. 1, 1896	Rosendale.	Hoffman.	30	7	2,580
Dec. 1, 1896	Rosendale.	Hoffman.	30	7	2,630
Nov. 4, 1896	Portland.	Anchor.	24	5	11,830
Nov. 4, 1896	Portland.	Anchor.	24	5	12,000
Nov. 4, 1896	Portland.	Anchor.	24	5	12,320
Nov. 4, 1896	Portland.	Anchor.	24	5	13,840
Oct. 28, 1896	Portland.	Anchor.	25	7	14,700
Oct. 28, 1896	Portland.	Anchor.	25	7	14,780
Oct. 28, 1896	Portland.	Anchor.	25	7	15,330
Oct. 28, 1896	Portland.	Anchor.	25	7	15,330
Oct. 29, 1896	Portland.	Anchor.	23	7	15,040
Oct. 29, 1896	Portland.	Anchor.	23	7	15,480
Oct. 29, 1896	Portland.	Anchor.	23	7	17,030
Nov. 2, 1896	Portland.	Anchor.	24	7	14,150
Nov. 2, 1896	Portland.	Anchor.	24	7	14,250
Nov. 2, 1896	Portland.	Anchor.	24	7	15,800
Nov. 4, 1896	Portland.	Anchor.	24	7	14,400
Nov. 4, 1896	Portland.	Anchor.	24	7	15,200
Nov. 4, 1896	Portland.	Anchor.	24	7	16,350
Nov. 4, 1896	Portland.	Anchor.	24	7	17,150
Nov. 6, 1896	Portland.	Anchor.	24	7	14,300
Nov. 6, 1896	Portland.	Anchor.	24	7	14,890
Mar. 8, 1897	Portland.	Anchor.	24	7	15,470
Mar. 8, 1897	Portland.	Anchor.	24	7	15,540
Mar. 4, 1897	Portland.	Anchor.	24	7	15,000
Mar. 4, 1897	Portland.	Anchor.	24	7	15,190
Mar. 4, 1897	Portland.	Anchor.	24	7	15,450
Mar. 4, 1897	Portland.	Anchor.	24	7	15,830
Mar. 4, 1897	Portland.	Anchor.	24	7	15,900
Mar. 4, 1897	Portland.	Anchor.	24	7	15,980
Mar. 8, 1897	Portland.	Anchor.	24	7	15,700
Mar. 10, 1897	Portland.	Anchor.	24	7	14,750
Mar. 10, 1897	Portland.	Anchor.	24	7	15,400
Mar. 10, 1897	Portland.	Anchor.	24	7	14,430
Mar. 10, 1897	Portland.	Anchor.	24	7	14,550
Mar. 10, 1897	Portland.	Anchor.	24	7	15,020
Mar. 29, 1897	Portland.	Anchor.	24	27	19,160
Mar. 29, 1897	Portland.	Anchor.	24	27	20,000
Apr. 8, 1897	Portland.	Anchor.	24	35	19,975
Apr. 15, 1897	Portland.	Anchor.	24	49	24,475
Apr. 15, 1897	Portland.	Anchor.	24	49	25,500
Apr. 13, 1897	Portland.	Atlas.	18	1	3,500
Apr. 13, 1897	Portland.	Atlas.	18	1	3,950
Apr. 13, 1897	Portland.	Atlas.	18	1	4,100
Mar. 24, 1897	Portland.	Atlas.	20	7	14,760
Mar. 24, 1897	Portland.	Atlas.	18	7	21,330
Mar. 24, 1897	Portland.	Atlas.	18	7	21,600
Mar. 24, 1897	Portland.	Atlas.	18	7	22,900
Mar. 24, 1897	Portland.	Atlas.	18	7	23,560
Apr. 28, 1897	Portland.	Atlas.	18	15	29,600
Apr. 28, 1897	Portland.	Atlas.	18	15	31,060

NOTE. — These tests were all on 2-inch cubes.

ON ODORS AND TASTES OF SURFACE WATERS, WITH SPECIAL REFERENCE TO ANABÆNA, A MICROSCOPICAL ORGANISM FOUND IN CERTAIN WATER SUPPLIES OF MASSACHUSETTS.

By D. D. JACKSON, Assistant Biologist, and J. W. ELLMS, Assistant Chemist, of the Massachusetts State Board of Health.

It is commonly believed by those who have not investigated the subject, that disagreeable odors and tastes in drinking waters are due to the decomposition of organic matter, and are either dangerous or indicative of danger to the public health. Biological investigations already published have sufficed to show that this is not always the case.[1]

There is no longer any doubt that in many cases — perhaps most cases — the peculiar odors and tastes of surface waters are due, not to decay, but to the presence of living or undecomposed microscopical organisms, either animal or vegetable, in the water affected. This conclusion rests upon various facts, one of which is that in many instances the intensity of the odor keeps pace with the growth of the organisms, while bacteriological examinations prove the absence of conditions of organic putrefaction or decay. The fact that certain microscopical organisms possess peculiar and characteristic odors during life is not surprising, when we consider how characteristic are the odors of some of the larger plants and animals with which we are all familiar.

Several of the microscopic forms[2] have been found to contain oily products in considerable quantities at a certain stage of their growth, and in the case of Uroglena an oil has been shown to be the cause of the disagreeable odor and taste which usually accompany the or-

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[1] "Odors in Drinking Waters." Report Mass. State Board of Health, 1892, p. 353.

[2] On Uroglena. Report Mass. S. B. H., 1891, p. 645. — Synura. 18th Annual Report Boston Water Works, 1893.

ganism. By a series of experiments recently undertaken, we are able not only to add to the evidence upon this point by showing that the natural odor of Anabæna is due to a similar oily product, but also to draw a sharp distinction between the natural odors of the microscopical organisms found in surface waters and the odors produced by their decay.

The following is a list of the microscopical organisms which have up to the present time been known to give to surface waters a disagreeable odor and taste. The genera in italics are those which have been thus far the most prominent in this respect.

The list of natural odors given are all odors of growth, and are products of the life of the organisms and not of their decomposition. It is only in the case of the Cyanophyceæ (so far as we are aware) that we have a decided odor both of growth and of decay. Beggiatoa[1] and some species of Chara[2] give off odors resembling that of hydrogen sulphide, which may be considered odors of decomposition. It will be seen later that these odors of decay are due to the peculiar chemical composition of the organisms.

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[1] Proc. Am. Soc. of Microscopists (1884), p. 90.
St. Thomas's Hospital Reports, Vol. xx (1890), p. 51.
St. Thomas's Hospital Reports, Vol. xiii (1883), p. 39.
Comptes Rendus, xcv (1882), p. 846.
Comptes Rendus, ii (1879), p. 1078.
The Lancet, January 7, 1893, p. 22.

[2] Jour. of the New England Water Works Association, June, 1896.

Microörganisms.	Natural Odor.	Odor of Decay.
DIATOMACEÆ:		
Asterionella	Aromatic to fishy.	
Tabellaria	Aromatic.	
Meridion	Aromatic.	
CYANOPHYCEÆ. (Blue-green Algæ.)		
Anabæna	Mouldy, grassy.	Pig pen.
Rivularia	Mouldy, grassy.	Pig pen.
Clathrocystis	Sweet, grassy.	Pig pen.
Coelosphærium	Sweet, grassy.	Pig pen.
Aphanizomenon	Faintly grassy.	Pig pen.
CHLOROPHYCEÆ:		
Volvox	Fishy.	
Eudorina	Faintly fishy.	
Pandorina	Faintly fishy.	
INFUSORIA:		
Uroglena	Fishy and oily.	
Synura	Ripe cucumbers.	
Dinobryon	Fishy, like rockweed.	
Bursaria	Irish moss or salt marsh.	
Peridinium	Fishy, like clam shells.	
Cryptomonas	Candied violets.	
Mallomonas	Faintly fishy.	

Few surface waters are ever found to be entirely free from odor, but, as a rule, these odors are so faint as to be perceptible only when taken after shaking a considerable quantity of the water in a closed vessel. A description of the manner of taking odors and of the common terms employed to designate them, is given in a paper on "The Odor and Color of Surface Waters," by Dr. T. M. Drown.[1]

There is a decided difference in the strength of the natural odors produced by the various genera, and even by different species of the

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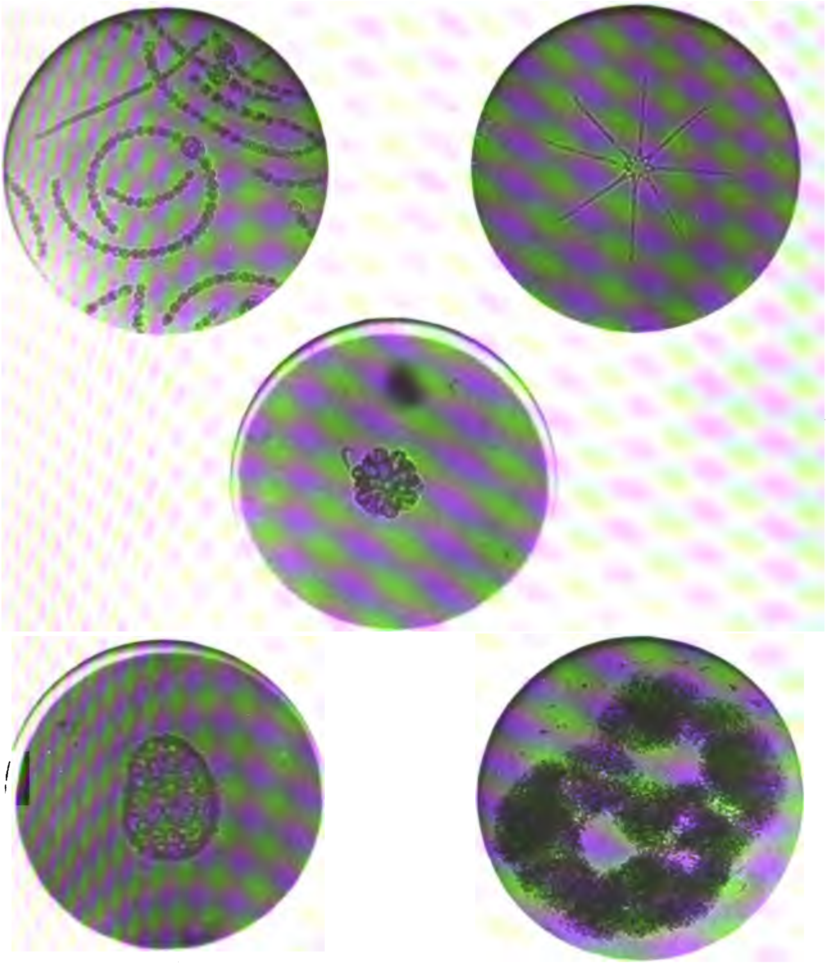
[1] Jour. New England Water Works Association, March, 1888.



Anabæna.
Synura.
Asterionella.
Uroglena.
Clathrocystis.

The five microscopical organisms which most commonly produce disagreeable odors and tastes in drinking waters.

FROM A PHOTOMICROGRAPH KINDLY LOANED BY MR. G. C. WHIPPLE.

same genus. Asterionella produces much the strongest odor yet observed among the Diatomaceæ, giving the aromatic odor and taste of geranium, and often when in very large numbers a disagreeable fishy odor. This change in the character of the odor is due to concentration. In the majority of cases when Asterionella has caused a disagreeable taste and odor, the growth has occurred in an open distributing reservoir, the source of supply of which has been wholly or in part a ground water. The difficulty may be overcome by pumping directly into the system, or by covering the distributing reservoir to exclude the light. Tabellaria gives a much less pronounced odor. Meridion[1] has not been found in large numbers in Massachusetts, and none of the other diatoms have yet been known to produce a disagreeable odor in water, although many genera have often occurred in enormous numbers.

The odor of growth of Anabæna is stronger in water than that of any of the other Cyanophyceæ yet observed, and some species of Anabæna are much stronger than others.

Rarely has Rivularia been found in large quantities in Massachusetts, but when so occurring it is hardly less offensive than Anabæna. Among the Chlorophyceæ only the Volvocineæ are known to give a disagreeable odor of growth to drinking water, and Volvox[2] is the only genus which has yet caused much trouble.

Uroglena heads the list of disagreeable infusoria, with a taste and odor of fish oil. Synura is probably the next in strength, giving a taste and odor something like ripe cucumbers. The odor from Dinobryon is faintly fishy, or like rockweed. Peridinium also gives a slightly fishy odor resembling clam shells. Cryptomonas gives an odor of candied violets.

The number of organisms per cubic centimeter necessary to produce a noticeable odor differs greatly with the various genera, and often with different species of the same genus. The odor is, as a rule, more pronounced when the organism is in a mature stage of growth. It would be convenient for reference if an approximate figure could be set for each objectionable species, showing the point where it

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[1] Sporadic Growth of Certain Diatoms. By J. D. Hyatt. Proc. of American Soc. of Microscopists, 1882.

[2] The data in regard to the odor of this organism are confined to observations made at Hemlock Lake, Rochester, N. Y. See Trans. Am. Soc. Civil Engineers, Vol. xxi, Dec., 1889, p. 483.

would begin to cause trouble in a water supply. This, however, in the present state of our knowledge, cannot be done. A paper on "The Relative Taste and Odor Imparted to Water by Some Algæ and Infusoria," by F. F. Forbes,[1] bears upon this point.

The odors of growth of the diatoms and of the infusoria have been fairly well established to be due to oily compounds, although the oil itself has been actually isolated from the organisms only in the case of Uroglena, as before mentioned. The odors produced by the Volvocineæ are so like those of the infusoria that there is little doubt that they also may be ascribed to oily products.

The nature of the grassy odor of growth of the Cyanophyceæ has never heretofore been experimented upon, to our knowledge, and, inasmuch as this class of organisms also gives an extremely disagreeable odor of decomposition, the cause for which was not well established, it was decided to make Anabæna, which is the most troublesome of the Cyanophyceæ, the object of special study.

ANABÆNA. ODOR OF GROWTH.

Odor-producing organisms have been concentrated by precipitating them with aluminum hydrate in a tall cylindrical galvanized iron tank of a capacity of about forty gallons.

We have also found that the various tastes and odors produced by the living organisms may be preserved for reference for a very considable period of time by putting the concentrated organisms into pure glycerine.

In the case of Anabæna a great many fruitless experiments were performed to obtain the odor-giving principle in a concentrated state. The water containing the organisms was filtered through absorbent cotton and filter paper, and many extractions and distillations were made without avail. During the fall of 1895 the growth in certain parts of Ludlow Reservoir, Springfield, was very luxurious, and in the sheltered coves where the water was shallow the growth was enormous, and was found to be a practically pure culture of *Anabæna circinalis*.[2] An excellent opportunity was therefore afforded to study this particular species.

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[1] Jour. New England Water Works Association, Vol. iv, December, 1891.

[2] Tableau synoptique des Nostochacees filamenteuses. Mém. de la Soc. des Sc. nat. de Cherbourg (1889), Bd. xxvi, pp. 138–152.

The odor of the organisms when fresh resembles the odor of mouldy grass, and reasoning from analogy with the other organisms in water already mentioned, it was inferred that the odor might be due to the presence of oily products. Accordingly, large quantities of the fresh organisms were treated with various reagents which would be capable of dissolving any oil which might be present in the cells. After several weeks of extraction the various samples were examined. It was found that the spores remained unacted upon, while the contents of the cells were in every case extracted. The spores and the extracted cells settled to the bottom of the flasks. The solutions above the precipitates were of a light yellowish color in the acetone, alcohol, and ether extracts. With gasolene the gelatinous material floated upon the water present, which was colored a deep blue from the extraction of the cyanophyll.

The liquid above the precipitates in the several extracts was filtered off and evaporated upon watch glasses. The odors from these residues were in all instances, with the exception of the residue from the gasolene, entirely unlike the original odor of the Anabæna. In the case of all the residues, except that from the gasolene, a large amount of organic material had been extracted, and this material gave a very distinct odor of its own, which may have covered up or changed the odor of any oily product present.

The gasolene used had been especially prepared for the purpose by allowing it to stand over concentrated sulphuric acid for nearly a year. It was then neutralized and carefully washed. This gasolene, of itself, gave no odor whatever upon evaporation. It also had the advantage over the other solvents in extracting nothing but the essential oil, in evaporating very rapidly, and in not being miscible with water.

On examination, the extracted material from the gasolene was found to consist of minute oil globules of exactly the same appearance as the essential oils, and giving the natural odor of fresh Anabæna very strongly and distinctly. The odor disappeared in a few days and only a resinous material remained. A microscopical examination of the extracts, which had previously been placed in a closed air cell, showed in one or two cases the presence of minute needle-like crystals which projected from the oil globules in all directions. It is a well-known fact that the essential oils often form needle-like crystals upon oxidation in the air. This explains the difficulty in isolating the minute oily products found in many of the microscopical growths in water. When concentrated by most methods they are oxidized or changed before the final product can be obtained. In most cases, when the odor due to an essential oil begins to diminish and finally to disappear, it has been found that an oxidation of the hydrocarbon has occurred, and the oil has become a resinous body which is quite inodorous.

Beilstein[1] says, regarding essential oils, that they are commonly terpenes or polymeric derivatives of them, and that only very rarely are they entirely without terpenes in their composition. These bodies are rapidly oxidized by moisture and air to resinous compounds.

In using ether, alcohol, or acetone, we have compounds all of which contain oxygen and all of which are more or less miscible with water. This makes the chance of oxidation much greater than in the case of gasolene, which contains no oxygen in its composition and is not miscible with water. It may well be that the odor had disappeared from the ether, alcohol, and acetone extracts because of the oxidation of the oil, whereas, in the case of the gasolene, the oxidation had not taken place at all, or at least, had not gone so far.

Upon examination of the gasolene extract of Anabæna, after standing eighteen months, the characteristic grassy odor was still readily recognizable upon evaporation of the gasolene. The odor soon disappeared, however, after the gasolene had evaporated, showing the probable rapid oxidation of the odor-giving oil.

It is not surprising that the extremely minute quantity of oily matter which is present in Anabæna, and which is sufficient to produce an odor, should be so difficult to isolate, when we consider the instability of compounds of this nature, and the opportunities for oxidation under the artificial conditions imposed.

The foregoing experiments, in connection with what has already been recorded in regard to the odors of growth of the Diatomaceæ and of the infusoria, point to the conclusion that the odors produced by the undecomposed microscopical[2] organisms in drinking water are all due to compounds of the nature of essential oils.

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[1] Handb. d. organischen Chemie. 2 Aufl., 3, 303.

[2] Report Mass. State Board of Health, Part II, page 797.

ANABÆNA. ODOR OF DECAY.

At Ludlow Reservoir, in the latter part of October, 1895, a considerable quantity of the Anabæna, which had been left upon the edges of the reservoir after the water had been drawn down, was in varying stages of decay. In a cove sheltered from the wind, the water in several places near the shore was covered with a greenish scum or slime. Portions of this scum were streaked with yellow and brown matter, while in various places the water appeared to be covered with a light blue coating of a gelatinous nature. Deposited upon the edge of the reservoir in the hollows of the ground were masses of a blue-green jelly which gave off a decidedly offensive odor. Large lumps of this jelly floated near the shore upon the surface of the water.

Several large bottles of the fresher material were collected and brought to the laboratory. Analysis of the green gelatinous Anabæna at a stage just before decay sets in shows it to contain, when dry, 9.66 per cent. of nitrogen. This very high percentage of nitrogen is undoubtedly one of the reasons for the production of an offensive odor during decomposition. The analysis is of a pure culture of *Anabæna circinalis.* Dr. T. M. Drown[1] made an analysis of the growth from Ludlow Reservoir in 1889, and obtained 7.42 per cent. of nitrogen, but at that time the growth was mixed with Clathrocystis and other organisms. Previous to that time Professor W. R. Nichols[2] analyzed the growth in Ludlow Reservoir and obtained 11.18 per cent. of nitrogen. This was also a mixed growth.

The material in the bottles immediately began to form a gas which forced the gelatinous matter up to the neck of the bottle in the form of froth. One of these bottles was sealed, and the gas evolved was collected in a flask inverted over mercury. The evolution of the gas ceased after four or five days, and during that time several complete analyses were made of the gas which was collected. This work was also duplicated with samples of Anabæna collected subsequently.

The gas given off from the decomposing Anabæna contained the merest trace of hydrogen sulphide, but gave a strong test for sulphate after being passed through bromine water. This shows that there were volatile sulphur compounds in the gas which were only partially

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[1] The Chemical Examination of Waters, Mass. State Board of Health (1890), p. 549. Examination of Water Supplies.

[2] Ninth Annual Report Mass. State Board of Health (1878), p. 157.

decomposed, and yet were in a state to produce a highly offensive odor.

The following table gives the average results of the analyses of several samples of this gas taken at different times:

ANALYSIS OF GAS EVOLVED FROM THE BACTERIAL DECOMPOSITION OF ANABÆNA.

Marsh gas	.8%
Carbonic acid	1.5%
Oxygen	2.9%
Nitrogen	12.4%
Hydrogen	82.4%

The large percentage of hydrogen given off suggests a number of interesting questions. The gas which remained dissolved in the liquid contained in the bottle, and which was consequently not evolved, was practically all carbonic acid and represented a very high percentage of the total gas produced.

The decomposing organisms in the bottles brought to the laboratory passed through several stages of decay. After the evolution of gas ceased, the green jelly-like mass became brownish in color, and floated upon the surface of the water. The water was highly colored by the cyanophyll which had been dissolved out of the cells of the Anabæna. The color of this water was a deep blue by transmitted light, and a blood red by reflected light. After several weeks the blue color disappeared, and the brown gelatinous mass containing the living spores of the Anabæna settled to the bottom of the bottle. An analogous state of affairs doubtless exists in reservoirs infested with Anabæna. The spores are set free in a similar manner by the decomposition of the organisms, and settle to the bottom of the reservoir to be revived when the conditions are again favorable for their growth.

The extremely disagreeable odor of the decomposing organisms, together with the presence of a considerable amount of sulphur in the gas evolved, led us to suspect the presence of a large amount of sulphur in the organism itself. It is well known that the mercaptans, and other organic compounds containing sulphur, give off very offensive odors, and it was thought that some such compounds might be formed by the bacterial decomposition of Anabæna. While we did not isolate any specific compound, analyses of the gelatinous material resulting from the decomposition of Anabæna showed the presence of a large amount of sulphur and a considerable amount of phosphorus. A sample of *Aphanizomenon flos-aquæ* from Lake Cochituate which was collected by G. C. Whipple, Biologist of the Boston Water Works, produced the "pig pen" odor upon decomposition, and also showed a high per cent. of sulphur upon analysis. Etard and Olivier[1] have shown that in case of Oscillaria this sulphur is obtained by the organism from the sulphates dissolved in the water.

The odor of decomposing Anabæna is evidently not due, to any extent, to the production of hydrogen sulphide, but to the partial breaking-down of highly organized compounds of sulphur and phosphorus. The odor is undoubtedly more offensive on account of the high per cent. of nitrogen present. It is true of the whole organic world that those products which give the most offensive odors of decay are partially decomposed, highly nitrogenous compounds, containing sulphur or phosphorus.

In conclusion, we wish to draw a marked distinction between the odors of growth and the odors of decay of the organisms occurring in surface waters.

The *usual* cause for the disagreeable odors and tastes occurring in potable water is found in the presence of large numbers of certain microscopical organisms which secrete compounds of the nature of essential oils.

These odors and tastes are caused by *living*, or undecomposed organisms; and although they are often very disagreeable, the compounds which produce them are as harmless as those which give odors and tastes to fresh vegetables or fish.

On the other hand, the "pig pen" odor of the Cynophyceæ (blue-green algæ) is produced by the decay of highly nitrogenous organic matter in which partially decomposed sulphur and phosphorus compounds play the leading part. The sanitary significance of these partially decomposed compounds in drinking water is yet to be determined, but analysis would indicate that their effect upon the general health would be unfavorable were it not for the fact that they occur in such minute quantities.

In the case of the odors of growth, the ready oxidation of the odor-giving principle to form a non-odorous compound is of practical significance. It is possible that by the selection of filtering materials which

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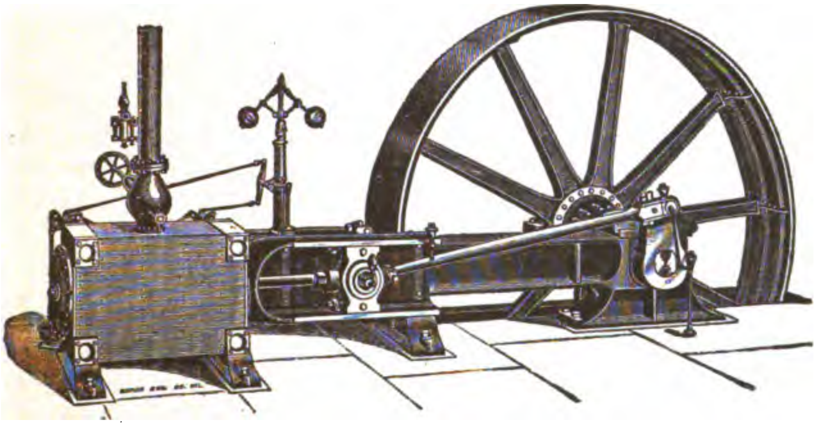
[1] Comptes Rendus de l'Academie des Sciences, Paris. Vol. 95, 1882, 846–849.

would liberate and subsequently either oxidize or absorb the oily products, we might be able during the season when these growths are most abundant, to materially improve many of our public water supplies which are periodically infested with disagreeable organisms.

There is a wide field open for the investigation of the growth and decay of micro-organisms from a chemical standpoint. A better knowledge of the chemical composition of the organisms themselves, and of the organic and mineral contents of the waters which the various genera infest, would undoubtedly better enable an expert to judge whether this or that proposed water supply is likely to be favorable or unfavorable to the growth of any of the objectionable micro-organisms occurring in surface waters.

We wish to express our obligations to Professor W. T. Sedgwick, Mrs. E. H. Richards, and Professor A. H. Gill, for valuable suggestions in the preparation of this paper.



Life and Letters of William Barton Rogers.

The Editor of the TECHNOLOGY QUARTERLY is authorized to receive subscriptions for the "Life and Letters" of President Rogers at $3.00 per copy (a reduction of twenty-five per cent).

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Everyone who knows this work appreciates its unique value, not only as containing the history of the early years of the Institute, but as giving an account of the formative period of American science.

Address Editor Technology Quarterly,
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REVIEW

—OF—

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VOL. III. 1897.

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the Massachusetts Institute of Technology.

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REVIEW OF AMERICAN CHEMICAL RESEARCH.[1]

VOL. III. NO. 1.

INORGANIC CHEMISTRY.

BY HENRY FAY, REVIEWER.

On the Diffusion of Sulphides through Steel. BY E. D. CAMPBELL. *Am. Chem. J.*, 18, 707–719.—In a previous paper (*Am. Inst. Min. Eng.*, 23, 621), the author has described the rapidity with which sulphide of iron diffused through steel at a bright red heat. Bars of soft steel of the dimensions 2.5 × 5 × 15 cm., and the ordinary fused sulphide of iron were used. Holes 12 mm. in diameter and 30 mm. deep were filled with 10 grams iron sulphide, and an iron plug was driven in. After heating to a bright red heat in a muffle, the bar was allowed to cool slowly. The hole was then found nearly empty, and drillings taken near the hole showed on analysis no increase in sulphur, while the scale formed at the surface by oxidation showed 2.6 per cent. of sulphur. These experiments were taken up later, but a different specimen of iron sulphide was used. Though carried out in exactly the same manner, no diffusion was found to take place. A Hoskins muffle furnace was arranged so that the sulphide in the hole could be watched during the heating. Using the normal sulphide of iron, FeS, in both open and plugged holes, the sulphide was seen to melt, but no diffusion took place. A subsulphide, approximately of the composition, Fe_2S, was next made, and a bar 5 cm. long was prepared with two holes equally distant from the center and ends; each hole was filled with 12 grams of the sulphide. The bar was placed in the furnace on platinum covered supports, and heated to a bright red heat in an oxidizing atmosphere for about two hours. No diffusion was noticed. An oxysulphide of iron was then prepared and found to diffuse quite rapidly. In from 10–15 seconds from the time the sulphide was observed to begin

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[1] This Review, which for two years past has appeared in the *Technology Quarterly* and as a separate publication, will hereafter be published only in this journal and in the *Technology Quarterly*. Copies of the two preceding volumes may be obtained by addressing the Librarian of the Massachusetts Institute of Technology, Boston, Mass.

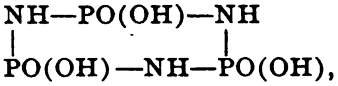
diffusing, diffusion appeared to be complete and the greater part of the sulphur had been oxidized in the air at the temperature of the experiment. To show that the oxysulphide diffuses the whole length of the bar, a bar 10 cm. long was prepared, and a hole was drilled 12 mm. from the end. At the further end a strip of asbestos was placed, held in position by a wire passing around the bar. The temperature was brought to a bright red heat, and after cooling the portions of asbestos in contact with top and bottom were found black from oxide of iron, due to the complete diffusion. Cuprous sulphide was found not to diffuse at all, but mixed with oxysulphide of iron it was carried along with it. Nickel sulphide does not diffuse alone, nor when mixed with iron oxysulphide. The author explains the phenomenon by assuming that oxysulphide of iron is an extremely mobile liquid at the temperature of the experiment, and that steel is probably porous at the high temperature, so that diffusion can take place; the diffusing substance would readily be absorbed by any porous absorbent material, such as asbestos or scale. Cuprous sulphide he considers is not sufficiently mobile to be drawn through the fine pores of the steel. Gravity affects the diffusion, showing that the diffusion takes place in the liquid, and not in the gaseous state.

On the Influence of Heat Treatment and Carbon upon the Solubility of Phosphorus in Steels. By E. D. Campbell and S. C. Babcock. *Am. Chem. J.*, **18**, 719–723.—This work was undertaken to see whether heat treatment and carbon influence the solubility of phosphorus, and to determine whether chemical evidence could be obtained to prove the existence of phosphorus in steels in different modifications. For this purpose samples were taken containing varying percentages of carbon, and subjected to different heat treatments. The phosphorus was determined in each in an annealed sample, in a hardened one, and in a normal portion, as it came from the mill. In each sample a determination was made of the total phosphorus, of the phosphorus soluble and insoluble in neutral mercuric chloride, and of that insoluble in neutral mercuric chloride but soluble in 4 per cent. hydrochloric acid. The phosphorus soluble in mercuric chloride was determined by shaking 5 grams of steel with 35 grams of mercuric chloride and 130 cc. of water. The filtrate was examined for phosphorus by adding 10 cc. of ferric chloride solution, in which the phosphorus had been previously determined, and 4 grams sodium acetate, precipitating as basic acetate, dissolving and reprecipitating with ammonium molybdate. The portion insoluble in mercuric chloride was placed, together with the mercury, in a boat in a combustion tube, and after the mercury had been volatilized, the phosphorus was determined in the residue. From the table of results given, the following conclusions are drawn: 1. With very low percentage of carbon, the effect of heat treatment upon the solubility of phosphorus is slight. Probably if carbon were entirely absent there would be no effect. 2. With increase of carbon the effect of hardening is to decrease the solubility of the phosphorus. 3. With a high percentage of carbon the solubility is increased by slow cooling. The author considers that these facts indicate the probable formation at a high temperature of a difficultly soluble compound of iron with carbon and phosphorus, which on slow cooling passes into an easily soluble one.

A Pure Carbide of Iron. By E. D. Campbell. *Am. Chem. J.*, 18, 836–847.—The investigation was undertaken to see whether a purer carbide of iron than any heretofore isolated could be obtained, and to determine whether a formula as simple as CFe_3 should be assigned to it. The steel used in the work was one containing 1.29 per cent. of carbon. It was cut into bars and the bars carefully annealed by packing between layers of sheet asbestos; below these was a layer of crushed charcoal, and above a mixture of one part of charcoal to five of wood ashes. The muffle in which the whole was placed, was brought to a bright red heat, the fires banked, and allowed to cool slowly. After cooling, the scale was removed by grinding on an emery wheel, and the bars were cut into strips 15 cm. long, 15 mm. wide, and 5 mm. thick. Twelve of these bars were hung on a ring of copper wire in a 4 per cent. solution of hydrochloric acid and connected with the positive pole of four storage batteries. The negative pole was a platinum cylinder suspended in a porous cup placed in the center of the circle of bars. A current of one ampere was allowed to act over night, and in the morning the residue adhering to the bars was removed with a brush of aluminum wires. The carbide was washed with potassium hydroxide and water, and the lighter portions decanted off. The carbide remaining was washed with alcohol and ether, the dried product consisting of a bright steel gray powder made up of thin plates or scales of specific gravity 6.944. After 29 electrolyses 575.8 grams of steel were dissolved and 55.1 grams of carbide obtained. On analysis the substance gave 6.646 and 6.625 per cent. carbon, 93.25 per cent. iron, and 0.026 per cent. phosphorus. The carbide is slowly but completely converted into ferric oxide by oxidation in moist air, and is completely soluble in moderately concentrated hydrochloric acid. An examination of the gases evolved on treatment with acid showed them to be hydrogen, ethane, and the unsaturated hydrocarbon butylene, probably mixed with a little dibutylene. Butane probably remained in the solution in the generating flask. The author considers it not improbable that iron and carbon may form a series of ferrocarbons of the general formula C_nFe_{3n}, analogous to the hydrocarbons C_nH_{2n}, in which a group of three bivalent iron atoms would replace two hydrogen atoms of the unsaturated hydrocarbon. On treatment with acids the corresponding hydrocarbon would be set free, and would be partly converted into the corresponding saturated hydrocarbon by secondary reactions.

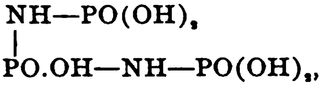
The Alkali Trihalides. BY CHARLES H. HERTY AND HOMER V. BLACK. *Am. Chem. J.*, **18**, 847–849.—It has been previously shown by Herty that the so-called compounds PbICl, $PbI_2.2PbCl_2$, and $PbI_2.5PbCl_2$ are isomorphous mixtures of lead iodide and lead chloride. To determine whether the alkali trihalides are of the same nature, rubidium dibromiodide was prepared by adding bromine to rubidium diiodide. On evaporation three separate crops of crystals, similar in appearance, were obtained, and each crop was analyzed, giving results which indicated that they were all of the same composition, namely, that represented by the formula $RbBr_2I$. They are therefore not isomorphous mixtures.

On Trimetaphosphimic Acid and Its Decomposition Products. BY H. N. STOKES. *Am. Chem. J.*, **18**, 629–663.—In a previous paper the author has shown that by shaking with water an ethereal solution of Liebig's phosphorus chloronitride, $P_3N_3Cl_6$, an acid is obtained which has the empirical formula $P_3N_3O_6H_6$, and to which he gave the name trimetaphosphimic acid. He regarded the acid as a metaphosphoric acid $(HPO_3)_n$, in which one-third of the oxygen is replaced by an equivalent number of imido (NH) groups. The acid is best prepared by agitating 30 grams of phosphorus chloronitride dissolved in 150 cc. alcohol-free ether with a solution of 110 grams of sodium acetate in 200 cc. of water. After 15 hours well formed crystals of the sodium salt appear, and after 70–80 hours the reaction is complete. The constitution of trimetaphosphimic acid depends upon that of the phosphorus chloronitride. The structural formula of the latter has not been definitely established, but it is reasonably certain that the phosphorus atoms are joined by nitrogen, otherwise the formation of hydrazine might be expected. It is quite likely, also, that chlorine is not united to nitrogen; for in this case hydroxylamine might be expected. The simplest formula meeting the requirements is one in which the nucleus consists of a symmetrical ring of three phosphorus and three nitrogen atoms. Direct replacement of chlorine would give an acid in which the grouping $-(OH)_2P = N-$ is repeated three times in the ring, but the author considers that the labile nature of the hydrogen, as observed in many organic substances containing nitrogen, makes it not improbable that the grouping may take the tautomeric form $-(OH)PO-NH$. This assumption is in accordance with the facts, and explains the formation and decomposition of trimetaphosphimic acid. The acid is extremely soluble, uncrystallizable, and undergoes rapid spontaneous decomposition. The final decomposition products are phosphoric acid and ammonia, but the intermediate products, diimidotriphosphoric acid, imidodiphosphoric acid, and pyrophosphoric acid have been isolated. Assuming the symmetrical ring formula referred to above:



$$\begin{array}{l}\mathrm{NH{-}PO(OH){-}NH}\\ |\qquad\qquad\qquad\quad |\\ \mathrm{PO(OH){-}NH{-}PO(OH)},\end{array}$$

the decomposition with water takes place with the formation of ammonia and diimidotriphosphoric acid:

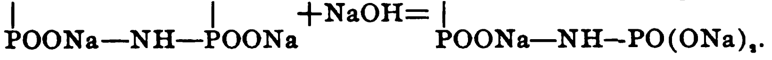


$$\begin{array}{l}\mathrm{NH{-}PO(OH)_2}\\ |\\ \mathrm{PO.OH{-}NH{-}PO(OH)_2},\end{array}$$

this again reacting with water to form ammonia and imidodiphosphoric acid: $\mathrm{NH}<\begin{matrix}\mathrm{PO(OH)_2}\\ \mathrm{PO(OH)_2}\end{matrix}$, and phosphoric acid. The imidodiphosphoric acid then reacts with water to form pyrophosphoric acid and ammonia; this reaction is shown to take place by heating the free acid with dilute acetic acid, when about 15 per cent. pyrophosphoric acid is obtained. The sodium salt of trimetaphosphimic acid, $P_3N_3O_6H_3Na_3.4H_2O$, was prepared by treating an ethereal solution of phosphorus chloronitride with sodium acetate. When crystallized above 80° C. it contains only one molecule of water. The ammonium salt,

$$P_3N_3O_6H_3(NH_4)_3.H_2O,$$

and the silver salt, $P_3N_3O_6H_4Ag_2$ are characteristic, and serve to identify the acid. The silver salt, $P_3N_3O_6Ag_6$ exists in two well defined forms. Its analysis serves to establish the empirical composition of the acid. One of these silver salts is white, amorphous, and soluble in ammonium nitrate, and is easily converted by this reagent into the other, which is red, crystalline, and insoluble in it. By crystallizing the tertiary sodium salt from an excess of sodium hydroxide a salt containing four atoms of sodium is obtained. The author considers it as an amido derivative of diimidotriphosphoric acid, assuming that sodium hydroxide is added directly to the molecule of the trisodium salt in this way:



$$\begin{array}{l}\mathrm{NH{-}POONa{-}NH}\\ |\qquad\qquad\qquad\quad |\\ \mathrm{POONa{-}NH{-}POONa}\end{array} + \mathrm{NaOH} = \begin{array}{l}\mathrm{NH{-}POONa{-}NH_2}\\ |\\ \mathrm{POONa{-}NH{-}PO(ONa)_2}.\end{array}$$

Silver nitrate precipitates a salt from the tetra sodium salt, but it decomposes so readily that satisfactory analytical results could not be obtained. Diimidotriphosphoric acid forms two series of salts, in which three and five atoms, respectively, of hydrogen are replaced. The alkali salts with three atoms of metal are neutral; those with five atoms have an alkaline reaction. The two remaining hydrogen atoms have not been replaced by metal. Imidodiphosphamic acid is probably identical with Gladstone's pyrophosphamic acid. It forms a tri and a tetra silver salt, the latter existing in two distinct forms. The acid can be distinguished from amidodiimidotriphosphoric acid by the insolubility of its magnesium salt, by its syrupy tertiary sodium salt, and by the yellow precipitate which its ammoniacal solution gives with silver nitrate.

On Tetrametaphosphimic Acid. By H. N. Stokes. *Am. Chem. J.*, **18**, 780–789.—Tetrametaphosphimic acid can be obtained by agitating tetraphosphonitrilic chloride, $P_4N_4Cl_8$, dissolved in 15 volumes of alcohol-free ether with five volumes of water. Chlorhydrines are formed as intermediate products, but remain dissolved in the ether, while the free acid separates in crystalline condition. From one of the chlorhydrines an acid was obtained, but in too small amount to determine its composition. Tetrametaphosphimic acid can also be obtained in the form of its ammonium salt by agitating the chloride with aqueous ammonia or ammonium acetate. In the latter case the yield is theoretical. The free acid crystallizes with two molecules of water, $P_4N_4O_8H_8.2H_2O$, which are not given off in vacuo. At 100° C. it loses weight at first rapidly, and then slowly, but the total loss never reaches the theoretical. Heated rapidly to 130–140° C. the loss is soon replaced by a gain, and after 30 hours at this temperature an increase of 11.15 per cent. was observed. The product consisted of unchanged acid, with ammonium phosphate and apparently pyrophosphoric acid. One hundred parts of water at 20° C. dissolve 0.64 parts of the crystallized acid. Boiling alkaline solutions cause no evolution of ammonia. It is extremely stable towards acids. Experimental data are lacking for a discussion of the constitution of this acid, as the decomposition products are extremely unstable. Presumably the phosphorus atoms in the nucleus P_4N_4 are united by nitrogen atoms, but whether they constitute a ring of eight atoms cannot be decided. Three series of salts are formed, $P_4N_4O_8H_6M'_2$, $P_4N_4O_8H_4M'_4$, and $P_4N_4O_8M'_8$. The dipotassium, tetrasodium, di- and tetra-ammonium, dibarium, and tetrasilver salts are described. If an ammoniacal solution of a salt containing four atoms of metal is added to an excess of silver nitrate, a yellow flocculent precipitate forms which is insoluble in ammonium nitrate. When, however, a neutral tetrametaphosphimate is added to silver nitrate containing a slight excess of ammonia, a small amount of a nearly white flocculent precipitate forms which is soluble in ammonium nitrate on gently warming; from this solution an orange yellow crystalline substance is thrown out on boiling for a moment. From the original filtrate a large quantity of the same salt is obtained by boiling. Each salt contains eight atoms of silver, and the crystalline salt is apparently a modification of the yellow precipitate formed in the first case. The author suggests that these salts may be regarded as corresponding to the tautomeric forms of the acid $(PN(OH)_2)_4$ and $(PO.NH.OH)_4$.

Mercuric Chlorthiocyanate. By Charles H. Herty and J. G. Smith. *J. Am. Chem. Soc.*, **18**, 906–908.—By fractional crystallization and analysis of the different crops of crystals, the authors conclude that mercuric chlorthiocyanate is a true chemical compound, and not an isomorphous mixture of mercuric chloride and mercuric thiocyanate.

Nickelo-Nickelic Hydrate, $Ni_3O_4.2H_2O$. By William L. Dudley. *J. Am. Chem. Soc.*, **18**, 901–903.—Nickelo-nickelic hydrate, $Ni_3O_4.2H_2O$, was obtained in crystals by fusing metallic nickel with sodium peroxide.

Contribution to the Knowledge of the Ruthenocyanides. By James Lewis Howe. *J. Am. Chem. Soc.*, **10**, 981–987.—The author has tried many methods for the preparation of ruthenocyanide to ascertain the efficiency of each, has given some qualitative reactions, and has prepared and analyzed the potassium and barium salts.

Some New Compounds of Thallium. By L. M. Dennis and Martha Doan, **with Crystallographic Notes,** by A. C. Gill. *J. Am. Chem. Soc.*, **18**, 970–977.—The authors have prepared the compounds thallous trinitride, TlN_3, thallous-thallic trinitride, $TlN_3.TlN_9$, thallous tellurate, Tl_2TeO_4, and thallous cyanplatinite, $TlPt(CN)_4$. The author calls the acid HN_3 hydronitric acid and its salts trinitrides. Owing to the fact that other nitrides besides those derived from this acid exist, it is far preferable in the reviewer's opinion to name the acid *hydrazoic acid*, in accordance with the proposal of its discoverer, and to call its salts *azides*.

Reduction of Concentrated Sulphuric Acid by Copper. By Charles Baskerville. *J. Am. Chem. Soc.*, **18**, 942–947.—The author refutes the statement of Andrews (*this Rev.*, **2**, 6,) that copper is not acted upon at 0° C., and not until 86° C. has been reached, which is above the point of dissociation of sulphuric acid. The previous work of the author has been repeated and confirmed. He also shows that, when air is absent, sulphuric acid is reduced by copper at a temperature far below 86° C. with formation of cupric sulphate, cuprous sulphide and sulphur dioxide.

ORGANIC CHEMISTRY.

J. F. NORRIS, REVIEWER.

The Action of Sodium on Aldehyde. BY PAUL C. FREER. *Am. Chem. J.*, 18, 552–562.—When aldehyde, diluted with ether, was treated with sodium, hydrogen was evolved and a white crystalline sodium derivative, believed to have the structure $CH_2 : CHONa$, was formed. The compound could not be analyzed, as it soon changed into a brown, sticky mass. Sodium reacted with an ethereal solution of aldehyde and benzoyl chloride. After the reaction was completed, the solvent was washed with potassium hydroxide to remove benzoic acid, dried, and evaporated in a vacuum. A thick, slightly yellow syrup, which soon became permeated with a mass of prismatic crystals, was obtained. The latter melted at 86°–87°, had the composition $C_{13}H_{16}O_4$, and were soluble in alcohol, ligroïn, benzene, and chloroform. By treatment with water at 100° in a closed tube, the compound was decomposed into benzoic acid, aldol, and aldehyde. Destructive distillation, decomposition at 100° with hydrochloric acid, and heating the pure compound at 150° in a sealed tube, yielded, in each case, the same products: benzoic acid, crotonic aldehyde, and acetic aldehyde. When warmed with alkali, solution takes place and aldehyde resin is formed. The compound does not react with dilute alkalies, bromine, cold potassium permanganate, or phenylhydrazine. From the behavior of the compound, the author concludes that it is aldehydo-aldolbenzoate,

$$\begin{matrix} C_6H_5COO \\ CH_3 \end{matrix} > CHCH_2CH < \begin{matrix} O \\ O \end{matrix} > CHCH_3.$$

In the preparation of the substance, sodium acetaldehyde, which is first formed, condenses to a derivative of aldol, which, in turn, reacts with the benzoyl chloride present. As the benzoyl group in the resulting compound is joined to oxygen, the structure of sodium acetaldehyde is $CH_2 : CHONa$. The liquid product of the action of sodium on aldehyde and benzoyl chloride was shown to be aldol benzoate by comparing its behavior, when subjected to destructive distillation, with that of a similar compound prepared from aldol, benzoyl chloride, and sodium.

On the Constitution of Some Derivatives of Formic Acid. BY PAUL C. FREER AND P. L. SHERMAN, JR. *Am. Chem. J.*, 18, 562–584.—As the physical and chemical properties of formic acid are not in accord with the constitutional formula assigned to it, the authors undertook an investigation of formylphenylhydrazine, formamide, and formic ester, in order to throw some light on the structure of the formyl group —CHO. When formylphenylhydrazine was dissolved in a concentrated alcoholic solution of sodium ethylate and the solution diluted with ether, a mono-sodium salt crystallized out. To determine the position of the sodium atom, the substance was treated with ethyl iodide under different conditions. When suspended in dry ether, mono-ethylformylphenylhydrazine was obtained, which melted at 106° and crystallized in rhombohedra. As the compound was not saponified by sodium hydroxide, and its reduction products were aniline and ethylamine, it follows that its structure is $C_6H_5NH—N(C_2H_5)—CHO$. It did not react with ethyl iodide and sodium ethylate or with sodium. When the sodium salt of formylphenylhydrazine was dissolved in absolute alcohol, a mono-ethyl derivative, melting at 78°–79°, and crystallizing in needles, was obtained. Its constitution, as shown by its reduction-products, unsymmetrical ethylphenylhydrazine, ethylaniline, and ammonia, is $C_6H_5NC_2H_5—NH—CHO$. When treated with ethyl iodide and sodium ethylate, diethylformylphenylhydrazine was formed. The latter compound did not react with sodium, and gave as reduction-products ethylamine and ethyl aniline. The formation of the two mono-ethyl derivatives excludes the possibility that the sodium atom is attached to oxygen because, were addition of ethyl iodide to take place at the unsaturated nitrogen-linking, with a subsequent splitting off of sodium iodide or hydriodic acid, but one ethyl derivative, with the structure $C_6H_5NH—NC_2H_5—CHO$, could be obtained. Acetic anhydride reacted with formylphenylhydrazine, forming a compound in which the acetyl group was joined to nitrogen. Benzoyl chloride and sodium ethylate gave a mono- and dibenzoylformylphenylhydrazine. The sodium derivative of the latter was prepared. Chlorcarbonic ester and formanilide reacted with the formation of ethylisoformanilide, $C_6H_5N = CHO.C_2H_5$, and diphenylformamidine, $C_6H_5N = CH—NH—C_6H_5$. Sodium reacted with formic ester in the cold, yielding hydrogen, carbon monoxide, and sodium ethylate. When amyl formate was used, the reaction was slower; sodium amyl formate was first formed and then broke down. The authors conclude that the above reactions prove that the sodium in sodium formylphenylhydrazine is attached to nitrogen and that, therefore, no hydroxyl group is present. They do not furnish any evidence of the presence of an aldehyde group and, consequently, a structural formula according to the present theories is not possible. On the other hand, there is evidence of a hydroxyl grouping in the salts of formanilide. No explanation can be given of the fact that diethylformylphenylhydrazine, in which there is a grouping similar to that in formic ester, does not react with sodium, whereas the ester reacts with sodium readily.

On Certain Derivatives of Trichlordinitrobenzol. By C. Loring Jackson and W. R. Lamar. *Am. Chem. J.*, **18**, 664–

685.—For several years the behavior of tribromdinitrobenzene, melting at 192°, with various reagents, has been studied by Jackson and his pupils. The action of the analogous chlorine derivative with aniline, sodium ethylate, and sodium malonic ester is described in the present paper. When heated with aniline, trichlordinitrobenzene, melting at 129°.5, gives the same trianilidodinitrobenzene which was obtained from tribromdinitrobenzene. With sodium ethylate in the cold, trichlordinitrobenzene lost two of its atoms of chlorine, which were replaced by two ethoxy groups, forming chlordinitroresorcine diethyl ether, which melts at 160°. The reaction is analogous to that with the bromine derivative. A hot solution of sodium ethylate changed tribromdinitrobenzene into dinitroresorcine diethyl ether, while, under the same conditions, the chlorine compound was converted into a mixture of dinitrophloroglucine triethyl ether, $C_6H(NO_2)_2(OC_2H_5)_3$, which melts at 104°–105°, and its diethyl ether, $C_6H(NO_2)_2(OC_2H_5)_2OH$, melting at 166°. When treated with sodium malonic ester, two bromine atoms are removed and bromdinitrophenylmalonic ester,

$$C_6H_2Br(NO_2)_2CH(COOC_2H_5)_2,$$

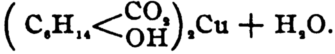
is formed. Trichlordinitrobenzene gives with the same reagent dichlordinitrophenylmalonic ester,

$$C_6HCl_2(NO_2)_2CH(COOC_2H_5)_2.$$

Both substituted malonic esters are saponified by boiling with sulphuric acid, forming the corresponding phenylacetic acids, but the dichlordinitrophenylacetic acid,

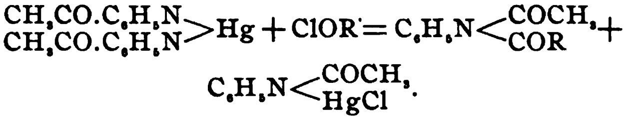
$$C_6HCl_2(NO_2)_2CH_2COOH,$$

differs from the bromdinitrophenylacetic acid in that the latter is so unstable that five crystallizations from alcohol convert it into bromdinitrotoluene, whereas the former can be crystallized from water without change. When boiled some hours with alcohol, dichlordinitrophenylacetic acid is converted into its ethyl ester. Both substituted malonic esters give red sodium salts, and are converted into nitrites by the action of nitric acid. Bromdinitrophenylacetic acid gives an intense green coloration with sodium hydroxide. Dichlordinitrophenylacetic acid is changed by the same reagent to a red compound, which soon fades to white.

Camphoric Acid. By W. A. Noyes. *Am. Chem. J.*, **18**, 685–692.—In this paper, the fourth contributed by the author on the subject of camphoric acid, evidence is brought forward which disproves the formula of camphor proposed by Tiemann. In a previous paper (*Am. Chem. J.*, 17, 421), several reasons were given for believing that camphoric acid is a derivative of succinic rather than glutaric acid. This opinion has received additional support from the work described in the present paper, and it follows, therefore, that Bredt's formula for camphor is also incorrect. As it has been shown by the author (*loc. cit.*) that dihydrohydroxycampholytic acid contains a tertiary hydroxyl group, it follows that the carboxyl of aminolauronic acid is also tertiary. Independent investigations of Walker (*J. Chem. Soc.*, 63, 506) and the author (*Am. Chem. J.*, 16, 509; and *loc. cit.*) prove that the carboxyl in dihydroaminocampholytic acid is secondary. There should, accordingly, be a marked difference in the rate of esterification of the two acids. Ten times as much ester was obtained from the latter as from the former. The result disproves Tiemann's formula, for according to it the rate of esterification should be identical in both cases. The ethyl ester of aminolauronic acid is a mobile, strongly basic liquid with an ammoniacal, aromatic odor, and forms a sulphate difficultly soluble in water, which crystallizes in pearly-white plates. When the sulphate of the ester of aminolauronic acid is treated with a strong solution of sodium nitrite, it is decomposed with the formation of the ethyl ester of γ-lauronic acid and a small amount of the ester of a new hydroxylauronic acid. The two acids are separated by distillation with steam, after saponification of the esters. The hydroxy acid, which is non-volatile, is extracted with ether and is left, after evaporation of the solvent, as a viscous, hygroscopic liquid, which forms an insoluble copper salt,  $\left(\mathrm{C_8H_{14}}<^{\mathrm{CO_2}}_{\mathrm{OH}}\right)_2\mathrm{Cu} + \mathrm{H_2O}$. The acid was shown to have a secondary hydroxyl group by the action of Beckmann's chromic acid mixture, which transformed it into the β-ketonic acid, which immediately decomposed into a ketone and carbon dioxide. Dihydro-cis-campholytic acid was prepared by reducing cis-campholytic acid with amyl alcohol and sodium. It melts at 244°, has the specific gravity 0.9833 at 20°, and is stable toward a cold solution of potassium permanganate. The amide melts at 161°. α-bromdihydro-cis-campholytic acid was prepared by treating the acid with phosphorus pentachloride and bromine. It melts at 129°–130°, and when treated with cold alcoholic potash, hydrobromic acid is removed and cis-campholytic acid is regenerated. This furnishes a new proof that the double union of cis-campholytic acid is in the α-β position and gives additional support to the view that the two campholytic acids are stereoisomers. Attempts to reduce the cis-trans-campholytic acid were unsuccessful. According to Armstrong's formula for camphor, cis-campholytic acid must be Δ'-tetrahydroxylylic acid. The reduction of xylylic acid, $\mathrm{C_6H_3(CH_3)_2(1,\ 3)COOH(4)}$, would give four stereoisomers, corresponding to which there would be four α-bromhexahydroxylylic acids. Two of these, supposing Armstrong's formula to be correct, would give ciscampholytic acid when treated with alcoholic potash ; and two would give either cis-trans-campholytic acid or Δ^6-tetrahydroxylylic acid. From the hexahydro acid, obtained by the reduction of xylylic acid, the α-brom derivative was prepared and, on treatment with alcoholic potash, did not yield any of the above products. The formula of Armstrong cannot, therefore, be the correct one.

Derivatives of Dihydro-cis-campholytic Acid. BY E. B. HARRIS. *Am. Chem. J.*, 18, 692–695.—From the amide of dihydro-cis-campholytic acid prepared by Noyes (see preceding abstract), an amine, $C_8H_{15}NH_2$, was prepared by the action of potassium hypobromite. It is slightly soluble in water, boils at 156°.5, and has the specific gravity 0.8431 at 20°. The chloride, sulphate, and chlorplatinate are described. In order to obtain the alcohol corresponding to the amine, the latter was converted into the sulphate and treated with sodium nitrite. The greenish-yellow oil obtained was separated by distillation with steam into an oil which boiled at 122°, probably the hydrocarbon C_8H_{14} ; a small quantity of a white crystalline substance, which was not identified ; and an oil which contained the alcohol $C_8H_{15}OH$. The latter was treated with Beckmann's mixture of sulphuric acid and potassium bichromate and the resulting ketone, after purification, converted into the oxime, which melted at 112°-113°. The properties of the oxime agree closely with those of the one prepared by Kipping (*J. Chem. Soc.*, 67, 357) from dimethyl—(1, 3)—cyclohexenone—(2). If the oximes are identical, campholytic acid is Δ'-tetrahydro—(1,2,3)—xylylic acid.

On Diacid Anilides. BY H. L. WHEELER. *Am. Chem J.*, 18, 695–703.—In recent papers (*Am. Chem. J.*, 18, 381 ; 18, 540) the author has shown that by the action of benzoyl chloride on the silver and mercury salts of the anilides, mixed diacid anilides can be obtained. In the present paper it is shown that the action of aliphatic chlorides is analogous to that of benzoyl chloride, and that the resulting diacid anilides react with alkali with the separation of the lower acid radical and the formation of the anilide of the higher acid. From this reaction it appears that the diacid anilides are nitrogen derivatives. The method of preparation was as follows : Silver formanilide or mercury acetamide was suspended in dry ether or benzene and one molecular proportion of acid chloride added. The action began immediately and was complete, in the case of the lower acid chlorides, in a few minutes. After filtering from the silver chloride or the halogen mercuric compound, the filtrates were shaken with water, and on evaporation of the solvent the diacid anilides were obtained as oils, which were purified by fractionation under diminished pressure. The reaction is as follows :



$$\begin{matrix}CH_3CO.C_6H_5N\\CH_3CO.C_6H_5N\end{matrix}\!>\!Hg + ClOR' = C_6H_5N\!<\!\begin{matrix}COCH_3\\COR\end{matrix} + C_6H_5N\!<\!\begin{matrix}COCH_3\\HgCl\end{matrix}.$$

The following compounds were prepared: Acetylacetanilide, formylacetanilide, formylpropionanilide, formyl-*n*-butyranilide, formylstearanilide, acetylpropionanilide, acetyl·*n*-butyranilide, acetylisovaleranilide, and acetylpalmitanilide. Formylpropionanilide and formylstearanilide are easily decomposed by heat, the former giving propionanilide, and the latter phenylisocyanide and stearic acid. Diacid amides are not formed by the action of acid chlorides on benzamide, the chief product being benzonitrile. From this fact it follows that different structures must be assigned to amides and anilides, if the action of acid chlorides is a direct double decomposition in both cases. The author suggests the possibility of the formation of unstable addition-products in one case, which break down into simple bodies.

On Malonic Nitrile and Some of its Derivatives. By B. C. Hesse. *Am. Chem. J.*, **18**, 723–751.—In order to determine whether the metal is joined to nitrogen or to carbon in the salts of malonic nitrile, the silver and sodium derivatives were prepared and their reactions with a number of reagents studied. Dry cyanacetamide, suspended in ether, does not react with sodium unless alcohol is present, when the mono-sodium salt is obtained. Dibromcyanacetamide is found by the action of one molecular proportion of bromine on cyanacetamide in aqueous solution. Malonic nitrile was prepared by fractionating the product obtained by heating equal weights of phosphorus pentachloride and cyanacetamide at 90° until the evolution of hydrochloric acid ceased. It is a white, ice-like solid, which melts at 29° and boils at 219°–220°. By the action of bromine on malonic nitrile, fused or in aqueous solution, a mixture of oils and amorphous and crystalline solids is produced. The latter bodies alone were studied, and proved to be the brom- and dibromderivatives of the nitrile. Brommalonic nitrile melts at 65°–66° and does not form a nitro compound with silver nitrite. Dibrommalonic nitrile melts at 123°.5–124°. The silver salt, formed by precipitating a cold aqueous solution of malonic nitrile (one molecule) with a cold solution of ammoniacal silver nitrate (two molecules), is a mixture of the mono- and disilver derivatives. This mixture gives with ethyl iodide, besides amorphous substances, diethyl malonic nitrile and ethyl isocyanide. The formation of the latter bodies is best explained if the structure assigned to the silver salt is AgN : C : C : C : NAg. The addition of alkyl iodide to the double bonds between the carbon atoms and subsequent elimination of silver iodide would give dialkyl malonic nitrile. The formation of an isocyanide is explained by the direct replacement of the silver by alkyl. The fact that no isocyanide is formed when the sodium salt of malonic nitrile is used is in accord with the above structure, as it is well known that sodium salts do not act by direct replacement as readily as silver salts. A mixture, probably of sodium malonic nitrile and sodium ethylate, was obtained in an attempt to prepare a disodium derivative of the nitrile. With methyl and ethyl iodides this mixture gave, when heated in sealed tubes for eight hours at 100°, dimethyl and diethyl malonic nitrile, melting at 32° and 44°, respectively. By the action of sodium ethylate on a mixture of malonic nitrile and ethyl chlorformate, sodium dicyanacetic acid ethyl ester was prepared. Malonic nitrile, sodium methylate, and methyl iodide gave a mixture of dimethyl malonic nitrile and dimethyl cyanacetimidomethyl ether, $\begin{matrix}CN\\(CH_3)_2\end{matrix}\!>\!C{-}C\!\begin{matrix}/\!\!/NH\\ \backslash OCH_3\end{matrix}$. The presence of the latter compound was proved by dissolving the mixture in water and precipitating methyl dimethylcyanacetate, $\begin{matrix}(CH_3)_2\\CN\end{matrix}\!>\!C.COOCH_3$, with hydrochloric acid. Analogous ethyl compounds were prepared. Diethylcyanacetamide, $\begin{matrix}(C_2H_5)_2\\CN\end{matrix}\!>\!C.CONH_2$, was formed in the preparation of diethylmalonic nitrile, and when the latter compound was boiled with absolute alcohol containing 1.3 per cent. of sodium. Diethylcyanacetic acid was prepared from the amide and, when heated in concentrated hydrochloric acid in a sealed tube at 160° for eight hours, was transformed into diethylacetic acid.

On the "Bechmann Rearrangement." BY JULIUS STIEGLITZ. *Am. Chem. J.*, **18**, 751–762.—The author offers the following explanation of the transformation of acid bromamides into isocyanates in the presence of an alkali. The alkali causes a direct loss of hydrobromic acid, producing the body $RCO.N<$ with a univalent nitrogen atom, whose reactivity is great enough to take away the alkyl group from the carbon atom. The fact that acid dibromamides, $RCO.NBr_2$, chloranilides, and analogous bodies, $RCO.NClR$, do not suffer a similar rearrangement with alkali is in accord with this view. A number of the reactions of the acid azides $RCO.N\!<\!\begin{matrix}N\\ \|\\ N\end{matrix}$, can be explained in the same way. Two atoms of nitrogen are liberated, leaving the group $RCO.N<$, which suffers a molecular rearrangement, forming an isocyanate. In the presence of reducing agents in alkaline solution, two groups might unite forming diacyl, $RCO.N = N.COR$, which, by taking up two hydrogen atoms, would give the diacylhydrazine $RCONH.NHCOR$ actually obtained. When reduced in acid solution, two atoms of hydrogen are added to the unsaturated group, RCO.N$<$, forming an acid amide. As it has not been determined whether the salts of the acid bromamides, which are formed before the transformation to the isocyanate takes place, have the structure RC(NBr)OMe or RCO(NBrMe), the author has investigated a number of compounds with analogous composition having alkyl groups in place of the metallic atoms. No rearrangement has been observed. Chlorimidoethylbenzoate, $C_6H_5C(NCl)OC_2H_5$, prepared by the action of sodium hypochlorite and hypochlorous acid on benzimidoethylether hydrochloride, is a colorless oil, insoluble in water, which boils at 131°–132° at 16 mm. pressure. An alcoholic solution evolves chlorine with hydrochloric acid and nitrogen with ammonia. When chlorimidoethyl benzoate was heated, decomposition took place, with violent boiling, in part according to the equation,

$$C_6H_5C(NCl)OC_2H_5 = C_6H_5CN + ClOC_2H_5.$$

Benzamide and a trace of an aniline derivative were secondary products of the reaction. Bromimidoethyl benzoate was much less stable than the chlorine compound.

Menthene Nitrosochloride and Some of Its Derivatives. By W. O. Richtmann and Edward Kremers. *Am. Chem. J.*, **18**, 762–780.—Menthene, prepared by heating menthol with anhydrous copper sulphate for ten hours, after six fractionations, boiled from 165° to 169°. A 15 per cent. yield of the fraction boiling at 167°–167°.5 was obtained and had the specific gravity 0.8103 and the rotary power $[\alpha]_D = +29°.63$. Menthene nitrosochloride was prepared from the different fractions of the menthene and purified by fractional crystallization. Products were obtained which melted from 106° to 117° and whose rotary power varied from —2°.408 to +16°.715. The menthene nitrobenzylamine prepared from the different specimens of the nitrosochloride melted at 105°.5–106°.5, and was inactive. The purest sample of nitrosomenthene obtained, melted at 64°–65° and had the rotary power —4°.683. The ketone prepared from the nitrosomenthene boiled from 205° to 218°. The fraction boiling at 207°–208° was obtained to the extent of 40 per cent. and had the specific gravity 0.9163 and the rotary power —1°.3189. A sample of inactive nitrosomenthane gave a ketone which had the rotary power +0°.4299. By the action of hydrogen sulphide on an alcoholic solution of the ketone, a hydrosulphide, $C_{10}H_{18}O.2H_2S$, was formed. With phenylhydrazine, a very unstable hydrazone, which melts at 72°.5–73°, was obtained. The product obtained by reducing the ketone consisted mainly of unchanged ketone. By the dehydration of the alcohol $C_{10}H_{18}O$, a hydrocarbon was not obtained, but a compound which formed an oxime and a hydrosulphide.

On the Non-Existence of Two Orthophthalic Acids. By H.

L. WHEELER. *Am. Chem. J.*, **18**, 829–836.—W. T. Howe (*Am. Chem. J.*, **18**, 390) recently published an account of a new orthophthalic acid and a number of its derivatives. The author has endeavored, in a series of eight experiments, to obtain the new acid by following the directions given. In every case ordinary phthalic acid was obtained. The author further shows that the analyses of the aniline salts of the two acids, although they agree with one another and the calculated figures as given, do not agree with the true values. The analyses of the brucine salts do not agree with either the calculated values given or the true ones.

The Action of Sulphuric Acid on Anisol. BY W. B. SHOBER. *Am. Chem. J.*, **18**, 858–865.—Anisol was treated with sulphuric acid, the amount of acid, the temperature at which the mixture was heated, and the time of heating, varying with each experiment. In order to separate the resulting acids, they were transformed into amides. Anisoldisulphonic acid was formed in every case when the mixture was heated on the water-bath to 92°, the proportion of the acid increasing with the increase in the proportion of the sulphuric acid, and with the increase in the time of heating. It is not formed at a temperature of 125°. When 10 grams of anisol and 80 grams of sulphuric acid were heated at 91° for 30 minutes, 97.6 per cent. of the resulting amides was anisoldisulphonamide. Paranisolmonosulphonic acid was formed in every experiment, the amount decreasing with increase of temperature, time of heating, and excess of sulphuric acid. 80 grams of sulphuric acid and 40 grams of anisol, heated at 92° for 35 minutes, gave a mixture containing 91.6 per cent. paramide. Orthoanisolmonosulphuric acid was formed in greatest quantity when anisol and sulphuric acid reacted at ordinary temperatures. 54.6 grams of sulphuric acid and 28.1 grams of anisol yielded a mixture containing 12.5 per cent. of the orthoamide.

Dipyridine Methylene Iodide and the Non-Formation of the Corresponding Monopyridine Products. BY S. H. BAER AND A. B. PRESCOTT. *J. Am. Chem. Soc.*, **18**, 988–989.—Dipyridine methylene iodide,  $C_5H_5N{<}\substack{CH_2\\ I\quad I}{>}NC_5H_5$, was prepared by boiling for one hour molecular proportions of pyridine and methylene iodide, diluted with an equal volume of alcohol. The compound crystallizes in yellow needles, which decompose at 220°, and is soluble in water and in hot alcohol, and insoluble in ether, chloroform, and benzene. Dipyridine methylene bromide was obtained by digesting pyridine and methylene bromide in a sealed tube for two weeks. It melts at 295° and crystallizes in colorless plates. It was impossible to make monopyridine products.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

Determination of Atomic Masses of Silver, Mercury and Cadmium by the Electrolytic Method. BY WILLETT LEPLEY HARDIN. *J. Am. Chem. Soc.*, **18**, 990–1026.—All the successful determinations described in this article were made by electrolyzing in a platinum dish potassium cyanide solutions of weighed quantities of various salts of the three metals, and by weighing the amount of metal deposited. Separate series, each consisting of ten experiments, were made in this way with silver nitrate, acetate, and benzoate; mercuric chloride, bromide, and cyanide; cadmium chloride and bromide. The final values of the atomic weights so obtained are 107.928 for silver, 199.99 for mercury, and 112.05 for cadmium, in close agreement with the values derived by Clarke from the work of previous investigators (107.92, 200.0 and 111.93.)

The Atomic Weight of Nitrogen and Arsenic. BY JOSEPH GILLINGHAM HIBBS. *J. Am. Chem. Soc.*, **18**, 1044–1050.—The author has determined the atomic weights of nitrogen and arsenic by passing hydrochloric acid gas over weighed quantities of potassium and sodium nitrates and over sodium pyroarsenate, and weighing the residual sodium chloride. The values obtained are 14.0117 and 74.916 respectively. Those selected as most probable by Clarke in his last year's report are 14.04 and 75.09.

Chemistry and Its Laws. BY F. WALD. *J. Phys. Chem.*, **1**, 21–33. As this article is by a foreign author, and as the substance of it has already appeared in a more extended form in a foreign journal (*Ztschr. phys. Chem.*, **18**, 357), a reference to its title will answer the purposes of this review.

On Ternary Mixtures. BY WILDER D. BANCROFT. *J. Phys. Chem.*, **1**, 34–50.—This article is a continuation of a previous one on the same subject (*see Tech. Quart.*, **8**, 306). The author shows that the solubility of salts in mixtures of water and alcohol can be expressed by the equation: $(x+A)y^n = C$, in which x represents the quantity of alcohol, and y the quantity of the salt, in a definite quantity of water, and in which A, n and C are constants determined from the experiments themselves. He shows further that the solubility x of a salt in an aqueous solution containing the quantity y of another salt can be expressed by the equation: $(x+A)(y+B)^n = C$, an equation which contains *four empirical constants*. The reviewer has already pointed out (*Tech. Quart.*, **8**, 306), that no physical significance whatever can be attached to such results, a fact which will be evident to any one acquainted with the properties of empirical equations; for, if the introduction of so many arbitrary constants be permitted, a great variety of mathematical functions could be found which would represent the experimental results with a practically equal degree of accuracy. The agreement is, in other words, almost a mathematical necessity, and is therefore no evidence of the correctness of the author's application of the mass-action law to the phenomenon in question.

Precipitation of Salts. By H. A. Bathrick. *J. Phys. Chem.*, 1, 157–169.—The author has determined the solubility of potassium, sodium and ammonium chlorides, and of potassium and sodium nitrates, in various mixtures of water and alcohol, and of the last two salts in mixtures of water and acetone. He shows that his own results and also those of Nicol on the solubility of salts in the presence of one another can be expressed by the formulas proposed by Bancroft. He also discusses the criticism of the reviewer (see preceding review), in regard to the use of so many arbitrary constants, and points out that one of them, A, has the same value for a definite salt, whatever be the other substance by which it is precipitated. But strangely enough, according to the author's own calculations, this statement is not correct. And, if it were, it is not to be doubted that the three remaining arbitrary constants would suffice to make almost any form of function express the results satisfactorily.

Solution and Fusion. By Wilder D. Bancroft. *J. Phys. Chem.*, 1, 137–148.—This article contains no new experimental data, but presents the opinions of the author on certain subjects related to those named in the title.

Nascent Hydrogen. By R. Franchot. *J. Phys. Chem.*, 1, 75–80.—The author finds that a neutral ferric sulphate solution is reduced by metallic zinc, cadmium and copper, and concludes that in acid solutions this direct reduction takes place simultaneously with that caused by the nascent hydrogen.

Speed of Esterification, as Compared with Theory. By Robert B. Warder. *J. Phys. Chem.*, 1, 149–156.—The author shows that the rate of esterification of alcohol and the three chloracetic acids, as determined by Lichty (*Tech. Quart.*, **8**, 99), does not conform to the requirements of the laws of mass-action in the form applicable to a reversible reaction of the second order, and he suggests four possible causes of the deviations.

H. M. GOODWIN, REVIEWER.

The Specific Heat of Metals. By F. A. Waterman. *Phys. Rev.*, 4, 161–191.—The author has perfected Hesehus' method of determining specific heats, and shows by numerous examples that it is capable of a high degree of accuracy. In this method the calorimeter is placed in the bulb of an air thermometer with an attached manometer, and the rise of temperature, due to the introduction of the hot substance, is exactly compensated by the addition of ice-water drop by drop until the manometer registers the original pressure within the air thermometer. An electric heater is provided for heating the substance to any initial temperature. This swings over the calorimeter for the introduction of the hot substance through a trap in the bottom of the heater. Without moving the calorimeter, the ice-water reservoir may be swung around in place of the heater, for the final operation. The apparatus described seems a model of convenience. The metals used were of a high degree of purity. The following results (the mean of a number differing by less than 0.1 per cent.) of the mean specific heat between 100° and 20° were obtained: Bismuth, 0.03035; tin, 0.05453; aluminum, 0.021946; copper, 0.09471; gold, 0.03068; zinc, 0.09547. The article contains in addition a compilation of the literature, and the results of all the more reliable specific heat determinations by different investigators; also a table of the most probable values of the mean specific heat of the metals, the determinations by different methods and observers being carefully weighted and combined. From a chemical standpoint the article is of especial interest as a presentation of the most accurately determined atomic heat values, illustrating the degree of validity of the Principle of Dulong and Petit. The author adopts 6.24+ as the most probable average value of the atomic heat.

On the Viscosity of Mercury Vapor. BY A. A. NOYES AND H. M. GOODWIN. *Phys. Rev.*, 4, 207–217.—The authors have determined the relative weights of mercury vapor, carbon dioxide and hydrogen, which were transpired under like conditions of temperature, (that of boiling mercury, 357°) and of pressure difference through the same capillaries in equal times, from which the relative viscosity and relative cross-section of the molecules of these gases could be computed. Experiments made at different pressures conformed to O. E. Meyer's pressure formula completely. For the more reliable capillary (74 cm. long and 0.34 mm. internal diameter), the values found for the relative viscosity η were: $\eta_{Hg} : \eta_{CO_2} = 2.08$; $\eta_{Hg} : \eta_{H_2} = 4.04$; $\eta_{CO_2} : \eta_{H_2} = 1.94$. The corresponding values of the relative mean cross-sections q were: $q_{Hg} : q_{CO_2} = 1.02$; $q_{Hg} : q_{H_2} = 2.48$; that is, the mean cross-section of the monatomic mercury molecule is nearly the same as the tri-atomic carbon dioxide molecule, and 2.5 times greater than that of the hydrogen molecule. These results indicate that atoms and molecules are of the same order of magnitude, and therefore that the interatomic spaces within molecules are not large in comparison with the size of the atoms.

Properties like viscosity which depend on the size or form of molecules are therefore not well adapted for distinguishing between monatomic and polyatomic molecules.

On the Specific Gravity and Electrical Conductivity of the Normal Solutions of Sodium and Potassium Hydroxides and Hydrochloric, Sulphuric, Nitric and Oxalic Acids. By E. H. Loomis. *Phys. Rev.*, 4, 252–255.—The following results were obtained by the usual pyknometer and conductivity methods for normal solutions, which had been prepared with special care as to the purity of the substances used:

Compound.	Sp. gr. $\frac{18°}{4°}$.	$K.10^7$.
NaOH	1.0418	148
KOH	1.0481	170
HCl	1.0165	279
HNO_3	1.0324	278
H_2SO_4	1.0306	183
$(COOH)_2$	1.0199	55

Note on the Theory of the Voltaic Cell. By H. M. Goodwin. *Phys. Rev.*, 4, 241–246.—This is a reply to certain criticisms of Mr. Bancroft of an article by the author on the theory of the voltaic cell and its application to the calculation of the solubility of depolarizers of electrodes of the second kind. The author shows by experiments that the electromotive force of elements of the form Zn, $0.1n ZnCl_2$, $0.1n ZnBr_2$, Zn is practically zero exactly as is required by Nernst's theory, according to which the potential difference between a metal and an electrolyte is primarily determined by the *kation* concentration of the solution and not by that of the anions. Mr. Bancroft predicted for cells of this type very considerable electromotive forces, because according to his views, the potential difference between a metal and electrolyte is primarily determined by the *anions*. Moreover, experiments on similar reversible cadmium cells demonstrate with what certainty one may predict results from the osmotic theory, when the kation concentration of the metals used as electrodes is known. Experiments made with the abnormally dissociated halogen salts of cadmium and its nitrate, completely confirmed the conclusion derived by other methods that the nitrate, chloride, bromide and iodide are very unequally dissociated with respect to the cadmium ion, the nitrate being the most, and the iodide the least dissociated.

On Irreversible Cells. By A. E. Taylor. *J. Phys. Chem.*, 1, 1–21, 81–91.—This investigation is a continuation of that of Bancroft on the chemical potential of the metals. The author finds in the good agreement of independent measurements of the electromotive force of non-reversible cells, reason for accepting Bancroft's view that such cells are limiting cases of reversible cells and possess a definite electromotive force. Further experiments, however, force him to reverse the Bancroft radical opinions regarding the influence of the anion. The main conclusions of his paper are namely: first, that the potential difference between a metal and an electrolyte is *not* a function of the negative ion of the salt solution; and second, that in certain cases dropping mercury electrodes do not give correct values for the single potential differences measured by that method.

Purification of Water by Distillation. By G. A. HULETT. *J. Phys. Chem.*, 1, 91–95.—The still used was an ordinary retort of two liters capacity with a platinum condenser so arranged that only the vapor condensed within this tube was collected. Water distilled with potassium permanganate gave after one-fourth had been rejected, a distillate of nearly constant conductivity of the value: $K \times 10^{10} = 0.77$. Ordinary distilled water first distilled from an acid solution of potassium bichromate, and afterwards from barium hydrate gave equally good if not better results: $K \times 10^{10} = 0.76–0.71$. It is also found that the quality of the water was independent of the *rate* of distillation when barium hydrate was employed. Free sulphuric acid should not be used as it passes over into the distillate.

Viscosity of Mixtures of Liquids. By C. E. LINEBARGER. *Am. J. Sci.*, 152, 331–341.—Continuing his researches on the properties of mixtures of "Normal" liquids, the author has in this paper extended his experiments to their viscosity. Ostwald's well known form of apparatus was used and all measurements were made at 25°. Sixteen different mixtures were investigated, and in no case was a maximum of viscosity observed; the origin of the maximum observed by other investigators is to be sought in their use of associated liquids. In most mixtures investigated, the observed viscosities are less than those calculated by the rule of mixtures. In certain mixtures, however, as those of benzene, with toluene, carbon disulphide and chloroform the differences are less than the experimental errors.

The Spectra of Argon. By JOHN TROWBRIDGE AND THEODORE WILLIAM RICHARDS. *Am. J. Sci.*, 153, 15–20.—With the unusual facilities for investigating vacuum tube spectra afforded by a Planté battery of 5000 cells, the authors have made some very interesting experiments on the conditions necessary for the production of the "red" and "blue" spectra of argon, with a sample furnished by Lord Rayleigh. It was found that with a tube of large capillary and 15 cm. in length containing argon under a pressure of one millimeter, 2000 volts were sufficient to produce the red glow, a very much lower potential than that (27,600 volts) estimated by Crookes. The introduction of a condenser and spark gap between the terminal of the Geissler tube caused the red glow to disappear, and the peculiar blue glow to take its place. The potential necessary was estimated at not over 2000 volts. By a number of other experiments it was shown that the blue glow is produced by an oscillatory discharge, while the red glow is the result of an unidirectional discharge. So sensitive is argon to electrical oscillations in this respect that the authors propose to call an argon tube fitted for the study of electrical waves, for which it seems peculiarly adapted, a talantoscope.

On the Hydrolysis of Ferric Chloride. BY H. M. GOODWIN. *Tech. Quart.*, 9, 254–271. The gradual change which a neutral ferric chloride solution undergoes when a concentrated solution is suddenly diluted, which is indicated by a gradual change in its color from a light yellow to a deep reddish brown, was investigated by measuring the simultaneous increase in the electrical conductivity (at 25° F. of solutions varying from 0.1 to 0.0001 molecular normal). The measurements showed: *First*, that the molecular conductivity of dilute solutions increases with the time. *Second*, that the rate of increase increases very rapidly with the dilution. *Third*, that the increase in the conductivity does not begin at once on dilution, but only after the lapse of a certain time. *Fourth*, that the time elapsing before the reaction apparently begins, increases very rapidly with the concentration; thus the reaction as indicated by change of color and increase of conductivity begins after about one minute for a 0.0006 normal solution, 15 minutes for a 0.0012 normal solution, 4 days for a 0.015 normal solution. *Fifth*, that the time required for the completion of the reaction increases enormously with the concentration; for example, it is 3 hours for a 0.0001 normal solution, but over a week for a six times stronger solution. And *sixth*, that the reaction when once started progresses slowly at first, then more and more rapidly up to a maximum, after which the velocity decreases, until a condition of equilibrium is finally reached. The explanation suggested to account for this remarkable behavior is that, on first diluting a ferric chloride solution, the hydrolytic reaction $\overset{+++}{\mathrm{Fe}} + \mathrm{H_2O} = \overset{++}{\mathrm{FeOH}} + \overset{+}{\mathrm{H}}$ instantly takes place, whereby the conductivity is increased by an amount proportional to the difference of the migration velocities of the hydrogen and ferric ions. This is in agreement with the fact that the initial conductivity increases more rapidly than can be accounted for by electrolytic dissociation alone. The subsequent progressive change of color and of the conductivity of the solution is due to the gradual formation of undissociated deeply colored colloidal hydrate, according to the reaction $x\overset{++}{\mathrm{Fe}}\mathrm{OH} + x2\overset{-}{\mathrm{O}}\mathrm{H} = (\mathrm{FeO_3H_3})_x$. A calculation under this assumption of the true initial *hydrolytic* dissociation from a combination of conductivity and freezing-point determinations makes it probable that the hydrolytic dissociation increases very rapidly with the dilution, being about 2 per cent. for a 0.1 to 0.2 normal solution, and 90 per cent. for a 0.0015 normal solution.

The Freezing-Points of Dilute Aqueous Solutions, III. BY E. H. LOOMIS. *Phys. Rev.*, 4, 273–297.—In this paper the author has extended his well known work on freezing-points to solutions of the following compounds: $LiCl$, $CaCl_2$, $SeCl_2$, $SnCl_4$, HNO_3, KOH, $NaOH$, KH_2PO_4, Na_2HPO_4, $Na(NH_4).HPO_4$, Na_3PO_4, Na_2SiO_3, and acetic, oxalic, succinic, tartaric, and citric acids. By working in a room at about 3° C., the temperature variations of which did not exceed 0.5° C., the experimental error previously estimated at 0.001° C. has been reduced one-half. Among the important relations brought to light by a consideration of the results may be mentioned the following: The molecular depression of the freezing-point of all chlorides reaches a minimum value which is especially pronounced in the case of the chlorides of the alkali earths. Stannic chloride exhibits an abnormally large molecular lowering, 12.61 for $m = 0.01$, which is probably to be explained by its being highly hydrolyzed in dilute solution. A study of the phosphates indicates that salts of the type KH_2PO_4 are dissociated into two ions, K and H_2PO_4; salts of the type K_2HPO_4 into three ions, K, K, and HPO_4; while the neutral phosphate K_3PO_4 is dissociated into four ions. Phosphoric acid itself is, as has been long known, but little dissociated, only one hydrogen ion being probably split off from the molecule. Sodium silicate also gave abnormal lowerings, the higher values observed being undoubtedly due to an hydrolysis of the salt. Acetic, tartaric and succinnic acids, and also the chlorides of lithium and calcium gave results in complete agreement with those of electrical conductivity measurements. Nitric acid, and potassium and sodium hydroxide, on the other hand, gave results for the dissociation deviating as much as 8 to 11 per cent. from conductivity values. The reason for this discrepancy is not known. It seems to the reviewer that much weight should be given to the results of this investigator, in view of the clearness with which he has discussed the precision side of this problem and his thorough appreciation of the nature and magnitude of the errors affecting his measurements.

On the Formation of Lead Sulphate in Alternating Current

Electrolysis with Lead Electrodes. BY SAMUEL SHELDON AND MARCUS B. WATERMAN. *Phys. Rev.*, 4, 324–327.—The formation of lead sulphate by the passage of an alternating current through a sulphuric acid solution between lead electrodes was found to diminish with rise of temperature, to increase very rapidly with the number of alternations up to twenty per second, after which it decreases, and to increase rapidly to a constant value with increasing current density.

Polarization and Internal Resistance of a Galvanic Cell. BY B. E. MOORE AND H. V. CARPENTER. *Phys. Rev.*, 4, 329–336. —The authors have studied the polarization at each electrode of a Leclanche cell, by combining each successively with a third non-polarized carbon electrode kept on open circuit. Both electrodes were found to be polarized, the larger part of the total polarization of the cell being at the carbon electrode however. That zinc in ammonium chloride would by the passage of any considerable current become polarized might have been predicted from Nernst's theory of the cell, since it is a non-reversible electrode with respect to the kation. The rapid recovery of the electromotive force of the cell on open circuit was found to be largely due to recovery from polarization at the zinc electrode, the recovery at the carbon electrode being much slower.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. TALBOT, REVIEWER.

Table of Factors. BY EDMUND H. MILLER AND J. A. MATHEWS. *J. Am. Chem. Soc.*, 18, 903–904.—The table presents about fifty factors, commonly required for analytical work. They are calculated from the atomic weights published in Clarke's table (*J. Am. Chem. Soc.*, 18, 213). The use of seven-place logorithms, and six decimal places in the values of the factors is somewhat misleading and involves unnecessary labor. Five-place logorithms suffice for the highest accuracy in chemical analysis, and even four-place logarithms and four places of decimals in the factors are sufficiently accurate, except in a few extreme cases.

Some Analytical Methods Involving the Use of Hydrogen Dioxide. BY B. B. ROSS. *J. Am. Chem. Soc.*, 18, 918–923.—The author proposed to determine iron by a procedure in which an excess of potassium bichromate is added, which is allowed to react with hydrogen peroxide, and, from the volume of oxygen liberated, the excess of bichromate is estimated. A similar procedure is proposed for the determination of sugar, wherein cuprous oxide is to be oxidized by potassium bichromate, and the excess of the latter estimated from the oxygen evolved on contact with hydrogen peroxide. The article leaves the reader in doubt whether or not the processes proposed have any real value.

The Separation of Thorium from the Other Rare Earths by Means of Potassium Trinitride. By L. M. Dennis. *J. Am. Chem. Soc.*, **18**, 947–952.—The author shows that thorium is quantitatively precipitated as hydroxide by potassium trinitride, and that its separation from cerium, lanthanum, and didymium may be promptly and completely effected by means of this reagent.

Notes on Reinsch's Test for Arsenic and Antimony. By Jas. Lewis Howe and Paul S. Mertins.—*J. Am. Chem. Soc.*, **18**, 953–955.—The authors find that a confusion of antimony with arsenic in this test is not likely to occur, since on heating the copper upon which the deposition has taken place, the arsenic forms well defined octrahedral crystals of the oxide, while the antimonious oxide shows no trace of crystallization. The deposition in the case of the arseniates is slow, and it fails altogether in the presence of nitric acid or chlorates. Organic matter does not interfere with the test. The antimony deposits more slowly than arsenic on the copper and shows a violet tint.

Notes on the Determination of Phosphorus in Steel and Cast Iron. By George Auchy. *J. Am. Chem. Soc.*, **18**, 955–970.—From the experiments cited, the author concludes that in order to insure a complete reduction of the molybdic acid to Mo_2O_3 dilution must be absolutely avoided after the solution has passed the reductor; that it is not necessary to wash out the reductor with acid, except after long standing; that when the zinc for reduction is placed in the liquid and the excess removed by filtration, the molybdic acid is reduced only to $Mo_{12}O_{19}$; that dilute solutions of this oxide are less stable than concentrated solutions; that a boiling temperature must be avoided during reduction and solution of the zinc, and that air must be excluded while cooling the solution before filtration; that cotton wool is preferable to paper as a filtering medium; that a considerable excess of sulphuric acid increases the stability of the reduced solution; and that the reduction by means of zinc within the solution, the excess of which is removed by filtration through cotton, is the most desirable method for phosphorus determinations. He also finds that sugar may be used to reduce and dissolve the manganese dioxide from the permanganate added to oxidize the phosphorus.

Metal Separations by Means of Hydrochloric Acid Gas. By J. Bird Moyer. *J. Am. Chem. Soc.*, **18**, 1029–1044.—The author's results may be briefly summarized as follows: Antimony trioxide was completely volatilized when treated in an atmosphere of dry hydrochloric acid; lead oxide changed to chloride, volatile at 225° C.; bismuth oxide completely volatilized; copper oxide changed to chloride, if first moistened with hydrochloric acid and dried. By means of these reactions the separation of lead from antimony, lead from bismuth, antimony from copper, and bismuth from copper may be effected. The arsenic may be volatilized from the arseniates of sodium, copper, silver, cadmium, cobalt, and nickel. The separation of the arsenic from iron and zinc is difficult. The arsenic and nickel in niccolite were separated after solution in nitric acid and evaporation to dryness.

The Separation of Vanadium from Arsenic. By Charles Field, 3rd, and Edgar F. Smith. *J. Am. Chem. Soc.*, **18**, 1051–1052.—Arsenic sulphide is completely volatilized from its mixture with vanadium sulphide without change of the latter, if treated in an atmosphere of dry hydrochloric acid, below 250° C. The separation may be utilized for quantitative analysis.

The Separation of Manganese from Tungstic Acid. By Walter T. Taggart and Edgar F. Smith. *J. Am. Chem. Soc.*, **18**, 1053–1054.—The authors' results are entirely negative, simply showing that neither yellow ammonium sulphide nor potassium carbonate are suitable reagents to effect the separation of the elements named. They make the independent statement that molybdic sulphide may be easily converted to oxide by ignition with anhydrous oxalic acid, after drying.

The Separation of Bismuth from Lead. By Arthur L. Benkert and Edgar F. Smith. *J. Am. Chem. Soc.*, **18**, 1055-1056.—The authors find that a quantitative separation can be effected by double precipitation of the bismuth as a basic formate, from a formic acid solution.

The Determination of Sulphur in Cast Iron. By Francis C. Phillips. *J. Am. Chem. Soc.*, **18**, 1079–1086.—The author finds that white iron may be completely oxidized, with the conversion of the sulphur to sulphates, by fusion of the finely divided iron with sodium peroxide or a mixture of sodium carbonate and sodium nitrate. Ferromanganese may be successfully oxidized by sodium carbonate and sodium nitrate. The percentages of sulphur determined by this method are apparently higher than by oxidation with nitric acid.

Carbon Determinations in Pig Iron. By Bertrand S. Sum-

MERS. *J. Am. Chem. Soc.*, **18**, 1087–1091.—The paper describes several devices to expedite the burning of large residues, for use in connection with the combustion apparatus, by means of which the most refractory residues may be burned in an hour and a half. The author finds the chromic acid method unreliable.

Notes on the Solubility of Bismuth Sulphide in Alkaline Sulphides. BY GEORGE C. STONE. *J. Am. Chem. Soc.*, **18**, 109.—The author finds that bismuth sulphide, which has been precipitated from acid solution, is not soluble in potassium or ammonium sulphide. Compare *J. Am. Chem. Soc.*, **18**, 683.

The Analysis of Coke. BY GEORGE C. DAVIS. *Am. Manufacturer*, **59**, 804.—The author claims that the foundryman does not need to know the percentage of phosphorus in the coke used, but should know the percentage of ash and of sulphur. The usual proximate analysis of coke, and the Eschka method for sulphur determinations are imperfectly described, but the paper presents no new facts.

On the Chemistry of the Cyanide Copper Assay. BY J. J. BERINGER AND H. W. HUTCHIN. *Eng. Min. J.*, **62**, 390–391.—The authors show that if potassium cyanide is addded to a solution of copper sulphate, until the precipitate which first forms is just redissolved, and ammonia is then added, a blue solution slowly forms. The color is intensified by the addition of ammonium nitrate. Increased quantities of ammonia, or ammonium salts do not necessarily intensify the reaction. A similar result was obtained if cupric cyanide is shaken with ammonia or ammonium nitrate. This may be decolorized by the addition of cyanide, but ammonia again restores the blue. The maximum quantity of cyanide was used in one case when only ammonia was present, in another where three-eighths of the ammonia was neutralized by hydrochloric acid. The reaction between the cupric cyanide and ammonia the authors express by the equation: $2Cu(CN)_2 + 6NH_3 + 2H_2O = 4NH_3.Cu(OH)_2 + (NH_4)_2Cu(CN)_4$, and they believe that their experiments and the general experience with the cyanide process suggest a "reversible reaction with a slowly attained state of equilibrium."

On the Application of Certain Organic Acids to the Estimation of Vanadium. BY PHILIP E. BROWNING AND RICHARD J. GOODMAN. *Am. J. Sci.*, **152**, 355–360.—The possibility of the estimation of vanadic acid by means of a standard iodine solution, (reduction having been effected by boiling with tartaric acid), is confirmed, and it is further shown that neither tungstic nor molybdic acids are reduced by tartaric acid in cold solution, and that tungstic acid is unaffected by either oxalic, tartaric, or citric acids in boiling solution, while citric acid reduces vanadium under these conditions. The general procedure is as follows: To a solution of vanadium, which may contain also a molybdate, or tungstate, add approximately one gram of acid (either tartaric, oxalate, or citric), for each one-tenth gram of substance. Heat the solution to boiling, unless tartaric acid is used in the presence of molybdates; in this case digest in the cold from fifteen to twenty hours. Add to the cold liquid five grams of potassium bicarbonate for each gram of acid used, add iodine solution and set aside until no further bleaching action is evident. Titrate for the excess of iodine with arsenious acid solution.

The Determination of Oxygen in Air and in Aqueous Solution. BY D. ALBERT KREIDER. *Am. J. Sci.*, 152, 361–367. —The author adapts for these determinations a procedure already described by him (*Am. J. Sci.*, 150, 287), wherein oxygen is allowed to act upon a concentrated solution of hydriodic acid, in the presence of nitric oxide. The excess of the acid is neutralized by potassium bicarbonate and the liberated iodine titrated with arsenious oxide. For these determinations the author uses special forms of apparatus, which are described in detail in the original article, together with all necessary precautions.

W. H. WALKER, REVIEWER.

The Separation and Determination of Potassium and Sodium. BY D. ALBERT KREIDER AND J. E. BRECKENRIDGE. *Am. J. Sci.*, 152, 263–268.—The paper presents a qualitative method for the separation and detection of potassium and sodium based on the relative solubilities of the perchlorates. It has been shown that, while sodium perchlorate is readily soluble in 97 per cent. alcohol, the potassium salt is, on the contrary, insoluble in that menstruum. This paper provides a method by which sodium may be detected after it has been separated from the potassium, which is essentially as follows: To the filtrate from which all the bases, including ammonia, have been removed, 0.5 cc. of pure perchloric acid (sp. gr. 1.70) is added, and the solution is evaporated on the steam-bath until white fumes of perchloric acid appear. When the quantity of sodium is large it is safer to evaporate several times to secure complete conversion to the perchlorate. Upon treating with 97 per cent. alcohol, the presence of potassium is revealed by the existence of an insoluble residue, which is collected on a dry filter. When the filtrate is saturated with gaseous hydrochloric acid, sodium, if present in amounts greater than 0.0005 gram, will appear as a granular precipitate. The authors think the method is all that can be desired for qualitative determinations. Perchloric acid free from sodium was made by distilling (under a pressure of from 3 to 5 mm. of mercury) acid prepared according to the procedure described by Kreider, *Am. J. Sci.*, 149, 443). This must be done very slowly and in a specially prepared apparatus.

Estimation of Cadmium as the Oxide. BY P. E. BROWNING AND L. C. JONES. *Am. J. Sci.*, 152, 269–270.—The authors demonstrate the ease and accuracy with which cadmium carbonate may be ignited in a Gooch crucible and weighed as oxide, eliminating all danger of the reduction and subsequent volatilization of the cadmium. The precipitation is made in a hot aqueous solution by means of a ten per cent. potassium carbonate solution, and the liquid is boiled for ten or fifteen minutes until the precipitate becomes granular. It is then filtered upon asbestos, washed thoroughly, and ignited at a red heat to a constant weight. The results show a very small plus error, which the authors prove to be due to slight inclusions of the alkaline carbonate.

The Determination of Tellurium by Precipitation as the Iodide. BY F. A. GOOCH AND W. C. MORGAN. *Am. J. Sci.*, 152, 271–272.—It has been already shown that when hydriodic acid and tellurious acid interact there is formed a tellurium tetraiodide which is converted by water into an oxyiodide, and by excess of an alkaline iodide into a soluble double salt. The authors show that this reaction takes place according to the equation:

$$H_2TeO_3 + 4H_2SO_4 + 4KI = TeI_4 + 4KHSO_4 + 3H_2O,$$

and this is made the basis of a volumetric method for the direct determination of small amounts of tellurium. By shaking the flask the precipitate of tellurium tetraiodide, which at first separates in a finely divided condition, is made to gather into a curdy mass and so leave a clear supernatant liquid. Advantage is taken of this behavior, and the point at which the precipitation of all the tellurium is complete is not difficult to determine. In the test experiments, the tellurium dioxide was dissolved in potassium hydrate, and sulphuric acid of half strength was added in such an amount that at the end of the titration the solution should contain one-fourth its volume of strong sulphuric acid. This solution is then titrated with a decinormal potassium iodide solution, until a further addition gives no precipitate. Using 127 as the atomic weight of tellurium, the authors find this method satisfactory.

Method for the Separation of Aluminum from Iron. BY F. A. GOOCH AND F. S. HAVENS. *Am. J. Sci.*, 152, 416–420.—

When a cooled concentrated acid solution of aluminum and iron chlorides is saturated with gaseous hydrochloric acid, almost all the aluminum separates in fine white crystals of hydrated aluminum chloride, $AlCl_3.6H_2O$, while all the iron remains in solution. On this difference in solubility is based a method of separation. The solubility of aluminum chloride in concentrated aqueous hydrochloric acid is very small, and is, moreover, greatly reduced by the addition of an equal volume of anhydrous ether. A complete separation seems to be most easily secured by mixing the concentrated aqueous solution of the chlorides with enough concentrated hydrochloric acid to make the entire volume 15–25 cc., cooling to about 15° C. and passing into the solution gaseous hydrochloric acid. When completely saturated, the solution is mixed with an equal volume of anhydrous ether; and this mixture again saturated with gaseous hydrochloric acid. The crystalline precipitate of hydrous aluminum chloride is collected on asbestos in a perforated crucible and washed with a mixture of equal parts of acqueous hydrochloric acid and anhydrous ether saturated with the gas. When the precipitate is ignited directly, the mechanical loss occasioned by the rapid volatilization of the acid and water of crystallization is so great that it was found expedient either to dissolve in water and reprecipitate as hydroxide, or to cover the chloride with some volatile oxidizing agent before ignition. Mercuric oxide was found to serve the purpose well. The precipitate is dried for one-half hour at 150° C., covered with about one gram of mercuric oxide, first gently heated under a ventilating flue, and then freely over the blast lamp. The results seem to be satisfactory.

PROXIMATE ANALYSIS.

A. H. GILL, REVIEWER.

On the Determination of Stearic Acid in Fat. BY O. HEHNER AND C. A. MITCHELL. *J. Am. Chem. Soc.*, 19, 32-51.—The method prepared by the authors is a quantitative one, unlike the classical method of Heintz; it consists in dissolving out at 0° the other fatty acids by alcohol saturated with stearic acid, and in weighing the residue consisting of stearic acid.

The Determination of Solid Fats in Compound Lards. BY G. F. TENNILLE. *J. Am. Chem. Soc.*, 19, 51-54.—The author shows that Wainwright's method at best cannot be depended upon for results closer than 1.5 per cent., and that, if the conditions are at all varied, the results may be 7 or 8 per cent. too high or too low.

F. H. THORP, REVIEWER.

Volumetric Determination of Acetone. BY EDWARD R.

SQUIBB. *J. Am. Chem. Soc.*, 18, 1068–1079; *Squibb's Ephemeris*, 4, 1759–1770.—This is a description of certain improvements in the process of J. Robineau and G. Rollin (*Moniteur Scientifique*, 41, 272–274), whereby greater simplicity, rapidity and ease of manipulation are secured, with sufficient accuracy for most purposes. The method is applicable to the determination of acetone in the presence of ethyl alcohol, and is especially recommended for use in testing the dilute solutions of acetone which are recovered by distillation in manufacturing operations, or in the making of acetone itself. For the details of the process reference must be made to the original article.

G. W. ROLFE, REVIEWER.

On the Conditions Affecting the Volumetric Determination of Starch by Means of a Solution of Iodine. BY F. T. LITTLETON. *Am. Chem. J.*, 19, 44–49.—The author has made an investigation of the colorimetric method proposed by Dermstedt and Voigtländer, (abstracted in *The Analyst*, 20, p. 210) and finds that the process has very little analytical value, owing to the varying composition of the iodide of starch, possibly due to dissociation, under different conditions of temperature, solvents, etc.

W. R. WHITNEY, REVIEWER.

A Modification of the Gunning Method for Nitrates. BY JOHN FIELDS. *J. Am. Chem. Soc.*, 18, 1102–1104.—The author claims to avoid the trouble caused by frothing in the Gunning method by gently heating the mixture of the sample with the sulphuric and salicylic acids, and then gradually adding 6–7 grams of potassium sulphide with shaking. The whole is boiled; and the digestion is usually complete in an hour. Distillation is then proceeded with as usual. Results have shown the modification to be as accurate as the Gunning method itself.

Notes on the Estimation of Caffein. BY W. A. PUCKNER. *J. Chem. Soc.*, 18, 978–981.—This is an experimental study of the extraction of caffein from dilute acid solutions by means of chloroform.

E. H. RICHARDS, REVIEWER.

Methods for the Determination of Organic Matter in Air. BY DAVID HENDRICKS BERGEY. *Smithsonian Miscellaneous Collection*, 1037, 1–28. This publication is a critical compendium of the various methods proposed for the estimation of the organic impurities in air. The results lead to the conclusion that the dust in the air is the chief source of organic matter. The use of pumice has found greater favor with the author than the experience of the reviewer would warrant. Moreover, no notice is taken of the effect of the presence of nitrites in using permanganate.

A Modification of the Babcock Method, and Apparatus for Testing Milk and Cream. By J. M. Bartlett. *Me. State College Agr. Expt. Sta., Bull.* 31, 1–8.—The author recommends adding hot water five minutes after mixing the sulphuric acid and milk or cream together, and claims that once whirling is then sufficient to cause the separation of the fat. The acid used (20 cc.) should have at 60° F. a specific gravity of 1.820–1.825, and the milk or cream (18 cc.) should be at a temperature of 70°–80° F., when it is mixed with the acid. A modified form of the graduated milk and cream bottles is also described.

TECHNICAL CHEMISTRY.

F. H. Thorp, Reviewer.

The Manufacture and Use of Thomas Slag. By F. E. Thompson. *Iron Age*, 59, 9.—The author first describes the treatment of the slag as made in the basic Bessemer process. Its value as a fertilizer is increased, if it is exposed to the weather several years before grinding ; but it may be ground as soon as cold. It is prepared by grinding in a "ball-mill" until 90 per cent of it will pass a 100-mesh sieve. A series of sieving tests is given. The fertilizer value depends on the quantity of phosphoric acid present, and on its condition. In Thomas slag the phosphoric acid is present as tetracalcic phosphate, which is not so soluble in neutral ammonium citrate, as is "reverted" phosphate or dicalcic phosphate ; but it is much less stable than tricalcic phosphate. The author then considers the causes of irregularities in the composition of the slag, which he charges to the method of running the convertor. The methods of analysis of this slag are then discussed. From his investigations he concludes that neutral ammonium citrate does not give a correct estimate of the fertilizer value of the phosphoric acid ; for it appears to dissolve the slag as a whole, and the per cent. of phosphoric acid dissolved bears a direct ratio to the total quantity of slag dissolved. Moreover, there is no evidence to show any difference between the phosphoric acid which it leaves in the slag and that which it dissolves out. Weathering appears to increase the solubility of the phosphoric acid in neutral ammonium citrate. The author considers Thomas slag to be a mixture of chemical compounds; for, if cooled slowly, several bodies separate as distinct crystals. According to recent reports, the slag is but slightly inferior as a fertilizer to dissolved bone or phosphate rock, and is superior to all insoluble phosphates.

American Utilization Processes of Garbage Disposal. By W. E. Garrigues. *Trans. Eng. Soc. Western, Pa.*, 12, 266–

276.—This is a condensed review of the system of garbage disposal in several large cities. The destructive processes are not discussed. The useful products obtained from garbage are grease and tankage. Grease is chiefly used for glycerine and candle stock. It will make only a very poor soap. Three systems of grease extraction are considered: with steam; by means of sulphuric acid; and by the use of naphtha. Tankage is used by the fertilizer manufacturers.

Composition of American Kaolins. By CHARLES F. MABERY AND OTIS T. KLOOZ. *J. Am. Chem. Soc.*, **18**, 909–915.—This article consists chiefly of analyses of clays from various places in the United States. Two analyses of the kaolin used at the Royal Berlin porcelain works at Charlottenburg are included for comparison. Several of the American clays approach very nearly the composition of the German article.

Chrome Tannage Patent. By GEO. W. ALDER. *U. S. Pat. No. 573631.* (Abstract, *Leather Manufacturer*, 7, 19).—The chrome solution is prepared by dissolving potassium or sodium bichromate in an excess of sulphuric acid diluted with two volumes of water, reducing the chromium salt by the addition of sugar or alcohol, then neutralizing and precipitating chromium hydrate and "chromium oxycarbonate" by the addition of sodium carbonate, and finally dissolving the precipitate, without filtering, by the addition of hydrochloric acid to the mixture. The resulting liquor is supposed to contain chromium chloride, chromium sulphate, sodium and potassium sulphates, sodium chloride, and either formates or acetates of these metals.

Chrome Tannage Patent. By HUGO SCHWEITZER. (Abstract *Leather Manufacturer*, 7, 20.)—The process consists in the "reduction on the animal fiber of bichromate of potash by means of hydroxylamine compounds, such as hydroxylamine, its sulpho acids and salts, in the presence or absence of any of the nitrogen-sulphone acids, which are formed to some extent in the reaction, which produces sulpho acids of hydroxylamine, thereby permitting the use of neutral, weakly acid or weakly alkaline solutions for the second bath."

Chrome Tannage Patent. By ROBERT WAGNER AND J. J. MAIER. *U. S. Pat. No. 574014.* (Abstract *Leather Manufacturer*, 7, 19.)—This is a one-bath chrome tannage process. It is proposed to take ten pounds of chrome alum, three pounds of saltpeter, six pounds of muriatic acid, fifteen pounds of salt, and ten pounds of whiting, and mix them with fifteen gallons of water. The whiting and salt are first mixed together (dry?) at a temperature of 70° (F?), and then the other ingredients are added and the whole stirred into the water.

Manufacture and Development of Carborundum at Niagara Falls. BY FRANCIS A. FITZGERALD. *J. Franklin Inst.*, **143**, 81–96.—After a discussion of the early forms of furnace, the author takes up the subject of the manufacture at Niagara. The materials used are sand, coke, sawdust, and salt. These are properly mixed and filled into an oblong brick furnace 16x5x15 feet, in the ends of which are the terminals consisting of 60 carbon rods 30 inches long and 3 inches in diameter. Connection between each carbon and the end plate is made with $\frac{3}{8}$ inch copper rod. The side walls of the furnace are built up each time a charge is introduced. The current used in the furnace at first is about 1200 amperes; but after the charge becomes hot the resistance decreases, and at the end of an hour the current is such that 746 kilowatts (or 1000 horse-power) are being used in heating the furnace. As the current increases, the electromotive force is reduced, until finally the resistance becomes constant. No apparent change is observed for half an hour; but then inflammable gases begin to escape from the furnace. After three or four hours the top of the furnace is covered by blue flames of carbon monoxide, which escapes in great quantities. After twenty-four hours the current is cut off, and the furnace cools. The side walls are removed; and the unchanged, loose mixture is raked off. The core is crystalline at the center; and about 4000 pounds of crystalline carborundum are obtained from one furnace. The carborundum is crushed, treated with dilute sulphuric acid, washed, and dried. After sifting it is ready for use. Carborundum is infusible, decomposing without melting; it is insoluble in water and acids; it has a hardness near 10; and its specific gravity is 3.23. It is replacing emery for many purposes.

Manufacture of Oxygen. BY MR. LINTON. *Proc. Eng. Soc. Western Pa.*, **12**, 222–231.—This is a review of the commercial methods of making oxygen, with special reference to the process of E. B. Stuart, of Chicago. It is similar to the Tessie du Motay process; but it is claimed that it avoids some of the difficulties of that method. A mixture of caustic soda and black oxide of manganese is heated to 500°–600° F., and the air is blown through it, by which process sodium manganate is formed. Steam is then blown through the mass, which dissociates the manganate, forming caustic soda, manganese binoxide and oxygen. The air is blown in for ten minutes and the steam for five minutes. The manganate mass obtained consists of one part manganate to two of caustic soda. It fuses to a liquid at the temperature of the reaction, which is carried on in cast iron retorts, set vertically. Each retort is charged with 1500 pounds of the mixture, and the two retorts yield 76,000 cubic feet of gas in twenty-four hours, at a cost of 7 cents per 1000 cubic feet.

Second International Congress of Applied Chemistry. By H. W. Wiley. *J. Am. Chem. Soc.*, **18**, 923.—This is a review of the proceedings of the meeting held at Paris, in July and August, 1896.

A. H. Gill, Reviewer.

Some Facts about Acetylene Gas. By J. C. M'Mynn. *Electr. Eng.*, **21**, 197–198.—This is a concise statement of the present knowledge of the subject.

Fuels. By A. V. Abbott and F. J. Dommerque. *Electr. Eng.*, **9**, 1–186.—This article deals succinctly with the origin, distribution, production and composition of the various fuels—wood, peat, coal, petroleum and gas, and discusses the advantages of each. A special and valuable feature of the treatise is the numerous tables and plots which it contains. The methods of proximate fuel analysis and of manipulating the Carpenter calorimeter, the Mahler bomb, and the Elliott gas apparatus are also given—in some cases, however, with insufficient detail as to their execution. As the article does not present original material, this reference to it will suffice.

The Testing of Coals. By Arthur Winslow. *J. Assoc. Eng. Soc.*, **17**, 84.—The paper is the outline of a plan of the author to study the North American coals, considering their adaptability for: (1) Steaming; (2) Coke making; (3) Domestic use; (4) Gas making; and (5) Blacksmithing. This article gives the properties of coals adapted to each of these uses. The investigation will be an interesting and exceedingly important one—one almost beyond the power of any one man to execute. A comparison of the calorific power as obtained by the calorimeter and by the Dulong formula would be very instructive. It is to be regretted that the Barrus calorimeter is to be used for the determination of the calorific power, as its results may vary as much as three per cent. from those obtained by the Mahler apparatus.

G. W. Rolfe, Reviewer.

A Study of the Clarification of Sugar Cane Juices. By J. L. Beeson. *J. Am. Chem. Soc.*, **19**, 56–61.—This paper is related to those previously published (*La. Sta.*, *Bull.* **38**; *this Rev.*, **2**, 110.). In an investigation of the commercial process of clarification ("defecation,") as applied to cane juices, the author finds that the gums and albuminoids of the juice fall into three classes: (*a*) those which form insoluble compounds with lime; (*b*) those which are precipitated by heat; and (*c*) those which are not rendered insoluble by either lime or heat. The latter class, however, can be precipitated by suitable reagents, and are found to comprise nearly one-half of the total amount of gums and albuminoids.

BIOLOGICAL CHEMISTRY.

W. R. WHITNEY, REVIEWER.

The Tannin of Some Acorns. BY HENRY TRIMBLE. *Am. J. Pharm.*, 68, 601–604.—The author has determined the tannin, moisture, and ash in different parts of the chestnut-oak acorn (*Quercus Prinus*) during the month of September when ripening occurs. As few comparative results are given, no important conclusions can be drawn as to the change in the quantity of tannin in different parts of the fruit during growth. The greatest amount of tannin comes from the testa, where over 48 per cent. was found. A comparison of the tannin of the cupule with that from many samples of oak bark was made, and analyses of both were carried out. The two are evidently identical. The article concludes with the results of the analyses of six different samples of acorn cupules.

Alfalfa. BY WILLIAM P. HEADDEN. *Col. Agr. Expt. Sta.*; *Bull.* 35, 1–92.—The author gives the results of his study of the plant, embracing analyses of each of the three cuttings of a season, and showing the amount and composition of the ash of the whole plant above ground at different degrees of maturity. Analyses were also made of the separate parts of the plant, the soil, etc. The analyses included determinations of moisture, ash, ether extract, crude protein, crude fiber, nitrogen-free extract, and amide nitrogen. Complete analyses of the ash are also given. In an appendix the methods of analysis and of the preparation of the samples are described, and a compilation of fodder analyses is given.

Rectification of Turpentine Oil. BY EDWARD KREMERS. *Pharm. Rev.*, 15, 7.—The author has carefully fractionated the commercial product after treating it with milk of lime. Tables giving the specific gravity and rotatory power of the fractions are given. He notes also that the rectified product undergoes the so-called resinification on standing.

The Caffein Compounds of Kola. BY JAMES W. T. KNOX AND ALBERT B. PRESCOTT. *J. Am. Chem. Soc.*, 19, 63–90; *Am. Pharm. Assoc. Proc.*, 1896.—This article gives an abstract of the existing chemical literature on kola, describes in detail methods for the determination of its free and combined alkaloids (chiefly caffein), presents analytical results obtained with different samples, and describes the separation, properties, composition, and artificial preparation of the glucoside present in kola.

The Chemistry of the Cotton Plant. BY J. B. MCBRIDE AND W. H. BEAL. *U. S. Dept. Agr.*, *Bull.* 33, 81–142.—This article shows the fertilizing and proximate constituents of all parts of the cotton plant—the roots, stems, leaves, bolls, lint, seeds, etc. Tables containing the results of hundreds of analyses are given, the entire subject having been very thoroughly treated.

Purification of Natural Cumarin. BY EDO CLAASSEN. *Pharm. Rev.*, 15, 28.—The crude cumarin is treated with hot benzine (sp. gr. 0.71), from which it crystallizes on cooling. The final portion of cumarin is separated from the benzine solution by shaking this with a five per cent. sodium hydrate solution.

On the Occurrence of Sulphur Derivatives in American Peppermint Oil. BY CLEMENS KLEBER. *Pharm. Rev.*, 14, 269.—The author shows the presence of dimethyl sulphide in American peppermint oil.

Terpin Hydrate. BY EDWARD T. HAHN. *Am. J. Pharm.*, 69, 73–75.—This short article contains a resumé of the methods for the production of terpin hydrate from turpentine. The author finds that by using oil of turpentine, methyl alcohol (sp. gr. 0.801) and nitric acid (sp. gr. 1.35) in the volume proportions 4 : 1 : 1, a satisfactory yield of the crystalline product is most quickly obtained. The crystallization is hastened by the addition of one volume of water after the reaction is complete.

A Contribution to the Knowledge of Some North American Coniferae. BY EDGAR S. BASTIN AND HENRY TRIMBLE. *Am. J. Pharm.*, 69, 90.—This portion of the work treats of the hemlock (*Tsuga Canadensis*). Samples of the bark were analyzed by fractional extraction, and the tannin also determined. Pure hemlock tannin was isolated and analyzed ; the results show it to be unexpectedly high in carbon and hydrogen and are not in agreement with the formula proposed by Boettinger, $C_{20}H_{18}O_{10}$. The authors found nearly half a per cent. more carbon in the hemlock tannin than in any one of ten oak tannins examined.

Chemical Analysis of the Bark of Honey Locust (Gleditschia Triacanthos). BY LOUIS P. CARSTENS. *Am. J. Pharm.*, 69, 40–41.—This article contains the results of the analysis by the usual extraction methods of a sample of the bark mentioned in the title. The alkaloid extracted with 95 per cent. alcohol was removed from the solution by chloroform, and crystallized from absolute alcohol.

Assay of Johore Gambier. BY W. O. RICHTMANN. *Pharm. Rev.*, 15, 27–28.—Results of analyses of six different samples are given, showing the amounts of moisture, ash, tannin, and catechin present. The author suggests that possibly a definite relation exists between the amounts of catechin and tannin in different gambiers ; for a low quantity of the one seems to occur where there is a relatively large quantity of the other. The conversion of one into the other may be brought about, he believes, by some vegetable organism.

Concerning Prepertles Belonging to the Alcohol Soluble Proteid of Wheat and of Certain Other Cereal Grains. By G. L. Teller. *Am. Chem. J.*, 19, 59–61; *Ark. Agr. Expt. Sta.*, *Bull.* 42, 75–104.—In working with the proteids in wheat, the author. observed that some nitrogen-containing substance was soluble both in dilute salt solution and in the 75 per cent. alcohol usually employed. This substance was shown to be a proteid by the usual reactions. Analyses of twenty different samples of wheat and other mill products showed that the nitrogen-content of this soluble proteid was practically the same in each case, while the other nitrogenous constituents varied considerably. The author believes the proteid to be gliadin. It has many of the properties of proteoses; but it is readily soluble in 75 per cent. alcohol, and from this solution it is not precipitated by common salt. The same or a similar body was found in the alcohol extracts of oats, rye, and barley. The experiments are more fully described, and detailed methods for the quantitative separation of the proteid are given in the *Bulletin*.

The Action of Enzymic Ferments upon Starches of Different Origins. By Winthrop E. Stone. *U. S. Dept. Agr.*, *Bull.* 34, 29–44.—The author's belief that starches from different sources are not identical, but that there are isomeric starches as there are isomeric sugars, is supported by experiments on the relative rates of decomposition of maize, wheat, rice, potato, and sweet potato starches, usually in the gelatinized state, by the enzymic ferments—malt diastase, ptyalin from human saliva, and pancreatin from beeves and swine. It was found that the time required for the complete decomposition of the different starches as determined by the failure of the iodine test, varied greatly with the source of the starch in the case of each of the ferments, and that the orders of susceptibility of the different starches to the various enzymes were also widely different.

G. W. Rolfe, Reviewer.

The Carbohydrates of Wheat, Maize, Flour and Bread. By W. E. Stone. *U. S. Dept. Agr.*, *Office of Exp. Sta.*, *Bull.* 34, 7–28.—A large amount of analytical data is given comprising estimations not only of the carbohydrates—the more common polysaccharides, hexoses and pentose derivatives—but also of ash, fat, fiber, and proteids. The change of composition, due to milling and baking, are discussed in considerable detail, the views in general conforming to the opinions usually accepted.

The most extraordinary feature of the paper is the remarkable starch showing. The author finds by his analyses that the starch-content of the cereals are from 20–30 per cent. lower than the figures generally given. What is yet more strange is that the figures of the other components show a practical agreement with the results of other investigators, so that a deficit of over 20 per cent. is left to be accounted for. This fact the author does not explain, but leaves us to infer that this large fraction of the grain is in reality totally overlooked in our usual methods of investigation, the discrepancy presumably being marked by the too high results of faulty starch determinations. Aside from an opinion that this missing material is not carbohydrate nor indeed food, the author gives no hint as to its nature, not even attempting a separation by solvents or other rough method of classification to throw light upon the mystery. It is certainly most remarkable if we are to believe that in the present state of the science practically a quarter of our common cereals consists of material in regard to whose nature we have not the most primitive ideas! In consideration of the importance of the matter and of the disagreement of the results with those of previous investigators, the reviewer suggests that a more complete and detailed explanation of the author's method of starch determination would have been most acceptable to his readers. Confidence in the results would have been greatly increased by statements in regard to the amount of reducible carbohydrates produced by the presence of the malt infusion, apparently no inconsiderable fraction of the whole; in regard to the methods of correction, the details of the Fehling test, the precautions taken by the author to satisfy himself that the final acid hydrolysis actually converted the carbohydrate to dextrose; and in regard to other minor points.

F. H. THORP, REVIEWER.

Mineral Constituents of the Watermelon. BY G. F. PAYNE. *J. Am. Chem. Soc.*, 18, 1061-1063.—**The Ash Analysis of the Watermelon, giving the Mineral Substances It Takes from the Soil.** BY G. F. PAYNE. *Ga. Dept. Agr. Bull. No.* 32, 29–31. Two melons gave, on analysis, 0.33 per cent. of ash, which was itself analyzed. The author concludes that a crop of 39,766 pounds per acre (which is three times the average yield per acre) takes from the soil 81.09 pounds of potash and 13.59 pounds of phosphoric acid.

The Use of Arsenites on Tobacco. BY H. GARMAN. *Ky. Sta Bull.* 63, 68–80.—This investigation is a study of the effect of spraying tobacco with Paris green. Samples of the dry tobacco were analyzed; and arsenic was found in all of them in amounts ranging from "traces" to 0.0139 per cent. As_2O_3. The question of danger to the consumer is not settled, but it is thought that no serious injury can result from the use of arsenites. Data as to the best time for spraying, the amount to use, and the quantity received by each plant, are also given.

Report of the Section on Agriculture and Chemistry. *Proc. Ninth Ann. Convention Assoc. Am. Agr. Coll. Exp. Sta., U. S. Dept. Agr., Bull.* 30, 10–14.—This bulletin gives a short summary of the work of the several experiment stations, during the year 1896, in agricultural and chemical studies.

Bordeaux Mixture, Its Chemistry, Physical Properties, and Toxic Effects on Fungi and Algae. By W. T. SWINGLE. *U. S. Dept. Agr., Div. Vegetable Physiology and Pathology, Bull.* 9.—Bordeaux mixture is said to be a mixture of calcium sulphate and cupric hydroxide, suspended in an aqueous solution of calcium sulphate and calcium hydrate. When freshly made, the cupric hydrate is of a colloidal nature, but on standing it becomes crystalline. The copper, even when in a very dilute condition, exerts a very destructive action on the germinating power of fungus spores and upon algae.

The Real Value of "Natural Plant Food." By L. L. VAN SLYKE. *N. Y. Agr. Exp. Sta., Bull.* 108.—The article is a warning against a certain fertilizer manufactured by the Natural Plant Food Co., of Washington, D. C. Analysis of the material shows it to be a very inferior article.

Analyses of Commercial Fertilizers. *Agr. Expt. Sta. Bull., Ga. Dept. Agr., No.* 32 ; *Ky., Nos.* 60 and 64 ; *Mass. Hatch Sta., No.* 42 ; *Me., Nos.* 22 and 30 ; *N. C., Special Bull. Nos.* 37 and 38 ; also *Bull.* 124 ; *N. J., No.* 113 ; *N. Y., Nos.* 95 and 107 ; *Pa. Dept. Agr., No.* 11 ; *Purdue Univ., Special Bulls., May and August, 1896 ; R. I., No.* 34 ; *W. Va., No.* 40 ; *Md., No.* 40.

W. R. WHITNEY, REVIEWER.

Reduction of Nitrates by Bacteria and Consequent Loss of Nitrogen. By ELLEN H. RICHARDS AND GEORGE WILLIAM ROLFE. *Tech. Quart.*, 9, 40–59. The authors found that the nitrogen of potassium nitrate, in water containing a tenth of a per cent. of milk was in some way lost in the cycle of changes: nitrate, albuminoid ammonia, free ammonia, nitrite, nitrate, after entering the nitrite stage. Investigation showed that the organisms growing in the solution generated nitrogen gas during their growth, and that practically all of the previously missing nitrogen of the nitrate was thus accounted for. The article concludes with some interesting suggestions concerning the storage of nitrogen in soils and waters.

The Excretion of Metabolized Nitrogen by Animals. By C. F. Langworthy. *U. S. Dept. Agr. Exp. Sta. Record*, 7, 817–825. —This article is a summary of the principal results of other experimenters upon the part played by nitrogen in the nutrition of animals.

On the Behavior of Coal-Tar Colors toward the Process of Digestion. By H. A. Weber. *J. Am. Chem. Soc.*, **18**, 1092–1097.—The digestive actions of pepsin and pancreatin when acting upon fibrin, in the presence of oroline yellow, saffoline, magenta, and methyl orange, were separately studied. Of these colors only oroline yellow retarded the action of the pepsin; but saffoline, magenta, and methyl orange interfered very seriously with the fermenting action of pancreatin. The use of such colors in articles of food and drink is therefore objectionable.

The Formation of Fat in the Animal Body. By Selik Soskin. *U. S. Expt. Sta. Record*, **18**, 179–192.—This article gives a historical account of investigation since 1742, made to discover the source of the fat in the animal body. It concludes with the acceptance of Pflüger's results and conclusions as opposed to those of Pettenkoffer and Voit, who believed that fat could be produced in the animal system from proteids alone.

E. H. RICHARDS, REVIEWER.

Food and Nutrition Investigations in New Jersey in 1895 and 1896. By Edward B. Voorhees. *U. S. Dept. Agr. Exp. Sta., Bull.* 35, 7–40.—This report deals mainly with the composition and cost of bread and of milk. Analyses are given of 139 samples of fresh bread and of 108 samples of milk. The work done on bread shows that while wheat and wheat flour may be considered as standard articles, bread made from the same flour may have a varying nutritive value. The results of a dietary study of a mechanic's family are also recorded.

Milk Fat and Cheese Yield. By L. L. van Slyke.—*N. Y. Agr. Expt. Sta., Bull.* 110, 251–280.—The author presents the results of a very large number of determinations of the relation of the amount of fat to the amount of casein in milk and to the yield of cheese obtained from it. Milk from fifty different herds of cows was examined during a period of six months. The experiments show that *in general* milk fat and casein increase simultaneously; but that the increase of the former is usually relatively greater than that of the latter. This is shown by the following table, in which are given the general averages for milks containing 3 and 4 per cent. of fat, respectively:

Per cent. fat.	Per cent. casein.	Ratio of casein to fat.	Percentage yield of cheese.	Ratio of cheese yield to fat.
3.00	2.10	0.70	8.55	2.85
4.00	2.40	0.60	10.40	2.60

Although the ratio of cheese yield to fat is somewhat greater in the case of the milks poorer in fat, yet the quality of cheese produced is proportionately poorer, so that the author concludes from these results that milk fat forms the fairest practicable basis to use in paying for milk for cheese making—that in no case should it be paid for by weight of milk alone, and that payment by cheese yield gives an unfair advantage to poor milk.

Analyses of Some Substances Sold as Cream of Tartar. BY G. F. PAYNE. *Ga. Dept. Agr., Bull.* **32**, 24–28.—Of ten samples purchased and analyzed, five contained no cream of tartar, two contained less than 57 per cent., and one less than 80 per cent.

The Study of Human Foods and Practical Dietetics. BY M. E. JAFFA. *Univ. Cal. Agr. Expt. Sta., Bull.* 110, 3–19.—The title is sufficiently descriptive of the general character of this bulletin. It is for the most part based upon previously published work; but it contains the following valuable results, expressed in per cent., calculated from original analyses of California fruit, nuts, and bread stuffs.

	Water.	Total nutrients.	Protein.	Fats.	Carbohydrates.	Mineral matters.	Fuel value of one ounce.
Wheat flour	12.5	87.5	8.0	1.1	77.9	0.5	102
Graham flour	12.1	87.9	8.5	1.9	75.8	1.5	103
Bread	32.3	67.7	6.4	1.7	58.7	0.9	80
Apples	83.2	16.8	0.2	0.4	15.9	0.3	20
Oranges	88.0	12.0	0.8	11.2		..	14
Prunes (all)	80.0	20.0	0.8	18.7		0.5	23
Apricots	85.0	15.0	1.0	13.5		0.5	18
Figs	79.0	21.0	1.5	18.9		0.6	24
Grapes	80.0	20.0	1.3	18.2		0.5	23
Olives	58.0	42.0	1.1	27.6	11.6	1.7	88
Walnuts	2.5	97.5	14.3	65.9	16.3	1.0	202
Almonds	5.3	94.7	17.6	56.2	19.1	1.8	191
Peanuts	8.0	92.0	28.0	40.0	23.0	2.0	164

APPARATUS.

A. H. GILL, REVIEWER.

A New Form of Potash Bulb. BY M. GOMBERG. *J. Am. Chem. Soc.*, **18**, 941. The bulb is shaped like a small Erlenmeyer flask and divided into three compartments. It is much less fragile than the usual form; and it will stand upon the balance pan. It is, however, difficult to manufacture; and whether it presents a sufficient surface for absorption is questionable.

A Rapid Measuring Pipette. BY E. L. SMITH. *J. Am. Chem. Soc.*, **18**, 905.—The apparatus described seems to be fairly accurate, to admit of rapid work and to be easily made.

A Simple and Convenient Extraction Apparatus for Food Stuff Analysis. By J. L. Beeson. *J. Am. Chem. Soc.*, 18, 744–745. The apparatus is an adaptation of the Johnston extractor, this being provided with a ground-glass stopper, which is closed with a rubber cap while weighing. The stopper is funnel shaped, and during the extraction it is inverted in the extraction tube, thus directing the solvent to the center of the sample and preventing loss by spattering.

On a Simple Automatic Sprengel Pump. By B. B. Boltwood. *Am. Chem. J.*, 19, 77–78.—The apparatus makes use of a water jet pump to draw the mercury through the Sprengel tube. In course of ten minutes operation vacua suitable for the display of electrical phenomena are obtained.

On Some New Forms of Gas Generators. By T. H. Norton. *J. Am. Chem. Soc.*, 18, 1057–1061.—The article shows how common laboratory apparatus may be utilized for this purpose.

A Modified Form of the Ebullioscope. By H. W. Wiley. *J. Am. Chem. Soc.*, 18, 1063–1067.

A New Electrolytic Generator for Oxygen and Hydrogen. By W. S. Franklin. *Phys. Rev.*, 4, 61.—The generator consists of a number of massive frames of an alloy of lead with four per cent. of antimony, bolted together and insulated from each other by rubber diaphragms. The gases are prevented from mixing by glass strips. The generator requires 19 volts per cell, the current through each cell being 24.6 amperes. The maximum purity of the hydrogen was 94.8 per cent.; that of the oxygen 86.2 per cent. The efficiency of the generator is about 36 per cent. It gives 660 liters of hydrogen and 330 liters of oxygen per hour, at a cost of about 80 cents, which is 8 cents per cubic foot of oxygen.

The Practical Use in the Chemical Laboratory of the Electric Arc Obtained from the Low Potential Alternating Current. By M. S. Walker. *Am. Chem. J.*, 18, 323–328.—The arc may be used: (1) To show the effect of high temperatures upon difficultly fusible and volatile substances; (2) for the reduction of metallic oxides; (3) blowpipe analysis; and (4) for the preparation of some compounds of carbon from the elements. The article describes the apparatus and methods to be employed in these various applications.

A New Form of Pyknometer. By J. C. Boot. *J. Am. Chem. Soc.*, 19, 61–62.—The usual bottle form is vacuum jacketed to prevent the troublesome expansion of the liquid during weighing and its outflow through the capillary.

Apparatus for the Electrolysis of Hydrochloric Acid. By Geo. O. Higley and B. T. Howard. *Am. Chem. J.*, 18, 587. The apparatus is a modification of that of Hofmann, so arranged that the hydrogen and chlorine are generated in separate vessels and traverse but a small layer of liquid. It is said to be very simple and accurate.

Apparatus for Distillation in a Vacuum. By P. C. Freer. *Am. Chem. J.*, 18, 584.—A modification of the Kahlbaum receiver, so arranged that the entire top can be covered with mercury, thus effectually preventing leakage.

Apparatus for Showing the Composition of Water. By P. C. Freer. *Am. Chem. J.*, 18, 584.—A modification of the Hofmann apparatus so arranged that the explosion can take place under diminished pressure and prevent the shattering of the tube.

METALLURGICAL CHEMISTRY.

H. O. Hofman, Reviewer.

A Hot-Blast System for Copper Matting and Silver-Lead Furnaces. By J. A. Nesmith. *Min. Sci. Press*, 73, 318.—The air on its way from the blower to the blast furnace passes through a chamber in which a jet of oil or gas is kept burning. The products of combustion become mixed with the air, superheat it, and pass off with it. The reason for allowing a mixture of carbon dioxide and air to enter the furnace is that the air having been superheated is more active and less of it is required in the blast furnace for oxidizing the fuel; hence dilution with carbon dioxide has no bad effect. On the other hand superheated air of such a composition will not have the tendency to localize the heat as would superheated pure air, but will distribute it. It seems to the reviewer that this method of working is not based upon correct principles. If the blast is to be superheated by the combustion of extraneous fuel, why undo the good effect by diluting with carbon dioxide? If the effect of the air superheated in the usual way is too strong, cut down the coke in the blast furnace, and this will weaken it in an economical way. Blowing large volumes of weak air through a furnace can only have the effect of making the heat creep up and give a hot top. While perhaps desirable in pyritic smelting, this is fatal to lead smelting. It would appear as if the relative prices of coke and of bituminous coal, oil, or gas would have to decide whether the blast is to be superheated or not; but if superheated, the products of combustion must be kept separate from the blast furnace air.

The Percentage of Zinc in Slags. BY E. A. WEINBERG. *Eng. Min. J.*, 57, 580.—The paper gives some facts obtained by the author in smelting roasted sulphide lead ore, rich in zinc, in a small water-jacket blast furnace. The best slag made contained: SiO_2, 32 per cent., FeO, 31; CaO, 7; Al_2O_3, 8.5, ZnO, 18.5; the rest being lead, copper, sulphur, and alkali; the matte assayed as high as 22 per cent. of zinc and was very rich in lead and copper.

Granulating Matte. BY S. E. BRETHERTON. *Eng. Min. J.*, 63, 43.—This is a short note outlining the method of granulating blast furnace matte at the works of the American Smelting Co., Leadville, Col. Granulated matte appears to roast more easily than when it has been crushed, rolled and screened, as is the common practice; further, granulating is much cheaper than any other method of comminuting.

Wall Accretions of Lead Blast Furnaces. BY M. W. ILES. *School Mines Quart.*, 18, 18–23.—This is a brief discussion of how wall accretions are formed in the lead blast furnace, what their general character is, and how their formation may be lessened, as it is not possible to avoid them entirely. An average analysis gave the following figures: SiO_2, 17.26; Fe, 13.26; Mn, 1.60; CaO, 3.20; S, 10.90; Zn, 18.42; Cu, 0.80; an average of all the assays made at the works under the author's charge in seventeen years: Pb 24.06 per cent., Ag 29.74 ounces and Au 0.197 ounce per ton. Wall accretions are formed mainly by the volatilization and condensation of metallic sulphides; these are often oxidized to some extent after deposition. The other constituents are particles of the charge that have during the descent become mechanically lodged in the accretion and may have undergone a chemical change later. For the practical details the reader is referred to the paper.

The Calculation of Copper-Matte Blast Furnace Charges. BY H. VAN F. FURMAN. *School Mines Quart.*, 18, 1–13.—As in a previous paper on a calculation of lead blast furnace charges, (*op. cit.*, 14, 134–148,) the author discusses first the general principles and then illustrates them by carrying out calculations in detail. The leading principles are that (1) the slag produced shall be good from a metallurgical and economical point of view, the range of composition being: SiO_2, 26–45; Al_2O_3, 0–20; FeO, 28–65; CaO, 0–28; ZnO, 0–14; and of specific gravity 3.50–3.75; (2) the different ores shall be used up in about the same proportions as they are received; (3) the matte shall be of a proper grade for further treatment, 50 per cent. of copper being a common figure; (4) the percentage of sulphur, arsenic, and antimony volatilized in the blast furnace, from 8 per cent. in ordinary matting to 90 per cent. in true pyritic smelting, shall be taken into consideration; (5) the chemical composition of the matte shall be ascertained; for, besides all the copper, three-fourths of the lead and one-half of the zinc enter it, the rest of the available sulphur combining with iron; (6) the total weight of the charge shall bear a certain relation to the size and working of the blast furnace, the figures varying from 2000 to 4000 pounds; (7) the percentage of fuel shall be correctly apportioned, from 10 to 15 per cent. of coke, (12 per cent. ash), if little sulphur is oxidized, the percentage being on the sum of ore and flux; (8) the loss in gold, silver and copper shall not exceed permissible amounts, *viz.*, loss in gold *nil*, in silver 95 per cent.; with 40–50 per cent. matte the slag shall not contain over 0.6 per cent. copper. Three examples show how these general considerations are followed under special conditions.

Improvements in the Electrolytic Refining of Copper. By T. Ulke. *Eng. Min. J.*, 62, 464–565. The author states that it is generally conceded now that the Farmer or Hayden process (arranging the plates in series without separate cathodes) is less satisfactory than the common multiple process and that the former is no longer used to any extent except at the works of the Baltimore Electric Refining Co. He further describes the method of circulating the electrolyte in use at the copper refining works of M. Guggenheim's Sons, at Perth Amboy, N. J., which is a slight modification by Schneider and Szontag of the one used for many years by Borchers Bros., Goslar, Prussia (see Borchers, Electrometallurgie, 1895, p. 185).

Present Method of Treating Slimes from Copper Refineries. By T. Ulke. *Eng. Min. J.*, 62, 512.—The slimes from electrolytic copper refineries, amounting to about 4 per cent. of the weight of the anode, contain, after the scrap copper has been screened off, 15–30 per cent. copper, 45–50 per cent. silver, less than 1 per cent. gold, and 20–35 per cent. of impurities, made up of lead, bismuth, arsenic, antimony, and tellurium. In some works, which have a lead plant in addition to a copper plant, the slimes are added either to the softening furnaces treating comparatively low-grade blast furnace lead or to the cupelling furnaces working the enriched lead. In other plants the slimes are first refined in the wet way and then in the dry way. Thus, at the Baltimore Electric Refining Co's works the screened slimes are boiled for three or four hours in dilute sulphuric acid (1 : 4) using a Körting injector, dried, melted down, and refined in a cupelling furnace. In the furnace at first a brownish slag with 20 per cent. lead and 10 per cent. antimony forms on the surface; it is drawn, cooled, picked over for prills of silver, and worked off with lead in a separate cupelling furnace. Then niter is spread over the precious-metal bath in the furnace, which refines the metal, forming a second slag, to be drawn off, containing as much as 20 per cent. tellurium. The doré silver is now ready to be cast into bars for parting.

The Separation of Nickel and Copper in Matte and the Recovery of the Contained Precious Metals. By T. Ulke. *Eng. Min. J.*, 63, 113–114.—The author gives a brief review of a number of processes for treating nickel-copper matte in the wet way, and a short outline of an electrolysis method of his own. Electrolytic refining of matte has so far always been a failure, and the method proposed does not show, as far as can be judged from the details given, why it should not share the same fate as its predecessors.

The Brown Patent Automatic Pulp Distributor. By H. P. Brown. *Eng. Min. J.*, 62, 512–513.—This article refers to a simple mechanical devise for distributing the pulp cheaply, evenly, and loosely in the large leaching tanks (diameter 24–26 feet, depth 5–6 feet) of gold and silver mills.

Purification of Sodium Hyposulphite Solutions. By A. R. P. *Eng. Min. J.*, 63, 63.—The author calls attention to the good results obtained in leaching silver ores with sodium hyposulphite after having freed this solvent from sodium sulphate by acidulating and over-precipitating with calcium sulphide. In regular work he uses sodium sulphide to precipitate the metals, and at the same time to convert sodium tetrathionate (formed in making Russell solution) into hyposulphite, he then follows this up by using calcium sulphide to eliminate obnoxious sodium sulphate as harmless calcium sulphate. It may be recalled in this connection that Ottokar Hofmann has always advocated the use of sodium hyposulphite as a solvent in combination with calcium sulphide as precipitant.

The Cyanide Process. By A. D. Nordhoff. *Min. Sci. Press*, 73, 441.—A complete list of the books and papers on the subject contained in the library of the University of California.

The Cyanide Process for the Treatment of Gold Ores. By J. W. Richards. *J. Franklin Inst.*, 143, 96–109.—This paper is a short review of the MacArthur–Forrest process, giving its development and chemistry, and describing some of the work that is being done in treating telluride ores in Colorado and native gold ores in Utah and the Transvaal.

The Cyanide Process. By R. P. Rothwell. *Eng. Min. J.*, 62, 386.—In this country the cyanide process was first successfully carried out at the Mercer Mine, Camp Floyd district, Utah. The gold occurs there in limestone and a high extraction is readily obtained with coarse ore. Usually ore has to be crushed through a 40-mesh screen, with the after-result that fully 50 per cent. of it can be passed through a 100-mesh sieve and such fine ore leaches slowly. If the pulp shows, in panning, particles of gold as coarse as the mesh-aperture, an exposure of a week to the solvent action of potassium cyanide has been found necessary to effect a satisfactory extraction. The ore best suited for cyaniding is one that is neutral or slightly alkaline and free from or very low in copper. Leaching telluride ores raw has not been satisfactory, the results varying greatly without any apparent cause. The reason is probably to be found in the different behavior of the tellurium minerals, sylvanite, petzite, calaverite, and hessite with potassium cyanide. At present tellurides are roasted before leaching; roasting can be carried on without any appreciable loss of gold by volatilization, but the gold is liable to be left in the form of smooth globules not readily attacked by cyanide; further, the ore must be dead-roasted, as neutralizing the ore with a wash of caustic soda has been found in many cases to reduce the extraction. In making laboratory experiments to serve as a basis for planning a mill, chemical tests ought to be supplemented by sizing-tests, to show the sub-division of the gold in the pulp, and by microscopical examination, to show the form in which it is present.

Electrolytic Precipitation of Gold from Cyanide Solutions. By S. Croasdale. *Eng. Min. J.*, 62, 57.—The paper is a record of a number of experiments carried out on a sufficiently large scale to allow the results to serve as a basis for industrial work. Amalgamated zinc, the most positive of the available metals, was used as the electro-positive, sheet lead as the electronegative pole. The current ranged from 0.04–0.05 amperes per square foot, the voltage was low, and the flow of solution such that the gold from half a pound of solution was deposited in 30 seconds on each square foot of depositing surface. A standard solution with 12.787 milligrams gold per liter gave up 98.04 per cent. of the gold; with a dilute solution of 1.84 grams gold per liter, the capacity had to be doubled to obtain an extraction of 93.48 per cent., the loss of cyanide from the 0.65 per cent. solution was only 2.845 per cent., and the solution from the precipitating vat was very active in dissolving gold. In using lead anodes as well as cathodes, the current had to be raised from 0.04 to 0.2 ampere per square foot, when much gas was set free and the solution, as it came from precipitating vat, was inactive though it became active after standing. The recovery of gold was 94.34 per cent., and the loss in cyanide 5.15 per cent.

A New Gold-Saving Process. BY P. LANGHAMMER. *Min. Sci. Press*, 73, 316.—The innovation consists in drying, sizing, and stirring the ore, which is said to detach the films of gold and make them amenable to the solvent, potassium cyanide, which is to be applied separately to each size.

The Value of the Pyrometer in the Down Comer. BY E. A. UEHLING. *Am. Manufacturer and Iron World*, 60, 115–117. —The writer calls attention to the importance of measuring in an iron blast furnace not only the temperature of the blast, but also that of the gas passing off through the down comer, which corresponds to from 5 to 8 tons for every ton of pig made and carries with it from 40 to 75 per cent. of the total heat energy contained in the fuel. Two temperature charts autographically recorded by the Uehling and Steinbart pneumatic pyrometer are given, each showing the temperatures of blast and of gas. One record represents the furnace in good condition, making 146 gross tons of good foundry iron with 147 gross tons of coke, the blast temperature ranging from 1000° to 1100° F. (average 1050°), and the gas temperature from 300° to 500° F. (average 400°). The other record of the furnace when working unsatisfactorily shows 129.5 gross tons of iron of inferior quality, with 171 gross tons of coke, blast temperature 1000°–1200° F. gas temperature 700°–800° F. By calculation the author finds that in the case given 50 per cent. more gas was evolved with the higher than with the lower temperatures, which corresponds to 730 and 296 pounds of carbon per ton of iron made.

[CONTRIBUTION FROM THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.]

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INORGANIC CHEMISTRY.

HENRY FAY, REVIEWER.

Action of Water of the Hubb Coal Mine upon Cast Iron. BY FRANK W. DURKEE. *Am. Chem. J.*, **18**, 849–858.—The author has examined samples of cast iron which had lain twenty-three years under water in the Hubb Coal Mine in Cape Breton, Nova Scotia, and has found that, while retaining its shape, it had materially altered in properties. The pieces were soft enough to be easily cut with a knife, and very brittle. A cross section showed an inner, softer part, lighter in color than the outer part. The transformed cast iron was magnetic, porous, and several times lighter than the same bulk of cast iron. Wrought iron which had been used in the mine was deeply corroded on the surface, but the interior was unaffected. The following figures, representing the average composition of the altered portion, were obtained by analysis: SiO_2, 12.25; Si, 1.67; C, 13.33; H_2O mechanically held, 3.53; H_2O combined, 5.21; FeS, 0.38; SO_3, 2.73; P_2O_5, 1.65; CaO, 1.25; MgO, 0.35; MnO, 0.30; FeO, 34.29; Fe as metallic iron and in the carbide Fe_3C, 23.06. Specific gravity, 2.5 The water in the mine was examined and found to contain in grams per liter: free and combined H_2SO_4, 0.4551; free H_2SO_4, 0.0230; Ca, 0.0419; Mg, 0.0222; SiO_2, 0.0153; Cl, 0.0284; As, 0.00005; Fe, Al, and Mg, 0.0096.

Experiment with Gold. BY M. CAREY LEA. *Am. J. Sci.*, **153**, 64.—On reducing some gold solutions with sodium hypophosphite the author noticed in special cases an emerald green color. This color is best produced by bringing together 15 cc. of a ten per cent. sodium hypophosphite solution, one cc. of gold chloride solution containing 0.10 gram of metallic gold and one drop of sulphuric acid. When the solution begins to darken 30 cc. of water are added. The solution now assumes a green transparent color, gradually becoming cloudy. If it is now filtered, it again becomes green and cloudy. This process can be repeated several times. The green color is due to a very small quantity of finely divided bluish-black metallic gold suspended in the yellow liquid.

Silver Hydride. BY EDWIN J. BARTLETT AND WM. F. RICE. *Am. Chem. J.*, 19, 49–52.—Silver hydride, AgH, was prepared by precipitating a dilute solution of silver nitrate with dilute hypophosphorous acid in excess. The solution becomes wine-colored at first, changing to black, and after a few minutes black, spongy flakes are precipitated, which are filtered at once. The filtrate, on long standing or boiling, deposits metallic silver. Silver hydride is not decomposed by water.

Silicide of Chromium. BY G. DE CHALMOT. *Am. Chem. J.*, 19, 69–70.—Chromium silicide, Si_2Cr, was obtained by heating together in an electric furnace silica, charcoal, and chromium sesquioxide. It crystallizes in long, gray needles having a metallic luster; it is not attacked by cold hydrochloric acid or aqua regia, but dissolves in hydrofluoric acid. A sufficient quantity of pure crystals was not obtained for analysis, but the composition was determined in two specimens, to which some free silicon adhered. The specific gravity is 4.393.

Action of Ferric Chloride on Metallic Gold. BY PARKER C. MCILHINEY. *Am. J. Sci.*, 152, 293–294.—The author, in testing the solubility of metallic gold, found that it is not soluble in concentrated hydrochloric acid when heated in a pressure tube at 150° C., nor in ferric chloride in absence of oxygen; but in presence of oxygen ferric chloride acts as a chlorine carrier, and dissolves appreciable quantities of gold.

Silicides of Copper and Iron. BY G. DE CHALMOT. *Am. Chem. J.*, 19, 118–123.—In a former article (*This Rev.*, 2, 7) the author described a copper silicide of the formula Cu_2Si_2. Vigoureux has already made it appear improbable that any other copper silicide than Cu_2Si exists. The author has repeated his work, and concludes that while some crystals analyzed by him seem to have the composition represented by the formula Cu_2Si_2 there are present in these crystals both free silicon and free copper, and that the silicide present has in reality the formula Cu_2Si. This is, the author thinks, a case of chemical equilibrium between copper silicide and its decomposition products, copper and silicon. Contrary to the statement of Vigoureux, it is shown that copper silicon alloys containing up to 20 per cent. of silicon do contain free silicon. The author has established the existence of an iron silicide having the composition represented by the formula $FeSi_2$. By treating an iron silicon alloy containing about 39 per cent. of silicon with cold hydrofluoric acid, to which water was added, from time to time, there was left a residue of gray metallic crystals, which had the composition $FeSi_2$. The silicide is completely soluble in cold hydrofluoric acid, especially if the acid is concentrated, but is less soluble than the iron silicides containing less silicon.

Drying and Deliquescence of Certain Salts. By F. W. Smither. *Am. Chem. J.*, **19**, 227–232.—Definite quantities of lithium, calcium, and magnesium chlorides, and of calcium and magnesium nitrates were mixed with powdered glass and dried at a temperature of 97°–98° C. during six hours a day for thirty days, weighings being made daily. Each portion was dried in a desiccator over night, and in some cases moisture was absorbed from the calcium chloride of the desiccator, so that comparable results were not obtained; furthermore the magnesium salts lost acid after heating for some days. To test the absorption of water by the same salts dried quantities were placed in beakers together with a piece of lampwick, which helped to expose the salt to a greater surface. The beakers were placed in a bell-jar containing water and were weighed almost daily for seven weeks and thereafter weekly for five weeks. The results are tabulated together with calculations of the number of molecules of water absorbed, from which it appears that no definite degree of hydration took place.

Metal Separations by Means of Hydrochloric Acid Gas. By G. Bird Moyer. *J. Am. Chem. Soc.*, **18**, 1029–1044.—The author has converted the oxides of antimony, bismuth, copper and lead quantitatively into chlorides by heating them in a current of hydrochloric acid gas. With ferric oxide some reduction took place. By the volatility of the chlorides of bismuth and antimony he has separated them from copper and lead, and by the volatility of arsenic trichloride he has separated the arsenic from the arsenates of silver, copper, cadmium, cobalt and nickel. The mineral niccolite, dissolved in nitric acid and evaporated to dryness, is readily freed from arsenic by this method.

The Action of Acid Vapors on Metallic Sulphides. By Jerome Kelley, Jr. and Edgar F. Smith. *J. Am. Chem. Soc.*, **18**, 1096–1098.—Arsenic, antimony, and stannic sulphides are converted into the chlorides by heating in a current of hydrochloric acid gas; stannous sulphide is also converted into the chloride, but cannot be volatilized. The dry sulphides of arsenic and antimony are completely volatilized when exposed to hydrobromic acid gas.

Tungsten Hexabromide. By Herbert A. Schaeffer and Edgar F. Smith. *J. Am. Chem. Soc.*, 18, 1098–1100.—Tungsten hexabromide, consisting of blue black crystals, was prepared by heating tungsten in a current of bromine diluted with nitrogen. It fumes in the air, and is decomposed by water into a blue oxide.

Note on the Ferrocyanides of Zinc and Manganese. By Edmund H. Miller. *J. Am. Chem. Soc.*, 18, 1100–1102.—This paper is a preliminary note relating to the composition of these salts.

Analysis of an Iron Rail Taken from a Gallery of an Unused Coal Mine. By Henry P. Talbot and A. G. Woodman. *J. Am. Chem. Soc.*, 19, 9–12.—This article gives the results of the analysis of a cast iron rail which had lain twenty-three years under water in the Hub Mine, at Glace Bay, Cape Breton. It was composed of an inner and outer portion, the densities of which seemed to increase with length of exposure to the air. The results are compared with those of Herting (*Chem. Ztg.*, 20, 54), who analyzed a similar rail. (See also above, this *Rev.*, 3, 51.)

The Oxalates of Zirconium. By F. P. Venable and Charles Baskerville. *J. Am. Chem. Soc.*, 19, 12–18.—Basic oxalates of zirconium were formed by precipitation. It was found impossible to obtain the neutral oxalate. The acid oxalate $Zr(C_2O_4)_2.H_2C_2O_4.8H_2O$, and the following double oxalates were prepared:

$$Zr(C_2O_4)_2.3Na_2C_2O_4.H_2C_2O_4.5H_2O,$$
$$[Zr(C_2O_4)_2]_2.(K_2C_2O_4)_2.H_2C_2O_4.8H_2O,$$
$$Zr(C_2O_4)_2.2(NH_4)_2C_2O_4.$$

Preparation of Sodium Nitroprusside. By F. S. Hyde. *J. Am. Chem. Soc.*, 19, 23–24.—Detailed directions for the preparation of pure sodium nitroprusside are given in this paper.

Some Peculiar Forms of Iron. By T. H. Norton. *J. Am. Chem. Soc.*, 19, 108–110.—A mass of pig iron which had been in the molten condition for over a year was analyzed and found to be practically pure iron, except for a high percentage of phosphorus—0.828. It was extremely hard, malleable, and crystalline, showing rectangular cleavage.—The support for the mantle of a Welsbach burner was found to be extremely brittle, crumbling easily. Analysis showed 0.097 per cent. carbon, while the original steel contained 0.642 per cent.

A Tungsten-Iron Alloy. By T. H. Norton. *J. Am. Chem. Soc.*, 19, 110.—Analysis of a hard and brittle tungsten-iron alloy of specific gravity 14.55, showed 93.43 per cent. tungsten and 6.18 per cent. iron.

Our Present Knowledge of Argon. BY C. LEROY PARKER. *J. Am. Chem. Soc.*, 19, 124–138.—This paper contains nothing original, but is a review of our knowledge of argon, to which is added a valuable bibliography.

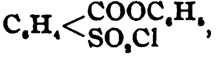
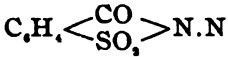
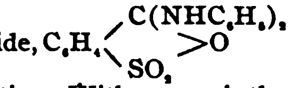
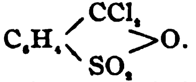
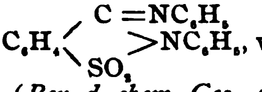
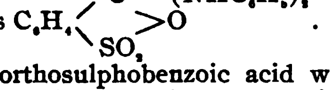
On the Volatility of Certain Inorganic Salts. BY T. H. NORTON AND D. M. ROTH. *J. Am. Chem. Soc.*, 19, 155–166.—The authors have examined the volatility of borax, of sodium and potassium fluorides, and of barium chloride. The results are tabulated and compared with the time it takes to volatilize 0.01 gram sodium chloride in the hottest part of the Bunsen flame.

H. P. TALBOT, REVIEWER.

On the Volatility of Ferric Chloride. BY HENRY P. TALBOT. *Am. Chem. J.*, 19, 52–59.—The experimental data show that no loss of ferric chloride occurs, when its solutions (whether neutral or acidified with hydrochloric acid) are evaporated to dryness on the water-bath or upon the hot plate, provided in the latter case they are not too strongly overheated. The residues so obtained were subjected to the temperature usually employed to dehydrate silicic acid (130° C.) for two hours, but suffered no loss of iron. Prolonged heating of these residues over a free flame occasioned but a slight loss (0.4 per cent.) of the iron present. Concentrated acid solutions of the chloride, when boiled in a distilling flask, allowed ferric chloride to pass into the receiver only when a slight separation of the solid had taken place on the side of the flask, which, in the acid atmosphere, was volatilized by the overheating of the glass. When ferric chloride solutions are evaporated with exposure to the air, a loss of chlorine ensues, and the basic ferric salt formed prevents loss of the iron as chloride. The presence of ammonium chloride with the ferric chloride occasioned no loss of the latter, even at 130° C. The residues, when heated over a free flame, suffered a loss of iron, as would be expected. The presence of aqua regia with the ferric chloride solution tends to occasion a slight loss of iron during evaporation. The maximum loss was 0.6 per cent. of the iron present, but in other cases very little or no loss could be detected. Vogel's experiments (*N. Rep. Pharm.*, 18, 157) were repeated, and it was found that a slight volatilization of iron seems to take place from an ethereal solution at the temperatures of the laboratory, but, on the other hand, the presence of ether or its vapor does not promote the volatilization of the ferric chloride from its boiling, concentrated, aqueous solutions.

ORGANIC CHEMISTRY.

J. F. NORRIS, REVIEWER.

Investigations on the Two Isomeric Chlorides of Orthosulphobenzoic Acid. BY IRA REMSEN. **IV. Purification of the Chlorides and Action of Various Reagents upon Them.** BY IRA REMSEN AND S. R. MCKEE. **V. The Relation of the Anilides.** BY IRA REMSEN AND J. R. HUNTER. **VI. Orthocyanbenzenesulphonic Acid.** BY IRA REMSEN AND W. J. KARSLAKE. *Am. Chem. J.*, **18**, 791–829.—In earlier articles (*Am. Chem. J.*, 17, 309–347; *Tech. Quart.*, **8**, 194) the preparation and properties of the two isomeric chlorides of orthosulphobenzoic acid were described, and evidence was presented which shows that the chloride melting at 79–79°.5 has the structure  $C_6H_4<\begin{matrix}COCl\\SO_2Cl\end{matrix}$. The reactions of the carefully purified chlorides with various reagents and the resulting compounds have been studied, and additional evidence in favor of the unsymmetrical structure for the low-melting chloride furnished. (**IV.**) To obtain the high melting chloride in pure condition, an ethereal solution of the mixed chlorides is evaporated to crystallization, after being shaken with dilute ammonia, which transforms the low-melting chloride into the ammonium salt of cyanbenzenesulphonic acid. The pure low-melting chloride (m. pt. 21°.5–22°.5) is obtained by fractional crystallization at 0° of the mixed chlorides from carefully purified ligroïn boiling at 90°–125°. Water decomposes the low-melting chloride about three times as fast as the high-melting chloride. 65 per cent. of the former was changed to acid after standing four days at the ordinary temperature. Both chlorides give the same products when heated with phenol; *viz.*, the diphenyl ester of orthosulphobenzoic acid and a compound, probably of the structure  $C_6H_4<\begin{matrix}COOC_6H_5\\SO_2Cl\end{matrix}$, which is changed by dilute ammonia into phenyl orthosulphaminebenzoate,  $C_6H_4<\begin{matrix}COOC_6H_5\\SO_2NH_2\end{matrix}$. The diphenyl ester was saponified when heated at 200°, with concentrated hydrochloric acid, and was transformed into the ammonium salt of benzoic sulphinide,  $C_6H_4<\begin{matrix}CO\\SO_2\end{matrix}>N.NH_4$, when heated at 125° for four hours with ammonia. With resorcinol both chlorides gave the same sulphonfluorescein. When the high-melting chloride was treated with aniline, only the fusible anilide,  $C_6H_4<\begin{matrix}SO_2NHC_6H_5\\CONHC_6H_5\end{matrix}$, (m. pt. 194°–195°) was obtained. The low-melting chloride yielded a mixture of equal amounts of the above compound and the infusible anilide,  $C_6H_4\left\langle\begin{array}{l}C(NHC_6H_5)_2\\SO_2\end{array}\right\rangle O$ which melts at 250°–270° with decomposition. With ammonia the high-melting chloride gives the ammonium salt of benzoic sulphinide, while the low-melting chloride gives the ammonium salt of orthocyanbenzenesulphonic acid. The latter transformation is additional evidence in favor of the unsymmetrical structure for the low-melting chloride,  $C_6H_4\left\langle\begin{array}{l}CCl_2\\SO_2\end{array}\right\rangle O$. When the latter compound was dissolved in ether and shaken with dilute ammonia, it was in part, changed into the high-melting chloride. By the action of benzene and aluminum chloride on the low-melting chloride the same compounds were formed which had been obtained by Remsen and Saunders (*loc. cit.*) from the high-melting chloride; namely, orthobenzoylbenzenesulphonchloride and orthobenzoyldiphenylsulphone. It was impossible to change the low-melting chloride into its isomer by heating in a sealed tube at 90°, or by shaking with water for half an hour. (V.) The two anilides of orthosulphobenzoic acid were prepared by the action of an ethereal solution of aniline on the mixed chlorides. By crystallization from alcohol the two isomers can be separated, as the fusible anilide crystallizes in thin white needles, while the infusible variety crystallizes in short thick prisms. Phosphorus oxychloride and phosphorus pentoxide removed one molecule of water from both compounds forming the dianil,  $C_6H_4\left\langle\begin{array}{l}C=NC_6H_5\\SO_2\end{array}\right\rangle NC_6H_5$, which had already been obtained by Jesurin (*Ber. d. chem. Ges.*, **26**, 2292) by the action of aniline on orthocyanbenzenesulphonchloride. The compound crystallizes in yellow monoclinic prisms, is changed by boiling acetic acid or alcoholic potash into the infusible anilide, and is decomposed into the anil $C_6H_4SO_2.CO.NC_6H_5$ and aniline by boiling hydrochloric acid. The infusible anilide reacts with benzoyl chloride, forming the anil and benzanilide. Since the above facts show that the two aniline residues are intact in the infusible anilide, and since the latter compound is obtained only from the unsymmetrical chloride, it follows that the structure of the anilide is  $C_6H_4\left\langle\begin{array}{l}C=(NHC_6H_5)_2\\SO_2\end{array}\right\rangle O$. (VI.) The mixed chlorides of orthosulphobenzoic acid were dissolved in ether and shaken with ice-cold dilute ammonia. From the water solution the ammonium salt of orthocyanbenzenesulphonic acid crystallized in botryoidal masses of transparent needles. The sodium, potassium, and barium salts were prepared, and from the latter orthobenzaminesulphonic acid, $C_6H_4<\substack{CONH_2\\SO_2OH} + H_2O$, was obtained in an endeavor to get the free cyan acid, $C_6H_4.CN.SO_2OH$. The ammonium salt of the former acid was obtained by boiling the ammonium salt of the latter with dilute hydrochloric acid for eight hours. The potassium, sodium, and barium salts of benzaminesulphonic acid were formed by boiling the ammonium salt of cyanbenzenesulphonic acid with an excess of the respective hydroxides.

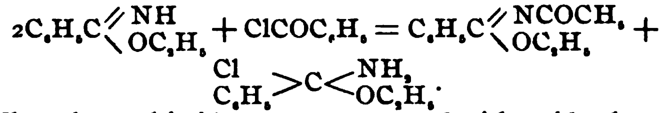
On Parabromdimetanitrotoluol and Some of Its Derivatives. By C. Loring Jackson and Martin H. Ittner. *Am. Chem. J.*, 19, 1–37.—The work described was undertaken in order to find out whether a bromine atom in the ortho position between two nitro groups, but not exposed to the loosening action of a third negative group in the para position, could be removed easily, and be replaced by a hydrogen atom under the influence of sodium malonic ester, as has been frequently observed by Jackson and his pupils in the study of more highly substituted aromatic compounds. The compound selected for investigation, parabromdimetanitrotoluene, proved to be not very reactive; but this was probably due to the influence of the methyl group. It was prepared from dinitrotoluidine, melting at 166°, and was converted by warm aniline into anilidodinitrotoluene (m. pt. 169°), which gave a nitroso derivative, which melts at 123°. Although sodium malonic ester did not act upon bromdinitrotoluene under a variety of conditions, sodium ethylate gave striking color reactions, which are to be described in another paper. The bromine was not replaced, as no dinitrotoluene was found. With ammonia, bromdinitrotoluene gives dinitrotoluidine, and with sodium hydroxide, dinitrocresol. Parabromdimetanitrobenzoic acid was made by oxidizing the corresponding toluene. It melts at 181°, and is more reactive than parabromdinitrotoluene, since the bromine atom is affected by the carboxyl group in the para position. Sodium hydroxide in the cold converts it into oxydinitrobenzoic acid (m. pt. 245°–246°). Bromdinitrobenzoic acid gives, with ammonium hydroxide, chrysanisic acid; with aniline, anilidodinitrobenzoic acid; and with sodium, malonic ester, at ordinary temperatures, dinitrocarboxylphenylmalonic ester, $C_6H_2CH(COOC_2H_5)_2(NO_2)_2COOH$ (m. pt. 176°.) A number of the salts and the ethyl esters of the acids were prepared. An attempt was made to build up very complex molecules from some of the substances described, in order to study the effect of complexity of structure on physical properties. The resulting compounds soon ceased to be crystalline, and the work was therefore abandoned. By the action of pyridine on bromdinitrobenzoic acid two compounds were obtained: a white body, probably a simple salt of the acid; and a very unstable yellow compound whose reactions pointed to the structure, $C_5H_5NBrC_6H_2(NO_2)COOHNC_5H_5$. Some preliminary work on the action of hydrochloric acid on bromdinitrobenzoic acid showed that the products were dinitrophenol ($OH, 1, (NO_2)_2 2,6$) and oxydinitrobenzoic acid.

Aluminum Ethylate. BY H. W. HILLYER AND O. E. CROOKER. *Am. Chem. J.*, 19, 37–44.—In a previous paper (*Am. Chem. J.*, 18, 621; *this Rev.*, 2, 80), Hillyer has shown that aluminum reacts with alcohol in which mercuric or stannic chloride is dissolved, liberating hydrogen and forming a gelatinous mass. During the reaction the metallic chlorides are reduced. The reaction has been studied further; and the authors are of the opinion that it is due to the joint influence of the aluminum-mercury couple and the aluminum chloride formed in the reduction of the mercuric chloride. The product of the reaction when distilled under a pressure of 23 mm. boiled at 235°–245°, and solidified to a gummy mass which melted at 135°. A mixture of one cc. of stannic chloride, 5 grams of chipped aluminum, and 50 cc. of absolute alcohol gives the best results. The authors consider that the chlorine found in the distillate, even after a number of distillations, shows the presence of aluminum chloride. The compound was analyzed for chlorine and aluminum, and, deducting the amount of the latter equivalent to the chlorine, the analyses give results closely approximating those required for aluminum ethylate, $Al(OC_2H_5)_3$. The properties of the compound agree with those of the ethylate prepared by Gladstone and Tribe (*J. Chem. Soc.*, 39, 1) by the action of aluminum and iodine on alcohol.

Paraisobutylphenoxyacetic Acid. BY W. P. BRADLEY AND F. KNIFFEN. *Am. Chem. J.*, 19, 70–76. — Paraisobutylphenoxyacetic acid was prepared by heating paraisobutylphenol and chloracetic acid dissolved in sodium hydroxide. The mixture was neutralized with sulphuric acid, treated with an excess of sodium carbonate, and extracted with ether to remove any excess of phenol. The resulting liquid was then evaporated to a small bulk, acidified, and the acid extracted with ether. The compound is a cream white solid, melts at 86°.5, and crystallizes from ligroïn in radial crystals. The barium and magnesium salts crystallize well. The amide, prepared from the methyl ester, crystallizes from ligroïn in white plates, which melt at 134°. The anilide, metanitranilide, ortho- and paratoluides, and hydrazide are described. A tetranitro derivative of the anilide was formed by the action of fuming nitric acid. The fact that the four nitro groups are divided equally between the two benzene rings was proved by the action of potassium hydroxide, which decomposed the compound into the ortho- and paradinitraniline.

Formation of Diacetylenyl (Butadiine) from Copper Acetylene. BY A. A. NOYES AND C. W. TUCKER. *Am. Chem. J.*, 19, 123–129.—The object of the investigation was to establish the constitution and to explain the formation of the crystalline compound of the formula $C_4H_2Br_6$, obtained by Sebanejeff, (*Ber. d. Chem. Ges.*, 22*c*, 249) by passing acetylene, from copper acetylene, into boiling bromine. The attempts to prepare the body by the action, upon boiling bromine, of acetylene generated from calcium carbide, were unsuccessful. The gas obtained by the action of hydrochloric acid on the copper compound prepared from acetylene generated from calcium carbide was passed into boiling bromine. A 4 per cent. yield of crystals, identical in properties with those of Sebanejeff, was obtained. Substitution of potassium cyanide for hydrochloric acid, and varying the condition of combination of the gas with bromine did not affect the result. As the addition of strips of metallic copper to the copper acetylene during decomposition prevented the formation of the compound, it seemed probable that its formation was due to the oxidizing action of the cupric chloride formed by the contact of the decomposing mixture with the air. Copper acetylene was decomposed in the presence of cupric chloride, and the yield was increased to 9 per cent. When molecular quantities of copper acetylene and cupric chloride were heated for 3 hours, the latter was entirely reduced. Analyses and molecular weight determinations of the bromide showed that its formula is $C_4H_2Br_6$. It melts at 183°.5 (corr.), crystallizes in colorless orthorhombic plates, evolves bromine when heated above its melting-point, and furnishes a distillate, which partially recombines with the bromine vapors, when heated at 220° under a pressure of 40 mm. That the body is not a derivative of the hydrocarbon $(CH)_4$ is shown by the facts, that it is obtained from the oxidation-products of acetylene or its copper compound, and that the gas evolved from copper acetylene is completely absorbed by ammoniacal cuprous chloride, thus showing it to consist only of triple-bonded compounds. The only explanation is that the bromide is formed by the union with bromine of the hydrocarbon C_4H_2, diacetylenyl or butadiine, obtained from its copper compound, which is formed according to the reaction $2C_2Cu_2 + CuCl_2 = C_4Cu_2 + 2Cu_2Cl_2$. That the hydrocarbon combines with only six atoms of bromine is explained by the principle that unsaturated compounds containing a large proportion of halogen often do not become completely saturated. From the gases evolved from copper acetylene a liquid was condensed, which boiled at 40° to 50° and gave with bromine diacetylenyl hexabromide. The crude product was not the pure hydrocarbon, for it contained a large proportion of chlorine.

On the Action of Acid Chlorides on the Imido Esters and Isoanilides, and on the Structure of the Silver Salts of the Anilides. By H. L. Wheeler and P. T. Walden. *Am. Chem. J.*, 19, 129–139.—As the silver salts of the anilides react with acid chlorides as if the metal were joined to nitrogen, and with alkyl halides as if the metal were joined to oxygen, it follows that both reactions cannot be direct double decompositions. It seems probable that addition first takes place, and that this is followed by separation of silver halide. In order to show which of the two possible structures of the silver salts of the anilides $RC\begin{smallmatrix}\diagup NR'Ag\\ \diagdown\!\!\diagdown O\end{smallmatrix}$ or $RC\begin{smallmatrix}\diagup\!\!\diagup NR'\\ \diagdown OAg\end{smallmatrix}$ is correct, the action of acid chlorides was studied on the isoanilides and imido esters, which, it is probable, contain the grouping $RC\begin{smallmatrix}\diagup\!\!\diagup NR'\\ \diagdown OR''\end{smallmatrix}$. With the isoanilides an unstable addition-product is first formed, which breaks down with evolution of alkyl chloride and formation of a mixed diacid anilide. As the reaction takes place readily and is analogous to that between the acid chlorides and the silver salts of the anilides, it follows that the metal is joined to oxygen in the latter compounds. This is in accord with the conclusion of Comstock and Kleeburg (*Am. Chem. J.*, 12, 495). Acid chlorides react with imido esters forming an addition-product from which hydrochloric acid is eliminated. The acid reacts with the excess of the imido ester:

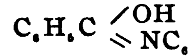


$$2C_6H_5C\begin{smallmatrix}\diagup\!\!\diagup NH\\ \diagdown OC_2H_5\end{smallmatrix} + ClCOC_6H_5 = C_6H_5C\begin{smallmatrix}\diagup\!\!\diagup NCOCH_3\\ \diagdown OC_2H_5\end{smallmatrix} + \begin{matrix}Cl\\ C_6H_5\end{matrix}\!>\!C\!<\!\begin{matrix}NH_2\\ OC_2H_5\end{matrix}.$$

When the acyl imido esters are treated with acids they react with water to form diacid amides and alcohol. The decomposition is analogous to the action of the silver salts of the amides and anilides with acids, and is evidence, therefore, that the diacid amides have both acid groups joined to nitrogen. The action of bromine and iodine on the imido esters is similar to that of the acid chlorides. The new compounds described are formylbenzenesulphonanilide, $C_6H_5N(CHO)SO_2C_6H_5$, benzoylimidoethylbenzoate, $C_6H_5C(NCOC_6H_5)OC_2H_5$, acetylimidomethylbenzoate, bromimidomethylbenzoate, $C_6H_5C(NBr)OCH_3$, and iodimidomethylbenzoate.

On the Effect of Light on the Displacement of Bromine and Iodine from Organic Bromides and Iodides. By J. H. Kastle

AND W. A. BEATTY. *Am. Chem. J.*, 19, 139–149.—The authors have found that chlorine liberated from dichlorsulphonamide by the action of light can displace bromine and iodine from their most stable compounds, and that the bromine of dibromsulphonamide, when liberated, can displace iodine from the benzene ring. In the dark there is no liberation of chlorine from the amide and, consequently, no displacement of bromine or iodine from organic halides, except from unstable compounds like iodoform, where a direct reaction takes place. Chlorine water caused a similar decomposition. Experiments showed that up to 50° the reaction is more dependent upon light than heat. At 14°–18° a mixture of dibrombenzene and chlorine water, after six hours exposure to direct sunlight, gave a good test for bromine, while a similar mixture, heated for five hours in the dark at 50°, suffered no change. Above 50° the reaction takes place in the dark. When *p*-dibrombenzene and chlorine water were exposed to the sunlight for a number of days, a large proportion of the bromine was liberated and a substance, probably a mixture of *p*-chlorbenzene and *p*-brombenzene or *p*-chlorbrombenzene, was formed.

The Constitution of Benzanilide. BY N. KNIGHT. *Am. Chem. J.*,. 19, 152–154.—If the formula of benzanilide is  $C_6H_5C\genfrac{}{}{0pt}{}{\diagup NHC_6H_5}{\diagdown\!\diagdown O}$, the same product should result when benzenesulphanilide is treated with benzoyl chloride, or when benzanilide is treated with benzenesulphonchloride. If the formula is  $C_6H_5C\genfrac{}{}{0pt}{}{\diagup OH}{\diagdown\!\diagdown NC_6H_5}$, the reaction-product should be different. The above reactions were studied, but, as in both cases there was a complete breaking down, and a number of substances were formed, no conclusion as to the structure could be drawn. The chief products of the reaction were dibenzoyl anilide and the aniline salt of benzenesulphonic acid.

On the Decomposition of Diazo Compounds. IX. On the Reactions of Ethyl and Methyl Alcohols with Paradiazometatoluenesulphonic Acid in the Presence of Various Substances. BY JOHN J. GRIFFIN. *Am. Chem. J.*, 19, 163–183.—The work described in this communication, the ninth from the laboratory of the Johns Hopkins University on the subject of diazo compounds, is in accord with the results already published. It has been found that, when paradiazometatoluenesulphonic acid is decomposed below 45° in methyl or ethyl alcohol in the presence of sodium methylate, sodium carbonate, sodium hydroxide, or zinc dust, only the hydrogen reaction takes place. The yield of the resulting acid was determined by converting it into the amide. The best yield (50 grams amide from 100 grams diazo compound) was obtained by effecting the decomposition in ethyl alcohol in presence of zinc dust, treating the resulting mass with phosphorus trichloride and then with ammonia. It is remarkable that the product obtained by decomposing the diazo compound in presence of sodium carbonate did not react with phosphorus trichloride, but was changed into the sulphonchloride by the pentachloride. The diazo compound was not decomposed when treated at 45° with alcohol and calcium carbonate. When decomposition takes place in alcohol saturated with ammonia, the ammonium salt of paratoluidinemetasulphonic acid is formed. Metatoluenesulphonamide melts at 108°, and crystallizes from concentrated solutions in brilliant hexagonal scales and from dilute solutions in large fern-like growths. The amide was oxidized to metasulphaminebenzoic acid, from which the barium and silver salts were made.

On Metatoluenesulphonic Acid. By John J. Griffin. *Am. Chem. J.*, 19, 183–198.—From a study of the literature of metatoluenesulphonic acid, a review of which is given by the author, it is evident that the properties of the acid and its salts are not definitely known. A large amount of pure metatoluenesulphonamide, which was obtained in the work described in the previous review, was converted into the acid, from which the barium, lead, calcium, sodium, potassium, silver, magnesium, manganese, zinc, and copper salts were prepared. These are described in detail. From the study of the acid and its salts it is evident that the compounds described by Müller (*Ann. Chem.*, 169, 47) and by others who have employed analogous methods of preparation were impure products.

The Preparation of Diethyl Malonic Ester. By W. A. Noyes. *J. Am. Chem. Soc.*, 18, 1105.—The time required for the preparation of malonic ester is much reduced by heating the reacting substance with sulphuric acid for an hour instead of treating with dry hydrochloric acid gas. The yield of the ester is equal to the weight of the chloracetic acid taken. This is 10 to 15 per cent. better than by the old method.

Color Reactions of Nitric and Chloric Acids with Certain Aromatic Bodies. By E. C. Woodruff. *J. Am. Chem. Soc.*, 19, 156–169.—The color reactions of nitric and chloric acids with a large number of aromatic compounds were studied, in order to find some new practical tests for the two acids both separately and in mixtures. The procedure was to treat the test solution, generally as a mixture of 10 grams of aromatic body and 100 cc. sulphuric acid, with a drop of a nitrate or a chlorate or a mixture of the two. After standing a short time, potassium hydroxide or ammonium hydroxide is added and the solution is diluted. The color is noted at three stages, before and after neutralization, and after dilution. The results with twenty hydroxyl and amido derivatives are tabulated. Phenol serves to distinguish between the two acids, as nitrates give a strong picrate-colored solution, while chlorates give a brownish-yellow color. Nitrates can be detected in the presence of chlorates, bromates, and iodates, as they give a strong blood-red color with a mixture of dimethylaniline, paratoluidine, and sulphuric acid. Reference must be made to the original article for a number of other interesting observations.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

W. O. CROSBY, REVIEWER.

Italian Petrological Sketches, II. The Viterbo Region. BY HENRY S. WASHINGTON. *J. Geol.*, 4, 826–849.—Lavas of two distinct types, obtained from the Viterbo region, which lies a few kilometers southeast of the volcanic district of Lake Bolsena, are described, the trachytic lavas under the names vulsinite, ciminite and peperino, and leucitic lavas, under the name of leucite-trachyte. One original analysis of ciminite is given, and three earlier ones are quoted for comparison. These show that while as regards the silica, alumina, lime or iron the rock approaches the andesites rather than the trachytes, yet that the potash is largely in excess of the soda, and that the rock is far richer in total alkalies than is the case with the true andesites. On the other hand, the magnesia is also abnormally high for a trachyte. Analyses are also given of the vulsinite, leucite-trachyte, and a phonolite, which occurs very sparingly, as dikes and enclosed masses.

Italian Petrological Sketches, III. The Bracciano, Cerveteri and Tolfa Regions. BY HENRY S. WASHINGTON. *J. Geol.*, 5, 34–49.—As in the Viterbo region, the rocks embrace both non-leucitic and leucitic types; but these are regarded as specifically distinct from the Viterbo rocks, and are described, the former under the name toscanite, and the latter under the names leucitite, leucite-tephrite, and leucite-phonolite. Original analyses of all these are given in tabular form; and the distinctive chemical features are briefly indicated.

The Principles of Rock Weathering. BY GEORGE P. MERRILL. *J. Geol.*, 4, 704–724; 850–871.—This is an able and comprehensive summary of our knowledge of the subject, and must prove of great value to students. Both the chemical and physical aspects of the problem are discussed; and no more important results are presented than those derived from the author's earlier contribution to the literature of rock decay.

The Anorthosites of the Rainy Lake Region. By A. P. Coleman. *J. Geol.*, 4, 907–911.—In the vicinity of Rainy and Bad Vermilion Lakes very basic and very acid igneous rocks—anorthosites and quartzose granites—are found associated. One analysis of each is given, and an analysis of anorthosite from Quebec is quoted for comparison. It appears that the anorthosite from the Rainy Lake region is one of the most basic of the massive rocks, having about eight per cent. less silica than the typical anorthosites of Eastern Canada. A suggestion for a binomial nomenclature of these rocks is followed by a brief discussion of their age and petrologic relations.

The "Augen"-Gneiss Area, Pegmatite Veins and Diorite Dikes at Bedford, N. Y. By Lea McL. Luquer and Heinrich Ries. *Am. Geol.*, 18, 239–261.—Two analyses of the feldspar in the pegmalite veins show that it is a normal orthoclase.

A New and Important Source of Phosphate Rock in Tennessee. By James M. Safford. *Am. Geol.*, 18, 261–264.—The Trenton limestone of the region about Nashville, and especially the member of it known as the Capitol limestone, is normally more or less phosphatic, the richer parts showing upon analysis from 15 to 25 per cent. of phosphate. The true phosphate rock is a residuum after the leaching by meteoric waters of the phosphatic limestone. It is found immediately beneath the soil in layers from three to eight feet thick, and is in every respect of a distinctly residuary character. An analysis by J. M. McCandless, of Atlanta, gave: Calcium phosphate (bone phosphate), 77.54; iron and alumina, 1.50; calcium carbonate, 6.83. Other analyses made in Nashville show the calcium phosphate to range from 60 to 81 per cent.

The Arlington Iron. Minnesota No. 2. By N. H. Winchell. *Am. Geol.*, 18, 267–271.—This iron, weighing 19¾ pounds, was found two and a half miles northeast of Arlington, Minn., in March, 1894. It proved on examination to be a typical metallic meteorite, and an analysis by F. F. Sharpless, gave the following results: Fe, 90.781; Ni, 8.605; Co, 1.023; P, 0.045; total, 100.454. It yielded no sulphur, silicon, or manganese, and only traces of chromium, copper and combined carbon.

Missourite, a New Leucite Rock from the Highwood Mountains of Montana. By Walter H. Weed and Louis V. Pirsson. *Am. J. Sci.* 152, 315–323.—The Highwood Mountains form an isolated group consisting of extinct, greatly eroded volcanoes. Forming the core of one of these denuded volcanoes is a granular rock of a new type and of exceptionally interesting petrologic character to which the authors have given the name

Missourite. The microscope shows the following minerals: apatite, iron ore, olivine, augite, biotite, leucite, and some zeolitic products. As the presence of leucite in a granular plutonic rock was before unknown, particular pains were taken to place its identification beyond doubt. It was isolated by means of a heavy solution, and found to have the specific gravity, optical characters, and composition ($KAl(SiO_3)_2$) of leucite. With one exception, this is the first analysis of a leucite from other than an Italian locality. The zeolitic products were similarly isolated and analyzed, and proved to be analcite and a natrolite in which potash and lime have replaced soda. A mass analysis of the rock by E. B. Hurlburt is also given. This brings out strongly the leading characteristics of the rock, its very high lime, iron, and magnesia, which have compelled the formation of large quantities of pyroxene and olivine; the predominance of potash over soda, which with the low silica have conditioned the formation of the leucite, and which explains why no feldspars have formed. The mineralogical composition is believed to be: iron ore, 5; augite, 50; olivine, 15; biotite, 6; leucite, 16; analcite, 4; and zeolites, 4 per cent. Analyses of absarokite, shonkinite, and a leucite basalt are quoted for comparison; and it is shown that this rock fills a place which has hitherto been vacant in all systems of rock classification. It is the massive, granular, plutonic representative of the leucite basalts and bears the same relation to them that gabbro bears to the ordinary plagioclase basalts or granite to rhyolite.

Chemical Composition of Hawaiian Soils and of the Rocks from Which They Have Been Derived. By A. B. Lyons. *Am. J. Sci.*, 152, 421–429.—The author states that the relation in chemical composition of soils to the rocks from which they are definitely derived, can be studied most easily and profitably in a volcanic country, where disintegration of the rock is rapid and is attended by great chemical changes. The chemical composition of these volcanic soils is peculiarly interesting and full of surprises to one unaccustomed to their vagaries. Ten original analyses of the soils are given, classified as follows: New soils from lapilli (recent fragmental lava); new soils from lava only partially disintegrated; old soils from thoroughly disintegrated ancient lava. The new soils are of a sandy character, containing but little clay; and yet the mineral constituents requisite for plant food—potash and phosphoric acid—are present in extraordinary abundance. Two of the lapilli soils are almost incredibly rich in phosphate, containing respectively 2.92 and 6.47 per cent. P_2O_5. The old soils are clayey, of a deep red color, and relatively poor in phosphate, though comparing very favorably in potash with the new soils. The lavas are highly basic rocks, the more recent forms running as low in silica as 35.86 per cent., the average of the nine analyses given being 47.86 per cent. The ultra-basic recent lavas, especially, are rapidly decomposed by acids with separation of gelatinous silica and evolution of hydrogen sulphide. The variations are 0.17 to 2.75 per cent. K_2O, and 0.26 to 1.25 per cent. P_2O_5; the averages are 1.07 per cent. K_2O and 0.65 per cent. P_2O_5. A third table of analyses gives the composition of lavas altered by exposure to the weather. There has been a notable loss of silica, the average being reduced to 21.32 per cent., with a minimum of 4.54 per cent.; while the alkalies and alkaline earths have almost wholly disappeared. A fourth table compares the averages of all the analyses of sound lava, rotten lava, and soil.

Some Queries on Rock Differentiation. BY GEO. F. BECKER. *Am. J. Sci.*, 153, 21–40.—This paper is an able and timely criticism of the general theory of magmatic differentiation, and especially of the attractive phase of this theory that was first distinctly formulated by Iddings, which regards molten magmas as complex solutions, and hence, in accordance with Soret's principle, subject to differentiation by molecular diffusion when the temperature is not uniform. The author does not deny that diffusion plays some part in lithogenesis, recognizing its operation in the formation of phenocrysts and in the "diffusion aureoles" surrounding eroded crystals. But his criticism is aimed at the view that masses of rock hundreds of meters in thickness could be thus separated, even if the time allowed for completion of the process were equal to an entire geological period. The results of experiments are cited to show that even under the most favorable conditions molecular diffusion is an exceedingly slow process. For example, it is calculated that at the expiration of a million years water would be just sensibly discolored by copper sulphate at a distance of 350 meters from the point of contact with a saturated solution and that semi-saturation would have reached only a distance of some 84 meters. It is assumed that for a typical lava these periods would be at least 50 times greater. Probably a mass of lava of a volume of one cubic kilometer would not have had time to segregate into distinctly different rocks by molecular flow if it had been kept melted since the close of the Archaean, even if the temperature of the top could have been kept sensibly above the temperature of the bottom, a highly improbable condition. If the bottom were more highly heated than the top, convection currents would effectually prevent any segregation in accordance with Soret's principle. Convection is regarded as inevitable in every instance and as constantly and completely neutralizing any possible effect of diffusion. The author next examines the theory that rock differentiation is due to the separation of the magmas during cooling into two or more immiscible fluids, citing the experiments of Alexejew, Pfeiffer, Sorby, Braun, and others. The conclusion reached is that while such a breaking up of magmas probably occurs under favorable conditions, no known causes are adequate to the segregation of the immiscible fluids. The author thus virtually abandons the whole theory of rock differentiation, and for an explanation of the great diversity of igneous rocks falls back upon the view that the differences between well-defined rock types are due to original and persistent heterogeneity in the composition of the globe.

On Igneous Rocks from Smyrna and Pergamon. BY HENRY S. WASHINGTON. *Am. J. Sci.*, 153, 41–50.—This paper contains detailed descriptions and chemical analyses of two rock types, augite-andesite and biotite-dacite.

Notes on the Artesian Well Sunk at Key West, Florida, in 1895. BY EDWARD OTIS HOVEY. *Bull. Museum Comp. Zool.*, **28**, No. 3, 65–91.—In 1895 an artesian well was sunk at Key West, Florida, to the depth of 2,000 feet. Samples of the borings were taken every 25 feet from the surface to the bottom; and this paper embodies the results of a microscopic and chemical examination of these. The material is throughout an almost perfectly pure lime-rock, loosely compacted in the main, and varying from sandy to oölitic in texture, indicating a shallow water origin for a large part of it. Nearly all the samples contain a small proportion of quartz in the form of a fine grained angular sand. Thirteen samples from as many different depths were analyzed. These are seen to be all slightly magnesian, the MgO varying from 0.29 to 6.70 per cent. The silica (chiefly quartz) varies from 0.03 to 5.10 per cent. All the samples contain some phosphoric acid, but this together with the iron and alumina amounted at the most to only 0.40 per cent.

The Genesis of the Talc Deposits of St. Lawrence County, N.Y. BY C. H. SMYTH, JR. *School Mines Quart.*, 17, 333-341.—The crystalline limestones of St. Lawrence County are frequently tremolitic, and pass into tremolite and enstatite schist. The talc is clearly due to the alteration of these anhydrous silicates. Its secondary origin is proved in most cases by its pseudomorphic character, retaining perfectly the form and structure of the original minerals, and showing every gradation in the process of alteration. The so-called veins of talc are, therefore, simply altered beds of tremolite and enstatite schist. The chemistry of the conversion of enstatite and tremolite into talc is expressed by the following equations:

$4MgSiO_3$(enstatite) + H_2O + CO_2 = $H_2Mg_3Si_4O_{12}$(talc), + $MgCO_3$;

$CaMg_3Si_4O_{12}$, (tremolite) + H_2O + CO_2 = $H_2Mg_3Si_4O_{12}$(talc) + $CaCO_3$.

The substitution of hydrogen for calcium in the latter reaction is quite in harmony with the generally accepted view that talc is an acid metasilicate, $Mg_3H_2(SiO_3)_4$. The essential agents of alteration are evidently provided by circulating water holding CO_2 in solution, and many occurrences of talc pseudomorphs show that the change may occur under ordinary conditions of pressure and temperature. Considering its origin, the composition of the talc is surprisingly close to that demanded by theory, as is shown by the analyses which are given.

Notes on the Ecloite of the Bavarian Fichtelgebirge. BY DAVID HALE NEWLAND. *Trans. N. Y. Acad. Sci.*, 16, 24–29. —This fragmentary petrographic sketch is accompanied by analyses of the rock and of certain of its component minerals. The discussion is brief and develops no points of general interest.

The Geology of Point Sal. BY HAROLD W. FAIRBANKS. *Bull. Dept. Geol. Univ. Cal.*, 2, 1–91.— This is a detailed study of a limited area of Cretaceous and Tertiary strata with associated volcanic rocks in the north-western part of Santa Barbara County, California. The petrographic descriptions are freely supplemented by chemical analyses of the various rocks, both sedimentary and igneous. The bituminous shales of the Miocene series embrace a white porcelain-like variety which gave: SiO_2, 86.92; Al_2O_3, 4.27; CaO, 1.60; $K_2O + Na_2O$, 2.48; loss on ignition, 5.13; total, 100.40. This agrees closely with an analysis by Lawson and Posada of the bituminous shale at Monterey. Two analyses of flint are also quoted for comparison. The author rejects the view that this rock is an acid soda rhyolite, and regards it as essentially of organic origin, a consolidated tripolite. The volcanic ash interstratified with the Miocene strata is proved by analysis to be an acid rhyolite, containing 74.841 per cent. of SiO_2. Augite-teschenite, previously described by the author as analcite dialase, forms large dikes in the gypsiferous Miocene strata. This rock is of especial interest on account of the abundant occurrence of analcite in it. The author is confident that the analcite is secondary after some soda-rich original silicate, like nepheline. Analyses are given for the rock as a whole and for its chief constituents—augite, feldspar, and analcite. From the analyses the proportions of the component minerals are computed and found to agree very closely with the results of a mechanical separation by means of a heavy solution and magnet. An elaborate discussion of the composition and a comparison with European teschenites bring the author to the conclusion already stated that the analcite was derived from nepheline, although not a recognizable trace of nepheline now remains. Analyses are also given of gabbro, andesite, and spheroidal basalt. The paper concludes with a discussion of magmatic variation, the author's view being that the rocks in question have come up from a deep basic zone in the earth's crust—a wide-spread body of basic magma of nearly homogeneous composition. This primitive basic magma has experienced both primary and secondary differentiation in the chimneys subsequent to its eruption, through a variety of causes, Rosenbusch's theory of segregation in obedience to chemical affinity being regarded as the most generally applicable.

Notes on the Occurrence of a Rich Silver and Gold Mineral Containing Tellurium, in the Griffith Lode, near Georgetown, Clear Creek County, Colorado. By RICHARD PEARCE. *Proc. Col. Sci. Soc.*, Oct. 5, 1896.—The mineral occurs only in small quantities, associated with pyrite, galenite and chalcopyrite, in a feldspathic matrix containing small quantities of magnesite. The color is dark gray with a bright metallic luster; hardness about 3. An analysis by F. C. Knight of approximately pure material gave: Ag, 50.65; Te, 18.80; Pb, 9.34; Cu, 4.65; Fe, 4.00; Bi, 1.16; S, 8.06; $MgCO_3$, 1.95; alloy of Au and Ag, 0.48; insoluble residue, 1.07; total, 100.16. The author refers the gold wholly to the alloy, which he found to be 725 fine, and regards the mineral as an intimate mixture made up as follows: Hessite, 51.22; argentite, 20.93; Cu_2S, 5.82; FeS, 6.28; PbS, 10.78; Bi_2S_3, 1.45; Au and Ag alloy, 0.48; $MgCO_3$, 1.95; insoluble residue, 1.07; total, 99.95. The Cu_2S and FeS are supposed to be combined as chalcopyrite; and it is noted that the relation between the hessite and argentite corresponds closely to the formula $2Ag_2Te + Ag_2S$.

Notes on the Occurrence of Tellurium in an Oxidized Form in Montana. By RICHARD PEARCE. *Proc. Col. Sci. Soc.*, November 2, 1896.—No complete analyses are given; but the author concludes that below the zone of oxidation sylvanite occurs with rich silver minerals.

Sepiolite. By E. HELMHACKER. *Eng. Min. J.*, **62**, 80–82. This paper discusses the mode of occurrence of sepiolite in Asia Minor and other regions, its derivation from serpentine, and the varieties based upon differences of composition.

Wolfram Ore. BY E. HELMHACKER. *Eng. Min. J.*, **62**, 153–154.—The author describes the occurrence of the mineral wolfram with the tin ores of the Erzgebirge and other districts, discusses its influence in the manufacture of steel, gives analyses of the three grades obtained by concentration, and discusses the method of analysis.

The Geology of the Fox Islands, Maine. BY GEORGE OTIS SMITH. *Dissertation at Johns Hopkins Univ.*, 1–76.—This thorough and every way admirable petrologic study embodies original analyses of several of the igneous rocks, including an andesite and an aporhyolite.

General Geology of the Cripple Creek District, Colorado. BY WHITMAN CROSS. *Ann. Rep. U. S. Geol. Survey*, **16**, (*part 2*), 13–109.—The rocks of the Cripple Creek District include the pre-Cambrian granites, gneisses and schists, and the tertiary volcanics. The most characteristic product of the Cripple Creek volcano is the phonolite. This is chiefly composed of alkali feldspar and nepheline, with sodalite and nosean, and a pyroxene rich in alkali and iron. Four closely accordant analyses by Dr. Hillebrand are given, and three others are quoted for comparison. The proportions of SO_3 and Cl prove sodalite to be more abundant than nosean; the aegirine augite varies with the proportion of lime; zircon crystals are exceedingly rare, and the zirconia disclosed by the analysis is attributed to the rare mineral levenite. From 25 to 40 per cent. of the rock is soluble in HCl, indicating a large amount of nepheline. A trachytic phonolite is next described, with a single analysis, which shows that it differs chiefly from the typical phonolites in the increased percentage of lime. The solubility test indicates a much smaller proportion of nepheline. A nepheline syenite occurring at one point is regarded as a granular representative of the phonolites. The analysis shows that although more basic it is very closely related to the phonolite magmas. The other volcanic rocks described are augite-syenite-porphyry, andesite, plagioclase-basalt and nepheline-basalt, tuff and breccia and rhyolite. These lithologic descriptions are introductory to a detailed structural study of the Cripple Creek volcano, chiefly as exposed in the numerous mines.

Mining Geology of the Cripple Creek District, Colorado. BY R. A. F. PENROSE, JR. *Ann. Rep. U. S. Geol. Survey*, **16**, (*part 2*), 111–209.—No part of the work of the United States Geological Survey deserves higher commendation than its splendid series of timely monographs on the economic geology of the country. The unique character of the Cripple Creek district makes the present contribution especially noteworthy and valuable. The brief introductory and historical sections are followed by a chapter on the ores. The gold occurs chiefly in combination with tellurium; but near the surface the tellurium occurs chiefly in oxidized forms, and the gold is mainly free. That this free gold has come chiefly from the oxidation of the telluride is proved by the angular shape of the pieces of gold, their pseudomorphic striation, their porosity and the presence of oxidized tellurium materials in the rusty coating of the gold. Hillebrand has proved the gold telluride to be calaverite, the proportion of silver being much too low for sylvanite. Auriferous pyrite also occurs, but is not deemed an important source of gold. Among the oxidation products of the pyritic ores is a mineral which Hillebrand has shown to be a hydrated ferric silicate related to chloropal. The analysis gave: SiO_2, 41.80; Fe_2O_3, 37.0; H_2O, 19.90; CaO, 1.10; total, 100.00. The widely distributed manganese oxide is supposed to be derived chiefly from the carbonate or silicate. In a few mines silver occurs in notable amounts, as shown by several analyses and assays; but these do not indicate clearly its mineralogical relations. Lead occurs only very sparingly, as galena or its oxidation products. Zinc also occurs sparingly as the sulphide, sphalerite, and a single analysis is given. Copper is one of the rarest metals in the district; but one occurrence of tetrahedrite containing 11.19 per cent. of silver is noted. Among the gangue minerals a purple fluorite is most characteristic. Besides quartz, there are hydrous forms of silica, including hyalite. The so-called jasper is proved by analysis to be a highly ferruginous opal. Along the line of the veins, especially, the feldspathic constituents of the rocks are extensively kaolinized, and three analyses are given to show that the composition of the kaolin is essentially the same whether derived from the granite, phonolite, or andesite. Calcite and gypsum are rather rare secondary minerals. The next chapters are devoted to the mode of occurrence of the ores, and the source and mode of deposition of the ores. The ores have been derived from the country rocks, both granitic and volcanic, at a considerable depth, and have been deposited largely through fumarole action, in fissures or fissured zones, with extensive replacement of the rocks.

Economic Geology of the Mercur Mining District, Utah. BY J. EDWARD SPURR. *Ann. Rep. U. S. Geol. Survey*, 16, (*part 2*), 343–455.—This latest of the economic monographs of the Survey describes the most recently developed of all the great mining camps of the West. Like Cripple Creek, this is now distinctively a gold-mining camp, and one of a sufficiently unique character, for the gold ores remained undiscovered for many years within 100 feet of the now long abandoned silver mines.

There are two ore-bearing horizons about 100 feet apart near the middle of a great series of limestone strata, each occurring as an impregnation or replacement of limestone along the lower contact of an intrusive sheet of porphyry. The principal vein materials of the lower or Silver Ledge are silica, barium, antimony, copper, and silver; and of the upper or Gold Ledge, are realgar, cinnabar, pyrite, and gold. Very careful assays of the unaltered limestones, shales and porphyries show that the precious metals are very generally present in appreciable amounts; but the Silver Ledge contains only a trace of gold and the Gold Ledge practically no silver. The silver ores are especially distinguished by the fact that they do not contain a trace of lead. Complete analyses by Dr. Hillebrand, embracing over twenty determinations in each case, are given for the silver ore and for both the unoxidized and oxidized gold ores. The chapters on the origin of the ores are replete with interest for the student of chemical geology. The silver ores are regarded as aqueous deposits, but not as the product of a general aqueous circulation. The water which was intimately combined with the porphyry at the time of its eruption and was perhaps the motive cause of the eruption was separated from the lava at the moment of cooling and found its way into the adjoining rock. Being still intensely heated, and carrying in solution many of the chief elements of the eruptive mass, it exerted for a brief period a powerful altering force on the easily soluble limestone, and in the course of this alteration the ores were deposited. The mineralization of the Gold Ledge took place at a distinctly later period than that of the Silver Ledge, and the general nature of the phenomena indicates that the agents were gaseous rather than liquid; that they ascended along the open vertical fissures, probably from some uncooled body of igneous rock below, and impregnated the zone at the lower contact of the porphyry sheet, which was already altered and porous from the effects of the earlier Silver Ledge mineralization, with arsenic, mercury, and gold. The fact that the chief associated minerals of the gold are realgar and cinnabar, and that the gold itself was probably first deposited as the telluride, is regarded as a striking confirmation of this view.

On the Occurrence of Vanadium in Scandinavian Rutile. By B. HASSELBERG. *Astro-Phys. J.*, 5, 194–198.—The presence of vanadium was unexpectedly discovered in samples of the mineral rutile, from both Norway and Sweden, from a careful study of the spectrum obtained by the volatilization of the above mineral in the arc. Whether the amount present is sufficient for analytical determination remains an open question.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

A Revision of the Atomic Weight of Magnesium. BY THEODORE WILLIAM RICHARDS AND HARRY GEORGE PARKER. *Proc. Am. Acad. Arts and Sci.*, **32**, 55–73.—Three samples of magnesium ammonium chloride were prepared by somewhat different processes, great care being used to remove all impurity. Portions of this salt were then gradually heated to redness in a platinum boat in a combustion tube in a current of dry hydrochloric acid, and the residual magnesium chloride was allowed to cool either in that gas or in dry nitrogen, which was then displaced by dry air. The apparatus was so arranged that the platinum boat could be pushed into a weighing tube and the glass stopper of the latter inserted within the combustion tube without exposing the salt to the air. The salt, after weighing, was dissolved in water. In one series of experiments an excess of silver nitrate was added, and the precipitated silver chloride was collected and weighed. In three other more reliable series the ratio, $MgCl_2 : 2Ag$, was determined by adding to the salt a nearly equivalent weighed amount of pure silver dissolved in nitric acid and estimating the slight excess of silver or chlorine in the liquid after allowing the precipitate to settle by comparative measurements of the degree of opalescence produced by adding to separate portions of it minute quantities of silver nitrate and ammonium chloride. The first three series of experiments consisting respectively of five, three, and five determinations gave 24.369, 24.380, and 24.365 as the atomic weight referred to oxygen as 16. The fourth series, consisting of six determinations, was made with even greater precautions than the preceding ones, two distinct samples of magnesium chloride and three of silver being employed. The results obtained are 24.360, 24.364, 24.362, 24.362, 24.363, and 24.363, giving as a mean 24.362, which the authors adopt as the final value of the atomic weight. This brief summary of the results is a sufficient comment on the wonderful accuracy of the work.

The Velocity of the Reaction between Ferrous Chloride, Potassium Chlorate, and Hydrochloric Acid. BY A. A. NOYES AND R. S. WASON. *J. Am. Chem. Soc.*, **19**, 199–210.—The authors present nine series of measurements which show that the reaction is one of the *third order*, its velocity being directly proportional to the concentration of each of the three substances; also six series on the effect of varying the temperature between 0° and 50°. It is shown that the latter effect can be expressed by the thermodynamical logarithmic equation of van't Hoff, whose applicability to several other reactions has already been demonstrated by Arrhenius. The effect is one of the same order of magnitude as that in the case of other actions already investigated.

A Recalculation of the Atomic Weights. By Frank Wigglesworth Clarke. *Smithsonian Miscellaneous Collections*, 1075, 1–370.—This valuable publication is a presentation and critical discussion of all the existing data relating to the combining weights of the elements.

Mercuric Chloride. By D. McIntosh. *J. Phys. Chem.*, 1, 298–300.—In explanation of the observation of Etard that the solubility of mercuric chloride in methyl alcohol is represented by two distinct curves intersecting at about 38°, the author has investigated the nature of the salt separating from the solution above 40° and below 35°. Above the former temperature small compact crystals consisting of the pure salt separate; while below 35° needle-like crystals form, which are shown, by analysis and by determining whether heat is produced or absorbed by the successive addition of varying quantities of alcohol to the salt, to have the composition $HgCl_2.CH_3OH$. The transition temperatures in pure methyl alcohol and in mixtures of it with water were determined by observing with the eye the point at which the needle-like crystals first make their appearance, and by noting the point during the cooling of the solution at which the thermometer reading remains constant for an appreciable interval of time. The results are tabulated.

Mass Law Studies, I. By S. F. Taylor. *J. Phys. Chem.*, 1, 301–303.—The author has determined at 20°, 25°, and 35° the quantities of water which can be added to various mixtures of alcohol and benzene, and the quantities of benzene which can be added to mixtures of alcohol and water, before separation into two layers takes place. The results differ widely from those previously obtained by Bancroft at 20°. The publication of two such discordant series of results from the same laboratory without any attempt to explain the discrepancy seems to the reviewer unjustifiable.

Quintuple Points. By Wilder D. Bancroft. *J. Phys. Chem.*, 1, 337–343.

Solids and Vapors, II. By Wilder D. Bancroft. *J. Phys. Chem.*, 1, 344–348.—Compare *this Rev.*, 2, 36.

Distillation with Vapor. By C. H. Benedikt. *J. Phys. Chem.*, 1, 397–402.—The author cites numerous previous observations showing that non-volatile substances are present in vapors in much larger amounts than would correspond to their vapor pressures, and he describes an experiment of his own in which he distilled a saturated solution of naphthalene in ether in contact with solid naphthalene, analyzed the distillate, and found it to contain a proportion of naphthalene corresponding to a partial vapor pressure of 37 mm., which is more than four times greater than the vapor pressure of pure naphthalene. The author suggests that this may be due to an increase in the vapor pressure of the dissolved substance by the solvent or to a solubility of it in the vapor. The result of the author's experiment seemed so improbable, considering its discordance with the established laws of the vapor pressure of solutions, that the reviewer was led to repeat it; and he was not surprised to find that the distillate passing over between 62° and 82° (the thermometer-bulb being in the liquid) from a concentrated solution of naphthalene in ether left on evaporation at the ordinary temperature about 0.1 per cent. of the former substance instead of 8.8 per cent. as found by the author.

Two Liquid Phases, I. BY WILDER D. BANCROFT. *J. Phys. Chem.*, **1**, 414–425.

A Triangular Diagram. BY WILDER D. BANCROFT. *J. Phys. Chem.*, **1**, 403–410.—The author discusses the plan proposed by Roozeboom for representing, by means of an equilateral triangle the variations in composition of a phase consisting of three components.

Cuprous Chlorid. BY J. K. HAYWOOD. *J. Phys. Chem.*, **1**, 411–413.—Lescoeur has previously shown that cuprous chloride is partially decomposed by water into cuprous oxide and hydrochloric acid, and that successive portions of wash water contain equal quantities of hydrochloric acid until the chloride is completely converted into the oxide, a result in complete accord with the laws of equilibrium. The author has repeated the experiments; and he concludes from his own results that those of Lescoeur were purely accidental and due to the fact that the conditions under which the successive treatments of the chloride with water were made were so nearly identical. It is difficult to see how this could have been the case; for Lescoeur continued the washing until the chloride was entirely decomposed, so that the amount of it in contact with the water must have steadily diminished.

A Contribution to the Study of Water Solutions of Some of the Alums. BY HARRY C. JONES AND E. MACKAY. *Am. Chem. J.*, **19**, 83–118.—The article begins with a brief summary of the previous work relating to the composition of double salts in solution. The authors next describe, as preliminaries to their investigations, a convenient apparatus for the preparation of pure water for conductivity measurements, and a volumetric method of determining aluminum. To prepare the pure water ordinary distilled water, to which potassium permanganate and sulphuric acid are added, is distilled from a large flask into a tubulated retort turned upwards containing an alkaline permanganate solution which is itself kept boiling, so that a continuous distillation occurs; joints are made with asbestos paper and a tin tube serves as a condenser. The authors determined the molecular conductivity of potassium, aluminum, and chromium sulphates and of six of the aluminum, chromium, and iron alums, at dilutions varying from 3 to 4000 liters. It was found that in dilute solutions the alums have a conductivity which is almost exactly the mean of the conductivities of their constituents; but that in more concentrated solutions (0.2—0.025 molecular weight per liter) the conductivity is somewhat less (9.2 per cent. in one case) than the mean. The authors have also determined the freezing-points of the solutions of the same salts, and find that the lowerings caused by the alums are in the more concentrated solutions 10-11 per cent. less than the sum of those of their constituents. The authors consider the differences both of conductivity and freezing-point to be greater than can reasonably be accounted for by the change in electrolytic dissociation of the salts on mixing, and conclude therefore that undissociated alum molecules probably exist to some extent in the more concentrated solutions, but that they are completely broken up in the more dilute solutions. Incidentally the authors have found that the very dilute solutions of the alums increase in electrical conductivity with time, a phenomenon already observed and discussed by Goodwin (*this Rev.*, 3, 22) in the case of ferric chloride.

H. M. GOODWIN, REVIEWER.

The Multiple Spectra of Gases. BY JOHN TROWBRIDGE AND THEODORE WILLIAM RICHARDS. *Am. J. Sci.*, 153, 117–110.—The interesting investigations of the authors on the dual spectra of argon under the influence of a continuous and oscillatory discharge are extended in this paper to nitrogen, hydrogen, the halogens, and helium. The method employed is that previously described (*this Rev.*, 3, 22). A continuous discharge in nitrogen caused the gas to glow with a delicate pink light, and gave rise to a channelled spectrum. Introduction of a gap across which a brush discharge took place caused the glow in the capillary to become more blue, and the red lines in the spectrum to disappear. Introduction of a condenser, whereby the unidirectional was changed to an oscillatory discharge, caused a complete change in the appearance of the discharge; the glow became bluish green, and the spectrum changed to the well-known bright-line spectrum of nitrogen. By gradually damping the oscillations by the introduction of a resistance or inductance in the circuit, the first spectrum gradually reappeared. The same was true of hydrogen; the usual four line spectrum is produced only by an oscillatory discharge; a continuous discharge causes the red glow in the capillary to change to white, and the spectrum to change to one composed of very many fine lines among which are the four characteristic hydrogen lines, by no means especially prominent however. The halogens likewise give two spectra according to the nature of the discharge producing them. With helium the difference of the two spectra is less marked. The bearing of the results on astro-physical problems is pointed out. The work is being extended to other gases under varying conditions of temperature and pressure.

The Temperature and Ohmic Resistance of Gases During the Oscillatory Electric Discharge. BY JOHN TROWBRIDGE AND THEODORE WILLIAM RICHARDS. *Am. J. Sci.*, 153, 327–342.—The resistance which a rarified gas offers to the passage of an oscillatory discharge is very much less than that which it offers to a unidirectional one. The authors have determined the resistance of a Plücker's tube to an oscillatory discharge in the following way. Many hundred photographs of the oscillatory sparks of condensers of different capacities discharged through variable known resistances were taken as viewed in a very rapidly revolving mirror. A curve was then constructed with resistances as abscissae and the corresponding number of half oscillations determined from the photographs as ordinates. Plücker tubes were then substituted for the known resistances, and the spark again photographed. From the number of oscillations thus determined, the corresponding resistance of the tube was interpolated from the plot. The results of a large number of experiments with nitrogen and hydrogen are summarized as follows: 1. The resistance of a gas at low pressure to the oscillatory discharge is very small (5 to 10 ohms). 2. The resistance is in general greater, the less the quantity of electricity. 3. Down to a very small pressure this resistance decreases with the tension of the gas. 4. The form of the tube has an important effect on the resistance of the gas. 5. With the oscillatory discharge it is evident that the electrodes produce far less effect than with the continuous discharge.—The authors then discuss the cause of the different types of spectra produced by direct and oscillatory currents, favoring the view that the continuous discharge is the result of a "polarized condition in which the molecules are in some way bound together by the electric energy striving to force itself through them," while the oscillatory discharge is accompanied by dissociation of the molecules. For the production of such dissociation an enormously high temperature is required, which, however, is entirely outside the bounds of measurement, owing to the brief period of the discharge. Bolometric measurements in a vacuum tube gave no indication of what this may be, as in such measurements only the mean temperature of the gas in the neighborhood of the bolometer is measured. The reviewer would raise the question whether the color and spectrum of a discharge may not be the result of a transformation of electrical energy into radiant energy, either directly or perhaps intermediately through chemical energy, rather than of a very high temperature arising from the transformation of the energy of the discharge into heat, especially in view of Pringsheim's experiments on heated gases and vapors, which go to show that gases cannot be brought to incandescence by heat alone.

Does a Vacuum Conduct Electricity? By John Trowbridge. *Am. J. Sci.*, 153, 343.—This question, which was answered affirmatively by Edlund, and more recently negatively by J. J. Thomson, is again considered in the light of the author's recent experiments on vacuum discharges. The principal resistance encountered in a high vacuum discharge resides at the boundary of the electrodes and the medium. When once this resistance is overcome and a discharge passes through the tube, the resistance of the tube to subsequent oscillations is equivalent to only a few ohms. The author concludes that the resistance of the Crookes' tube to a disruptive discharge diminishes as a perfect vacuum is approached. It should be remembered, however, that the actual resistance offered by a so-called "absolute vacuum" to the *initial* discharge increases almost indefinitely with the vacuum, and that only after a discharge has once passed and broken down the medium, thus presumably modifying in some way the residual gas in the tube, is the resistance reduced for succeeding discharges to the low value measured by Prof. Trowbridge.

The Influence of a Static Charge of Electricity upon the Surface Tension of Water. By E. L. Nichols and T. A. Clark. *Phys. Rev.*, 4, 375–388.—The surface tension of water was determined under different states of electrification by the method of drops. The potential to which the water was raised was measured by means of a modified form of Henley electrometer; and the temperature of the drops as they fell from the dropper measured by means of a thermo-element. It was found that the surface tension diminished—at first slowly, but above 6000 volts rapidly—with increasing voltage. This result was found to be independent of the sign of the charge; and preliminary experiments indicate that the same relations hold true for other liquids than water.

The Lead Cell. By B. E. Moore. *Phys. Rev.*, 4, 353–374.—The theory of accumulators as given by Le Blanc in his *Lehrbuch der Electrochemie* is accepted by the author and reproduced in some detail. A number of experiments on the electromotive force of accumulators during charge and discharge were made at noted intervals of time, particularly immediately after the closing of the circuit, the results being represented graphically. A very rapid change of the electromotive force was noticed during the first few seconds of each run, which is probably due to changes in concentration at the electrodes. The currents used ranged from 10 to 20 amperes, but the current density is not stated. For further discussion of the results, which the author considers to be in agreement with the theory, the reader is referred to the original article. The reviewer would remark that in the valuable paper by Tower on Peroxide Electrodes (*Ztschr. Phys. Chem.*, 18, 17), which has evidently been overlooked by the author, we have the most satisfactory theory yet offered of the positive (peroxide) electrode of the cell while the negative electrode consisting of Pb and $PbSO_4$ in H_2SO_4 is simply a reversible electrode of the second kind, the theory of which is also well established (Goodwin, *Ztschr. Phys. Chem.*, 13, 621).

Empirical Formulae for Viscosity as a Function of Temperature. By A. Wilmer Duff. *Phys. Rev.*, 4, 404–410.—To obtain a formula expressing the dependence of viscosity on temperature for wide ranges of temperature the author integrates the equation: $-\eta\frac{dt}{d\eta} = a + bt + ct^2$ (the equation of the "subsidiary curve of subtangents"), and obtains the following formulæ containing four constants · $\eta = c\left(\frac{t+\alpha}{t+\beta}\right)^n$ and $\eta = c\,a^{-\tan^{-1}\alpha(t+\beta)}$. These formulas are tested with the data of Thorpe and Rodger and those of others. That the agreement should be better than can be obtained with a three-constant formula is self-evident.

Sulfur and Toluene. By J. K. Haywood. *J. Phys. Chem.*, 1, 232–233.—The boiling-points of toluene and of xylene were found to be raised about 2° and 4°, respectively, by the addition of an excess of sulphur.

An Examination of the Abegg Method of Measuring Freezing-Point Depressions. By E. H. Loomis. *J. Phys. Chem.*, 1, 221–232.—The examination consists for the most part of a comparison of the author's method and results with those recently published by Abegg. Abegg's method is regarded as entirely free from objections in principle and "marks a positive advance in freezing-point methods;" but that it may be used to better advantage, the author emphasizes the necessity of making a larger number of independent determinations of each solution than Abegg has done in order to eliminate the indeterminate errors which a consideration of his results shows to be present. It is pointed out that the apparent constancy of Abegg's freezing temperatures as indicated by the constancy of his thermometer within 0.0001° for hours at a time, is undoubtedly due to the "inertia" of the mercury thread in the thermometer, and not to an actual constancy of temperature to this amount; for from the experience of the author the most sensitive thermometers do not respond to temperature changes of several ten-thousandths of a degree, when once the thread has become stationary.

Osmotic Pressure and Variance. BY J. E. TREVOR. *J. Phys. Chem.*, 1, 349–366.—In this paper Gibbs' Phase rule expressed in the form $v = n + 2 - r$, where n is the number of independent substances present, r the number of phases, and hence v the degree of freedom or "variance" (according to the terminology of the author) of the system, is extended to systems containing any number of semi-permeable walls, or in other words, any number of phases in which the osmotic pressure varies from phase to phase. The general criterion is arrived at by the specific consideration of a number of simple and rather complicated systems, and may be formulated as follows: $v=n+2+x+y-r$, where v, n and r have the same significance as above, x is the number of additional pressures due to the introduction of x osmotic walls, and y the number of separations of a component by a wall impermeable to it. For example in the system: solution, vapor, solvent, we have two independent chemical substances n, three phases r, one wall x, and no "separation," as the dissolved substance is present on but one side of the wall; hence the system has two degrees of freedom, or is divariant, since $v=2+2+1+0-3=2$. Again, in the system: solution, solid salt, vapor, solution; we have $n=2$, $r=4$, $x=1$, and $y=1$, since the wall is impermeable to salt and it is present on both sides. This system is therefore divariant, since $v=2+2+1+1-4=2$.

A New Formula for the Wave-Lengths of Spectral Lines. BY J. J. BALMER. *Astro-Phys. J.*, 5, 199–209.—The author proposes the formula: $\lambda_n = a\frac{(n+c)^2}{(n+c)^2-b}$ or $\tau_n = A - \frac{B}{(n+c)^2}$ for representing the line series of different spectra where a, b, c, A, B are constants, λ_n the wave length, and τ_n its reciprocal. The claims made for the new formula are its simplicity and the fact that it is a closed function and not an abridged series (Kayser and Runge), and therefore that it more probably (?) represents the natural law underlying spectral phenomena. The formula is tested on the helium lines. The proposed formula is nearly identical with that proposed by Rydberg several years ago, as noted in an appendix.

Inner Thermodynamic Equilibria. By J. E. Trevor. *J. Phys. Chem.*, 1, 206–221.—The author discusses at some length the interpretation to be given to the several terms in the integral expression: $\varepsilon' = t\eta' - pv' + \Sigma\mu m'$ for the energy of a phase and to the terms resulting from its complete differential; $d\varepsilon = td\eta - pdv + \Sigma\mu dm + \eta dt - vdp + \Sigma m d\mu$. While the first three terms of this equation refer to external energy changes involved by a change in the system, the last three refer to internal energy changes alone and for all reversible changes of state their sum is equal to zero. The article presents in a clear manner the relation to one another of the various forms of thermodynamic potential functions used by different writers. The views set forth are stated to be substantially the same as those published by L. Natanson in 1891 (*Wied. Ann.*, 42, 178).

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. Talbot, Reviewer.

The Mechanical Analysis of Basic Phosphatic Slags. By H. W. Wiley. *J. Am. Chem. Soc.*, 19, 19–22.—The paper opens with a short sketch of the earlier literature relating to basic slags and the methods of their valuation. To bring about a mechanical analysis of the slags, the author proposes to agitate them vigorously with ninety per cent. alcohol. The particles remaining suspended for five minutes are separated, then those after a further interval of two and a half minutes, and the residue is sifted, using sieves with meshes one-tenth and one-quarter of a millimeter. The first two "separates" contain both the highest total and the highest available phosphoric acid. The data suggest that a partial separation, might advantageously be made by the manufacturers of basic slags, for the purpose of obtaining a more concentrated fertilizing material.

Improvements in the Colorimetric Tests for Copper. By George L. Heath. *J. Am. Chem. Soc.*, 19, 24–31.—Standard ammoniacal copper solutions which are permanent for long periods, may be prepared by replacing nitric acid by sulphuric acid after the solution of the pure copper in the former, provided a considerable excess of ammonia is added and the solution preserved in bottles with stoppers sufficiently tight to prevent any escape of ammonia. In the analysis of lean material for copper, a double precipitation of the iron and alumina by ammonia is found to yield better results, and in less time than either the precipitation by aluminum, or a single precipitation by ammonia.

Some Present Possibilities in the Analysis of Iron and Steel. By C. B. Dudley. *J. Am. Chem. Soc.*, 19, 93–108.—The paper gives a concise statement of the present attainments, both with respect to rapidity and accuracy, in the determination of carbon, graphite, silicon, sulphur, manganese and phosphorus in irons and steels. Valuable suggestions are also made respecting those points wherein these methods are still unsatisfactory, and upon which more research is desirable.

The Determination of Sulphur in Pig Iron. By A. A. Blair. *J. Am. Chem. Soc.*, 19, 114–115.—The author finds four kinds of sulphur in pig iron, the fourth being of a sort unacted upon by aqua regia, but oxidized by a fusion of the residue from the aqua regia with potassium nitrate. Bamber's method (*J. Iron Steel Inst.*, 1, 319) is recommended for the determination of sulphur in pig irons.

A Rapid Method for the Determination of Silicon in Silico-Spiegel and Ferro-Silicon. By C. B. Murray and G. P. Maury. *J. Am. Chem. Soc.*, 19, 138–139.—The finely crushed and sifted sample is dissolved in hydrochloric and sulphuric acids, the solution evaporated until only sulphuric acid remains, the ferric sulphate dissolved in hydrochloric acid. The silica is removed by filtration and tested with hydrofluoric acid. The operation may be completed in thirty minutes.

A Method for the Complete Analysis of Iron Ores, with Notes on Särnström's Method of Determining Manganese. By George Auchy. *J. Am. Chem. Soc.*, 19, 139–153.—The author makes suggestions as to the principles involved in the Särnström method of separating iron and manganese, and proposes certain modifications. A procedure for an analysis of an iron ore involving the Särnström separation is given in detail, and additional comments are made on the determination of phosphorus in steel and cast iron. Compare also *J. Am. Chem. Soc.*, 17, 943; 18, 228; 18, 385; 18, 498.

Standard Iodine for Sulphur Determinations. By Edward K. Landis. *J. Am. Chem. Soc.*, 19, 261.—The author work out a simple stoichiometrical calculation (such as could be made by any intelligent chemist), to find the quantity of a potassium permanganate solution necessary to liberate such an amount of iodine as will react with 0.5 gram of sulphur in the form of sulphuretted hydrogen.

W. H. WALKER, REVIEWER.

Is Alcohol a Source of Error in Volumetric Analysis? BY LYMAN F. KEBLER. *Am. J. Pharm.*, **68**, 667–675.—The answer to this question is of considerable importance when the value of alkaloids and alkaloidal residues is to be determined volumetrically. The "commercial alcohol" used by the author in this investigation was colorless, free from residue and foreign odor and of specific gravity 0.8179 at 15°. Solutions of Brazil wood, cochineal, haematoxylin, iodo-eosin, fluorescein, lacmoid, litmus, methyl orange, tropaeolin OO, phenolphthalein and rosolic acid were prepared in the usual manner, and five drops were taken as indicator for each titration. A tenth-normal sulphuric acid and a fiftieth-normal potassium hydroxide solution were then prepared, using haematoxylin as indicator, and after establishing the end-reaction with the other indicators, a set of experiments was carried out to determine the volume of the alkali solution required to neutralize a given volume of the acid solution when mixed with 50 cc. of water with diluted commercial alcohol, and with 94.5 per cent. commercial alcohol. The tabulated results conclusively show that with all the above indicators the commercial alcohol exerts a disturbing influence. This alcohol was then purified by fractionation, after treating successively with potassium hydroxide, tartaric acid, and silver nitrate; and its influence was investigated. The results show that in the experiments made with the commercial alcohol the disturbing action was due to some impurity; for the data obtained with the pure alcohol vary so little from those obtained from pure water, that, except with the indicators tropaeolin and methyl orange, the difference may be attributed to experimental errors. In the case of tropaeolin and methyl orange the stronger alcoholic solutions so interfere with the delicacy of the end-reaction as to render the results unreliable. Iodo-eosin and fluorescein also appear to be affected, but their end-reactions are so indistinct at best that little importance is attached to these variations. With the exception of the four indicators last named, the author thinks it safe to conclude that pure alcohol does not vitiate the accuracy of the volumetric determinations, but that commercial alcohol must be rigidly excluded.

The Determination of Copper and Nickel in Smelter Matte. BY TITUS ULKE. *Eng. Min J.*, 63, 164.—The sample is dissolved in a mixture of sulphuric and hydrochloric acids with the subsequent addition of a little nitric acid, and, after one evaporation to dryness, is redissolved in water and the copper determined by electrolysis with a current of one-fourth of an ampere. For the determination of nickel, the iron is separated by repeated precipitations with ammonia, and the nickel thrown out of the strongly ammoniacal solution at a temperature of 70°, by a current of two amperes.

Blast Furnace Cinders and Their Analysis. BY J. M. CAMP. *Proc. Eng. Soc. Western Pa.*, 13, 18.—This paper, though very comprehensive, does not claim to contain anything that has not already appeared in chemical literature.

A Rapid and Practical Method for Determining Carbon in Iron. BY J. GEORGE HEID. *Eng. Min. J.*, 63, 64.—The sample is treated with copper ammonium chloride in the usual manner, and the separated carbon is collected on an asbestos filter, where it is washed successively with water, alcohol, and ether; it is then transferred to a Rose crucible, dried at 120°, and weighed. A stream of oxygen is led into the crucible which is heated over a Bunsen flame, and the carbon is thus burned off in from three to five minutes; the difference in weight is the "total carbon." The "graphitic carbon" is obtained by dissolving the iron in dilute hydrochloric acid and determining the separated carbon as before.

PROXIMATE ANALYSIS.

F. H. THORP, REVIEWER.

Improvements on Dr. Squibb's Volumetric Method for Estimating Acetone. BY LYMAN F. KEBLER. *J. Am. Chem. Soc.*, 19, 316.—The author found Squibb's method (*J. Am. Chem. Soc.*, 18, 1068) unsatisfactory in two ways: a pure acetone must be used, which is not readily obtainable; and the end-reaction is too slow. After explaining his modified process, the author gives a table of comparative results by the methods of Messinger, Squibb, and himself, showing that Squibb's method gives results lower than his own.

G. W. ROLFE, REVIEWER.

The Quantitative Determination of Carbohydrates in Food-Stuffs. BY W. E. STONE. *J. Am. Chem. Soc.*, 19, 183–197.—The author gives a detailed account of his method of separation and determination of the various carbohydrates in our common cereals and their products. The separations are all made in one sample, and the author claims an advantage of rapidity and convenience over previous methods. Many of the descriptions of processes, especially that of starch determination, are somewhat vague. The omitted details of the discrimination between invert sugar and other sugars, dextrin and "soluble starch," would not have been so trite as to be devoid of interest. Much of the subject-matter given has been previously published.

The Quantitative Determination of Carbohydrates in Food-Stuffs, II. By W. E. Stone. *J. Am. Chem. Soc.*, 19, 347-349.—The author draws attention to the obvious error in the starch estimations of his previous publications already referred to in these pages. He still finds a noticeable weight of the grain unaccounted for in his corrected analyses. The reviewer trusts that he will not be misunderstood when he reiterates that a more complete explanation of methods and more data should be given in the description of starch analyses. In no class of analyses does there exist more confusion, not only in methods of manipulation but of calculation, than in that of starch and starch products. Thousands of analyses become valueless simply from lack of published data that are absolutely necessary as a basis of comparison and correction. In the interests of science no space should be begrudged to this end.

Notes on an Analytical Investigation of the Hydrolysis of Starch. By G. W. Rolfe and Geo. Defren. *J. Am. Chem. Soc.*, 19, 261-262.—The authors call attention to important errors of calculation and misprints in recently published papers. They also give a few additional deductions from the original data.

A. H. GILL, REVIEWER.

A Technical Analysis of Hydrocarbons, Vapors, and Gases in Literature and Laboratory. By W. H. Birchmore. *Am. Gas Lt. J.*, 66, 445-446 and 478-480.—The author reviews briefly the various methods for gas analysis in use from 1875 to the present time, and states that the best description of these methods is given in *Thorpe's Dictionary of Applied Chemistry.*

Heat of Bromination as a Means of Identifying Fats and Oils. By Bromwell and Mayer. *Am. J. Pharm.*, 69, 145.—The authors have applied the method of Hehner and Mitchell, modified by Wiley, to many different oils. They use a tube jacketed with cotton and calcined magnesia, and use the oils and bromine in chloroform solution.

A Brief Resume of Acetic Anhydride in Oil Analysis and a Modification of the Method for Estimating Menthol in Oil of Peppermint. By L. F. Kebler. *Am. J. Pharm.*, 69, 189–195. —The determination of the combined menthol is effected by submitting 10–12 grams of the oil to the Koettstorfer test. Each cubic centimeter of normal sodium hydroxide solution is equivalent to 0.156 grams of menthol in combination as an ester. For the total menthol, 10–12 grams of oil are subjected to the usual acetylating process, and treated as above. By deducting the amount of menthol in the form of esters from the total quantity found, the amount of free menthol is obtained. The process can be easily carried out in three hours. The author states that in the examination of oil of peppermint the following points should be taken into consideration:

(1) Specific gravity at 15° C., which in the eight samples examined varied from 0.9065 to 0.9147; (2) the boiling-point, which varied from a little below 200° C. to about 230° C.; (3) amount of menthol. The combined menthol varied from 3 to 16 per cent., the total from 30 to 80 per cent. These data, together with the aroma and identity tests, will show the character of almost any sample.

TECHNICAL CHEMISTRY.

F. H. Thorp, Reviewer.

Manufacture of Albumen at Chinkiang. By A. C. Jones. *U. S. Consular Rep.*, 53, 386.—This deals with the preparation of albumen from ducks' eggs. The eggs are broken and the yolks separated from the whites. The whites are then stirred until uniformly mixed, and then dried in shallow tin pans, at a temperature of 40° to 50° C. The drying occupies about 70 hours. Sometimes the albumen is put into vats and allowed to ferment, the process being hastened by the addition of some chemical, the nature of which is not revealed. The impurities rise in the froth, or settle to the bottom, and the clear albumen is drawn off and dried as above. The yolks are stirred through sieves and then mixed with salt, borax, and other chemicals. The thick, orange-colored liquid is filled into barrels and shipped. Its chief use is in the leather industry, for dressing. The chemicals used in preparing the albumen and yolk are said to be salt, borax, acetic acid, ammonia, boracic acid, and calcium chloride, but the quantities used and the methods of their employment are not stated.

Asphalt and Asphalt Pavements. By Geo. W. Tillson. *Proc. Am. Soc. Civil Eng.*, 23, 179–199.—Regarding the composition of asphalt, the author quotes Peckham, Boussingault, and

Endemann. The geographical distribution of asphalt deposits is also shown, followed by an account of the methods of obtaining and refining Trinidad, California, Bermudez, Utah, Kentucky, Indian Territory, and European asphalts; their physical properties are given, and in most cases also the chemical composition, but no authorities are quoted for the analyses. The greater part of the paper is devoted to the use of asphalt for pavements, and this is treated from the engineering and not from the chemical point. The author holds that a chemical analysis is of no particular assistance in forming an opinion of the suitability of an asphalt for a given pavement; it may however be of value in determining the amount of flux to be added for any given purpose. The refined asphalt should contain 50 to 60 per cent. of bitumen, which should be composed of about 75 per cent. petrolene, and 25 per cent. asphaltene.

Notes on Portland Cement Concrete. By ANDREAS LUNDTEIGEN. *Proc. Am. Soc. Civil Eng.*, 23, 135.—The author discusses the advantages derived from the addition of finely powdered siliceous material to Portland cement for concrete. He quotes Michaëlis to the effect that a large part of the lime in Portland cement is set free during the hardening, and also concludes from his own observations that this is true. The lime thus set free, may take up carbon dioxide from the air and is then rendered non-injurious, or it may be dissolved away by water, leaving the concrete porous, or in case sea-water reaches the concrete, the salts it contains will combine with the calcium hydrate to form double salts, which crystallize, or swell, and cause disintegration of the concrete. The author recommends the addition of a siliceous material which he calls *sil.* It is a volcanic ash from Nebraska, Colorado, and other places. Analysis shows its percentage composition to be: Silica, 71.78; titanic acid, 0.80; alumina, 12.71; iron oxide, 2.29; magnesia, 0.35; lime, 1.01; water of constitution, 4.52; alkalies (by difference), 6.54. Ash containing a large amount of water of constitution, is considered best for this use. The siliceous material combines with the free lime. Numerous tables showing the effect of such additions are given. The ultimate strength appears to be considerably increased.

European Portland Cement Industry. By FREDERICK H. LEWIS. *Eng. Record*, 35, 312, 334, 378, 403, 444, 466.—This paper gives a description of several manufacturing establishments visited by the author while traveling abroad.

A. H. GILL, REVIEWER.

Analysis of Popo Agie, Lander and Shoshone Petroleum. By E. E. SLOSSON. *Univ. Wyom. Bull.*, 2, 21–34.—About 60 kilograms of the Popo Agie oil were distilled, and collected in 52 fractions, the flashing and burning points, and the specific gravity of each of which were determined. Another sample was treated similarly, except that superheated steam was introduced after the kerosene had distilled off, which produced a larger proportion of products similar to lubricating oils. The results of the experiments seem to indicate that the commercial products would be, in percentages, about as follows: Naphtha, 2–5; kerosene, 30–40; lubricating oil, 35–50; paraffin, 3–5; coke, 7–10; and gas, 10–12. Lander petroleum is much lighter than the usual Wyoming oils, while Shoshone petroleum is very heavy, and, like the Popo Agie, contains sulphur.

The Presence of Hydrogen, Hydrocarbons, and Nitrogen Peroxide in Boiler Furnace Gases. BY R. S. HALE. *Eng. News*, 37, 107.—The author points out the fact that the absence of carbon monoxide is not a proof of the absence of free hydrogen or hydrocarbons. He shows that oxygen has a greater attraction for carbon than hydrogen at temperatures about 600° C. In calculating the distribution of the oxygen entering the grate nearly 0.8 per cent. frequently remained unaccounted for. It was thought this might be due to the presence of oxides of nitrogen, and upon examination it was found that in one case 0.9 per cent. of oxides of nitrogen was actually formed.

The Calorific Value of Certain Coals as Determined by the Mahler Calorimeter. BY N. W. LORD AND F. HAAS. *Eng. News*, 37, 188–189.—The authors give the ultimate chemical analysis and heating value of forty samples of Ohio and Pennsylvania coals. The varieties were Upper Freeport, Ohio, Pittsburgh, Darlington, Hocking Valley, Thacker, West Va., Pocahontas, and Mahoning. To prevent portions of coal from being blown away by the oxygen, it was compressed into cylinders. The agreement of the calculated results by Dulong's formula with the calorimetric results is remarkable, the maximum difference being 2 per cent., and the minimum 0.1 per cent. This is a trifle greater than the results of which ultimate analysis would yield, the possible error of the latter being for hydrogen 0.5 per cent., for carbon 0.2 per cent. This would cause an error in substitution in the formula of 1.4 per cent. They could find no relation between the "fixed carbon" and the heating value, but they found that the coal from a given seam extending over considerable areas, may be regarded as essentially of uniform heating value.

Calorimetry. BY C. D. JENKINS. *Am. Gas Lt. J.*, 66, 442.—The article gives the results of tests made with the Junker Gas Calorimeter on various gases, both coal and water. It suggests that the proper standard for comparison is gas saturated with moisture at 60° F. and 30 inches barometric pressure. The apparatus gave with hydrogen 326.8 B.T.U., as against 328.8 obtained by Berthelot.

Calorimetry and Heat Unit Value of Gases. BY F. B. WHEELER. *Am. Gas Lt. J.*, **66**, 518.—The author compares the calorific power of various gases obtained by calculation with those obtained by direct determination with a calorimeter. He uses for the theoretical calculation Thomson's figures expressed in English units (B. T. U.) as follows:

$$\begin{array}{l} \text{CO, 348; H, 349;} \\ CH_4\text{, 1065; } C_6H_6\text{, 4010;} \end{array} \left\{\begin{array}{l} C_2H_4\text{, 1673} \\ C_2H_6\text{, 2509} \end{array}\right\} \begin{array}{l} \text{Usually figured as ``Illu-} \\ \text{minants''} = 2000 \text{ B.T.U.} \end{array}$$

At 32° F. and 29.92 inches. To reduce the heat units thus found to the standard adopted in calorimetric work, *viz.*, gas saturated with moisture at 60° F. and 30 inches, multiply by 0.9298. It was found that the theoretical results agreed with the practical within about one per cent.

Comparative Tests of Light Secured and Operating Expense of the Welsbach Lights and Oil Lamps. BY H. D. WALBRIDGE. *Am. Gas Lt. J.*, **66**, 405.—It was found that the Welsbach burner gave 84.6 candle power per hour, at a cost of 0.3 cent for gas and 0.1 cent for mantles. A good oil lamp, with round wick with central draft, gave 30 candle power and cost 0.48 cents per hour; while the B. & H. oil lamp gave 37.5 candle power and cost 0.54 cent per hour. Gas was reckoned at one dollar per 1000 cubic feet, and kerosene 12 cents per gallon.

BIOLOGICAL CHEMISTRY.

W. R. WHITNEY, REVIEWER.

The Gelatin from White Fibrous Connective Tissue. BY WILLARD G. VAN NAME. *J. Expt. Medicine*, **2**, 117–129.—The aim of the author has been to obtain a pure sample of one of the several probably distinct compounds known as gelatins, and to determine its chemical composition and properties, so that the exact relationship between gelatin and albumin may be made clear. As source of the gelatin the author chose the collagen of tendons from oxen. After extraction with water the finely ground material was treated with alkaline pancreatic juice. By this treatment tissue elements other than the collagen were dissolved. This was filtered from the solution, washed with water, and finally dissolved in boiling water. The concentrated gelatin solution was poured into a large volume of 95 per cent. alcohol and the precipitated product washed with absolute alcohol and with ether until it became brittle. It was then pulverized and extracted with ether to remove fat, dissolved in water, and again precipitated by alcohol, washed, etc., as before. The dried product was then analyzed. Samples were also prepared from ox tendons by three ways differing somewhat from the above. The results of the analyses of the different samples agree very well with one another, the average composition of the ash-free gelatin being: Carbon = 50.11, hydrogen = 6.56, nitrogen = 17.81, sulphur = 0.256, oxygen = 25.24, ash = 0.325. The chemical properties of the four samples were found to be identical. Many of the characteristic reactions of pure gelatin are given, including a study of its precipitability by many acids and salts.

The Relative Strength of Antiseptics. By LOUIS KAHLENBERG. *Pharm. Rev.*, **15**, 68–70.—After a brief historical account of the advance of the theories of solution, the author summarizes the valuable and instructive work of himself and True (*Botanical Gazette*, **22**, 181), and of Heald (*Botanical Gazette*, **22**, 125), upon the connection between the toxic action of aqueous acid, basic, and salt solutions upon various plants, and the condition of dissociation of these substances. The recently published work of Paul and Krönig (*Zeit. phys. Chem.*, Dec., '96), on the action of chemical reagents on bacteria is carefully reviewed. The author finds in this last, a confirmation of the views previously advanced by himself and True regarding the connection between electrolytic dissociation of compounds and their toxic or antiseptic action.

Formic Aldehyde; Its Practical Use. By F. C. ROBINSON. *Maine State Board of Health, 9th Report*, 1–24.—In 1893, a German chemical manufactory put upon the market a 40 per cent. aqueous solution of formic aldehyde, which they called formalin, and for which very valuable disinfectant properties were claimed. It seemed possible that this new germicide might soon replace all others, both because of its powerful germicidal effect and of the safety to the ordinary furnishings of rooms, paintings, fabrics, etc., accompanying its use. Mr. Robinson has given the gaseous aldehyde a practical trial and ingeniously devised an effective form of lamp which produces the aldehyde in the room where its use is desired. The alcohol vapor is changed to aldehyde by glowing platinum-black deposited upon a perforated asbestos disk, which partly covers the vessel containing the alcohol. He states among other important facts, that the aldehyde from two liters of alcohol, in a room of 3000 cubic feet capacity, destroyed typhoid and diphtheria cultures even when these "were rolled up in a mattress and the whole tied into as compact a bundle as possible." Experiments with the aqueous solutions were also made, but the vaporizing treatment was more successful. The article contains two illustrations showing the construction of the lamp above mentioned.

A Chemical Study of the Secretion of the Anal Glands of Mephitis Mephitica (Common Skunk), with Remarks on the Physiological Properties of this Secretion. By THOMAS B. ALDRICH. *J. Expt. Medicine*, 1, 323–340.—The secretion was subjected to fractional distillation. The distillate of which the boiling-point was 100°–110° contained about 35 per cent. of sulphur and the author analyzed the mercaptides produced by addition of lead acetate, mercuric chloride, and mercuric oxide to alcoholic or ethereal solutions of this distillate. The results show the probable presence of primary normal butyl mercaptan, together with small quantities of higher mercaptans. That portion of the secretion boiling above 130° contains no mercaptans. The sulphur which it contains is thought to be combined with some basic nitrogen radical.

The Occurrence of Raffinose in American Sugar Beets. By W. E. STONE AND W. H. BAIRD. *J. Am. Chem. Soc.*, 19, 116–124.—As the result of investigation of the non-crystallizing sirups from a Nebraska beet sugar refinery, the authors conclude that raffinose occurs in the juices of the American sugar beet in appreciable quantities. Photographic reproductions of crystals of pure sucrose, raffinose, and a mixture of the two show the marked effect of the presence of even a small proportion of the latter in causing the mixture to crystallize in elongated, sharp-pointed crystals, much more like those of pure raffinose than sucrose.

Marrubiin and Its Dichlorine Derivative. By HARRY MATUSOW. *Am. J. Pharm.*, 69, 201–209.—The author reviews the work already done by Harms, Kromayer, Hertel, and Morrison, and then describes his own investigations. He details carefully the isolation and purification of marrubiin and describes its properties, both physical and chemical. Results of analyses made by him are given, which show that marrubiin is not a glucoside, as was formerly believed. He also describes his preparation of the dichlorine derivative of marrubiin, gives its composition as derived by analyses, and states its physical properties.

The Phenol-Content of the Oil of the Monarda Fistulosa (L). By E. J. MELZNER. *Pharm. Rev.*, 15, 86–87.—This article, which is a further contribution of the author's work on the Wild Bergamot oil, contains three tables of results. These show the percentage of phenol in a dozen samples, as determined volumetrically and by titration with iodine solution, also the yields of oil from given weights of stems, leaves, flowers, and fruit of the plant, together with the specific gravities of the oils obtained. Comparisons with results of previous years are also given.

The Presence of Starch and Strontium Sulphate in Opium and their Influence on Assaying. BY LYMAN F. KEBLER AND CHARLES H. LAWALL. *Am. J. Pharm.*, **69**, 244-250.—The authors have found these ingredients in samples of commercial opium and the fact that all cases examined in one consignment showed practically the same quantities of impurity, leads them to conclude that a "manipulation" of large quantities of opium occurs before it is packed in the cases. As the morphine present is always well above the legal requirements it would be interesting to know the reason for the adulteration, if such it is.

Gelsemium. BY L. E. SAYRE. *Am. J. Pharm.*, **69**, 234-235. —This may be considered as a conclusion of the author's previous article on the subject (*ibid.*, **69**, 8-13). Analyses of the rhizomes, roots, and stems are given, showing that the gelsemine alkaloid, and gelsemic acid do not occur in the stem but only in rhizome and roots, so that admixture of the stems with the commercial roots is to be considered an adulteration.

Gelsemic Acid. BY VIRGIL COBLENTZ. *Am. J. Pharm.*, **69**, 228-231.—The author, after giving the brief history of this vegetable acid, points out an important source of error in previous analyses of the substance. He finds that a part of the carbon always separates in the combustion tube, in an incombustible graphitic form. Five different methods of combustion were tried and in none was the oxidation complete. A description of the wet combustion method using chromic acid in sulphuric acid, as employed by him, is then given, although this method also failed when gelsemic acid was analyzed. The analyses of bromo and acetyl derivatives, which were more successful, the author does not give, as he intends to study their molecular weights with an aim to determining their formulas.

Note on Phospho Cereal. BY T. H. NORTON. *Pharm. Rev.*, **15**, 46.—Results of analyses of the so-called phospho cereal and its decoction are given. The sample contained 5.18 per cent. of phosphorus, calculated as P_2O_5. Of this about one-quarter was extracted by fifteen minutes' boiling with water and less than one-half in two hours. Phosphites and hypophosphites were not present in the decoction, all the phosphorus being present as phosphoric acid. By this latter expression is doubtless meant phosphate instead of free acid.

The Proteose of Wheat. By Thomas B. Osborne. *Am. Chem. J.*, 19, 236-237. Exceptions are taken to the statement of Teller (*ibid.*, 19, 65) that the proteose and proteose-like body discovered in saline extracts of wheat flour by Osborne and Voorhees is gliadin. The author repeats the statement of the original article (*ibid.*, 15, 404) that the proteids of the extract were separated from the gliadin by ammonium sulphate solution, in which this body is insoluble. He believes that the proteose which was found in this salt solution cannot be gliadin.

Proximate Analysis of Orris Root. By S. Allen Tucker. *Am. J. Pharm.*, 69, 199-200.—The author gives the results of his experiments upon the granular substance, which was ground fine and extracted with petroleum ether, ethyl ether, alcohol, water, etc. His results for moisture and ash determinations, as well as of the qualitative analysis of the ash, are also given. Unfortunately, as no descriptions and details of the processes he employed accompany the article, the numerical values must be accepted with caution.

Parthenium Hysterophorous. By H. V. Arny. *Am. J. Pharm.*, 69, 169-180.—This is a continuation of work done by the author on this "common weed of Jamaica." Following a description of the plant, its blossoms, etc., the author states that besides starch, wax, gum, and mineral salts, there is also present an active principle to which the bitterness of the plant is due. This is obtained from the alcoholic extract of the drug by evaporation, solution in water, and extraction with chloroform. An improved process of extraction is also given. A well crystallized body was obtained, and its melting-point found to be 168–169° C. Its solubility in various reagents is given. The author is led to reject the belief that the body is either an alkaloid or glucoside, but considers it probably similar to santonin.

The Rotary Properties of Some Vegetable Proteids. By Arthur C. Alexander. *J. Expt. Medicine*, 1, 304-323.—The author has determined the specific rotary powers of the globulins of hempseed, flaxseed, and Brazil nuts, in aqueous solutions of salts, acids, and alkalies. The specific rotary powers differed with different salt solutions, decreased in general with the percentage of the proteid in solution, and changed but slightly with the temperature.

Changes in and Additions to Methods of Analyses Adopted at the 13th Annual Meeting of the Association of Official Agricultural Chemists. By H. W. Wiley. *U. S. Dept. Agr. Circular No. 2*, 1-6.—This pamphlet is a supplement to the official methods of Bulletin No. 46, consisting of corrections and substitutions to be interlineated into that report. The methods for analysis of fertilizers, soils, foods, and feeding-stuffs, tanning materials, and fermented liquors have all been improved. These corrections are many of them very important.

E. H. RICHARDS, REVIEWER.

California Walnuts, Almonds, and Chestnuts; their Composition and Draft upon the Soil. BY E. W. HILGARD. *Cal. Expt. Sta. Bull.*, 113, 1-15.—Nuts are a concentrated form of food. The walnut and almond kernels contain respectively 65 and 58 per cent. of oil, and 17 and 25 per cent. of proteids, while the chestnut yields about 11 per cent. of oil and of proteid, and 75 per cent. of carbohydrates, or nearly as much as prunes and apricots. The chestnut may, therefore, take the place of cereals, and the walnut and almond that of meats, under certain conditions.

Chemical Survey of the Water Supplies of Illinois. BY A. W. PALMER. *Preliminary Rep., published by the Univ. of Ill.*, 1-98.—This report is a valuable addition to our knowledge of the character of water supplies of the United States, and will well repay close study. "The aims of the survey include the determination of the present sanitary condition of the supplies drawn from the lakes, the streams, and the wells of the State; the determination of the normal condition of the contaminated waters; the formulation of local standards of purity based upon the results of analyses of water derived from unpolluted sources; the provision of such means as shall afford to citizens of the State opportunity to obtain immediate information regarding the wholesomeness of the potable waters in which they are directly interested; and the prevention and dissemination of disease from the use of impure water." Although the conditions of work in a State university demand the analysis of miscellaneous samples, collected under unknown conditions by untrained persons, and consequently render the results obtained from this class of water somewhat uncertain, the information given by the figures tabulated for 802 samples of such water is most interesting to all who have to do with the sanitary conditions of the Middle West. Of far more interest to the chemical and sanitary engineer are the results of the periodic examinations of wells in various parts of the State for the purpose of determining the character of the normal ground water of the State. The importance of this part of the work is evident from the statement that more than half the inhabitants of the State depend upon wells for their water supply. A comparison of the figures tabulated for the comparatively shallow wells shows a greater proportion of nitrates to chlorine than is usual in the waters of the East. Even in the deep drift wells the nitrates vary very much more than the chlorine. This is possibly due to the passage of the water through the rich prairie soil, presumably higher in nitrates than the poorer soils of the East, or to a lessened use of salt in the ordinary household operations. It would seem rather premature to establish standards before determining some of the causes of the unusual variations observed even in the best waters. The periodic analyses of the several surface waters are of great interest for reference and comparison. The plans of work and the methods of analysis used are, for the most part, taken from those published in the reports of the Mass. State Board of Health.

Dietary Studies at the Maine State College in 1895. By Whitman S. Jordan. *U. S. Agr. Expt. Sta. Bull.*, 37, 1-57. —This Bulletin contains the records of a large number of analyses of food materials and gives other data for the calculation of dietaries. The conclusions in regard to the use of milk in place of meat are somewhat influenced by the fact that a new manager, during the first weeks of service, would naturally use more meat than in the later time when he had gained experience. Milk may be a cheap food when the whole ration is a somewhat expensive one, when the milk can be bought at the low price of 4 cents per quart, and when the meat used costs 10 to 20 cents per pound; but when the daily expense must be limited to an outlay of 9 to 15 cents and milk costs 5 to 6 cents per quart, while beef may be had at 6 cents per pound, the conclusion does not hold. More data are needed before we can accept, as settled, the statement that the free use of milk lessens the use of other foods.

Sand Filtration of a Public Water Supply. By James O. Handy. *Proc. Eng. Soc. Western Pa.*, *1897*, 1-57.—The records of a year's working of an experimental filter used in connection with the city water supply of Pittsburg, Pa., are given in detail, together with a considerable number of chemical and bacteriological results.

Brief Comments on the Materia Medica, Pharmacy, and Therapeutics of the Year Ending October 1, 1896. By E. H. Squibb. *Squibb's Ephemeris*, 4, 1776–1923.

AGRICULTURAL CHEMISTRY.

F. H. THORP, REVIEWER.

Analyses of Fertilizers. *Agr. Ex. Sta. Bull. Ky. No.* 65; *Me. No.* 33; *Md. No.* 45; *Mo. No.* 34; *N. J. No.* 117; *Vt. No.* 57; *Wis. No.* 57.

Basic Slag as a Fertilizer. BY F. E. THOMPSON. *Scientific Am. Supp'l.*, 43, 17659.—The author gives a resumé of the published reports of the various State Agricultural Experiment Stations of the United States on the use of basic slag as fertilizer.

Effect of Bisulphide of Carbon on the Vitality of Seeds and Plants. BY M. H. BECKWITH. *Del. Agr. Exp. Sta. Rep.*, *1895*, 152.—The germination of wheat treated with carbon bisulphide before planting, was not affected to any extent. Strawberry plants were injured by exposure to the fumes before planting, but when growing no injury was noticed.

The Bleaching of Nuts by Dipping. BY E. W. HILGARD. *Cal. Agr. Col. Bul. No. 113.*—This paper gives an account of the use of sodium hypochlorite and bisulphite solutions, for bleaching the shells of nuts.

Ammoniacal Solutions of Copper Carbonate. BY C. L. PENNY. *Del. Agr. Sta. Rep.*, *1895*, 206.—The author finds that dilute ammonia will dissolve more copper carbonate than stronger solutions. For the preparation of fungicides, the ammonia should be diluted nine-fold before dissolving copper carbonate in it, and this solution is further diluted one hundred-fold before use.

G. W. ROLFE, REVIEWER.

The Insoluble Carbohydrates of Wheat. BY H. C. SHERMAN. *J. Am. Chem. Soc.*, 19, 291–316.—This is an important paper giving in much detail the preparation of many of these carbohydrates, their characteristic reactions, and the more approved methods for their determination. A brief review is given of the work done to solve the much discussed question of the food value of the celluloses and pentosans.

E. H. RICHARDS, REVIEWER.

Sorghum as a Forage Crop. BY THOMAS A. WILLIAMS. *U.S. Dept. Agr. Farmers Bull.*, 50, 1–20.—Beside the discussion relating to the cultivation of sorghum, there are given tables showing the results of chemical analyses of the plant and seeds, and a comparison with analyses of corn.

APPARATUS.

A. H. GILL, REVIEWER.

Note upon an Improved Specific Gravity Bottle. BY E. R. SQUIBB. *Squibb's Ephemeris*, 4, 1771–1775.—The usual form of bottle with the neck ground in, is modified by graduating and calibrating this neck, so that the bottle may be used for temperatures from 0° to 25°.

Some Apparatus for the Technical Laboratory. By E. S. Johnson. *J. Am. Chem. Soc.*, 19, 281.—The article describes apparatus for the measuring of reagents, filtration, and solution with the aid of heat. For details reference must be made to the illustrations in the original paper.

A New Calibrated Weighing Flask. By G. L. Heath. *J. Am. Chem. Soc.*, 19, 198.—The improvement consists of a collar ground upon the ordinary flask and a cap to fit it. This flask has the advantage that it can be stoppered without danger of sticking.

The Use of Aluminum for Condensers. By T. H. Norton. *J. Am. Chem. Soc.*, 19, 153.—It was found that aluminum possesses the same advantages over glass as tin, but is much lighter and a better conductor of heat; hence it is better adopted for use with low boiling substances.

A New Laboratory Grinder. By C. A. Buck. *J. Frank. Inst.*, *1897*, 194.—It has been in use in the laboratory of the Bethlehem Iron Co. for five hours a day for three years and given satisfaction. It will grind a charge of 30 grams of refractory magnetite from 80 mesh to an impalpable powder in fifteen minutes.

METALLURGICAL CHEMISTRY.

H. O. Hofman, Reviewer.

The Smelting of Zinc-Lead Sulphides. By L. Kloz. *Eng. Min. J.*, 63, 358.—In smelting zinc-bearing lead ores the zinc is carried off by the gases, the slag, and the matte, little of it entering the lead. The zinc carried off by the gases forms wall accretions to some extent which interrupt the descent of the charges; zinc oxide or silicate being difficult of fusion makes the slag less fusible and causes particles of matte to remain suspended in it, thus enriching it. In the large Rhodes' reverberatory furnace of Leadville, Colo., matte and slag tapped from the blast-furnace are given time to separate. In this way waste slag with one per cent. lead and 0.5 ounce silver per ton is obtained from slags running as high as six per cent. lead and 10 ounces silver.

The Distribution of the Precious Metals and Impurities in Copper, and Suggestions for a Rational Mode of Sampling. By E. Keller. *J. Am. Chem. Soc.*, 19, 243–258.—This paper is the first systematic investigation of the subject that has appeared in print. Experience teaches that precious metals and impurities are unevenly distributed in metallic copper. A careful investigation of blast-furnace, reverberatory-furnace, and converter coppers of different degrees of purity, shows that there is little regularity in the uneven distribution. In some cases the foreign elements concentrate toward the center of solidification (which lies above the geometrical center, as the metallic mold draws off more heat from the bottom than the air at the top), in others they concentrate toward the outside. Hence, ordinary methods of sampling bars or pigs give unsatisfactory results. What is required is a form of sample bar in which the distribution shall be even, and in pouring the ladle must be hot enough to prevent any sculling, as the liquid part is sure to show a different percentage of precious metal from that which solidifies on the ladle. A sample bar (or plate), the thickness of which is small in comparison with the length and width, has the desired form, as the concentration from side to center cannot go farther than a distance equal to the thickness of the plate, because at that moment the entire plate has solidified. The border of the plate for a distance equal to the thickness of it will show an irregular distribution, within the border, concentration having taken place in one direction only; a correct sample will result, if the plate be punched or drilled through. The tests were made on plates 15 inches square and one inch thick. In trying to give an explanation of the irregular distribution of impurities, the author first ascertained by experiment that a charge of molten copper remained uniform in composition, when it had once been made so by thorough agitation and mixing. The different elements show different degrees of concentration. This, in a general way, excepting sulphur, corresponds with their melting-points, the more readily fusible the metal, the greater is the unevenness of distribution. Atomic weight and specific gravity do not appear individually to have any bearing upon the subject, but if the concentration is compared with the atomic volumes of the elements, there appears to be a correspondence, the concentration being the largest, where the difference in atomic volume is greatest.

Phosphor Bronze. By M. H. Wickhorst. *Foundry*, 10, 53–57; *Iron Age*, 59, No. 12, 2–3.—This paper, read before the Western Foundrymen's Association, treats, in a general way, of bronzes, their properties and manufacture. Of special interest is a bronze with six per cent. phosphorus made by the Chicago, Burlington, and Quincy Railroad Company's brass foundry at Aurora, Ill., in order to have phosphorus in convenient form for the preparation of phosphor bronze. The method of its manufacture is described in detail.

A New Process for Separating Nickel and Copper. By R. P. Rothwell. *Eng. Min. J.*, 63, 328.—N. V. Hybinette and A. R. Ledoux have tested, on a large scale, at the Balbach works, Newark, N. J., a new process for separating nickel and copper sulphides. It consists in smelting nickel-copper matte with oxide of manganese and cooling, when the mixture will separate into two parts, the "top" containing most of the copper and manganese sulphide, the "bottom" most of the nickel sulphide. By repeating the operation the separation becomes perfect. The manganese can be used over again (how is not stated) or a manganese bronze made of the top.

Practical Treatment of Pyritic Gold Ores at Gibbonsville, Mont. By C. C. Burger. *Min. Sci. Press*, 74, 282–285.—This is a detailed description of the process in use, *viz.*: (1) Amalgamation in the battery and saving of concentrates; (2) roasting in twenty-four hours from 12 to 15 tons of concentrates with from 33 to 40 per cent. sulphur, in a two-hearth Pearce turret furnace, supplemented by a small hand reverberatory furnace holding two 1½-ton charges, to insure dead-roasting without diminishing the capacity of the mechanical furnace; (3) Chlorinating in a 1½-ton Thies barrel; (4) Filtering with compressed air in steel lead-lined cylinders swung on trunnions; (5) Settling any slimes that passed the filter cloth; (6) Precipitating with ferrous sulphate. The cost of chlorinating is less than $5 per ton. The ore is low-grade ($10 per ton), the gangue consists of quartz and magnesian slate, the concentrates are mainly pyrite, contain some arsenopyrite, and show from 0.5 to 1 per cent. copper.

Applications of the Cyanide Process in South Africa. By C. Butters. *Eng. Min. J.*, 63, 233–234.—This is a lecture delivered before the Chemistry Section of the Science Association of the University of California, Berkeley, Cal. It contains an account of the development of the process in South Africa, and gives the details of the present practice, which are of much interest to the metallurgist.

Sodium Dioxide in Cyaniding Ores. By J. H. Burfeind. *Eng. Min. J.*, 63, 399–400.—The author does not accept the statement that in cyaniding ores containing alkali earth sulphates, the extraction of precious metal is increased, and the consumption of cyanide diminished, by the use of sodium dioxide. He believes that alkali earth sulphates are in part converted into cyanides, which are solvents for gold, and an equivalent amount of potash into sulphate. Taking, *e. g.*, an ore with gypsum, some of it will be converted into calcium cyanide. In dissolving gold, the double cyanide of gold and calcium will be formed in addition to the double cyanide of potassium and gold. If such a solution is treated with zinc shavings, the products will be gold, calcium and potassium hydroxides, zinc cyanide, and hydrogen; potassium hydroxide and zinc cyanide will combine to a soluble double salt, while from the calcium hydroxide there will be precipitated calcium carbonate by potassium carbonate in the solution and by carbonic acid taken up from the air. This explains the fact that the precipitated gold is often rich in calcium carbonate. While the formation of calcium carbonate can be avoided by the use of sodium dioxide, it is practically non-available on account of its cost, and the removal of calcium carbonate from the gold precipitate is easy and costs next to nothing.

Separation of Gold and Silver from Low-Grade Bullion. By F. Gutzkow. *Eng. Min. J.*, 63, 380–381.—The sulphuric acid process being suited only for high-grade doré silver, millmen ship their low-grade bullion, of say 500 thousandths fineness, to lead refineries where the copper is removed by cupelling with lead. This involves a great expense to the millman who pays for transportation of the copper in his bullion east, and of the blue vitriol west, in addition to a high refining charge based on the gross ounce of bullion. The process in question aims to separate silver, gold and copper at the mill, producing fine silver, gold of greater or less purity, and blue vitriol. In the process the low-grade alloy is dissolved in a cast-iron vessel in sulphuric acid that is lighter than 66° Beaumé. When dissolved, heating is continued until the water is drawn off and the solution becomes so concentrated that anhydrous cupric sulphate is formed and separates. Now the clear silver solution is siphoned off, diluted and cooled, when silver sulphate crystallizes out and is treated in the usual way, while the mother-liquor of about 62° Beaumé is strengthened with fresh acid, and is ready to be used for a new charge. The gold and copper sulphates remaining with some silver sulphate and impurities in the iron vessel, are removed to a pan and boiled in water in the presence of some metallic copper, when the cupric sulphate will be hydrated and dissolved, and the silver sulphate decomposed. The blue vitriol solution is concentrated and crystallized, and the gold, contaminated with some silver and insoluble impurities, treated by one of the usual methods.

Chemical Hints to Foundrymen. By G. R. Johnson. *Foundry*, 10, 71–73; *Iron Age*, 59, No. 10, 5–8.—The paper is a study of the effect of carbon, silicon, sulphur, phosphorus, and manganese upon foundry iron. Many analyses of pig irons from the Embreville Iron Co., Embreville, Tenn., are brought together in tables, and the relations of chemical composition and physical properties shown.

The Bertrand-Thiel Open Hearth Process. BY J. HARTSHORNE. *Iron Age*, 59, No. 12, 2-4.—This article contains a discussion of a paper read by P. C. Gilchrist, before the Cleveland (England) Institute of Engineers.

W. H. WALKER, REVIEWER.

An Alloy Composed of Two-thirds Aluminum and One-third Zinc. BY W. F. DURAND. *Science*, 5, 396.—Of the alloys of zinc and aluminum, one having the above proportions gives the best results, showing itself equal to good cast iron in strength, and superior in many other qualities. It melts at about 800° F., does not readily oxidize, takes a fine finish, and perfectly fills the smallest parts of a mould. Like cast iron, it is brittle, but it is recommended when lightness and strength, combined with good finish and resistance to corrosion, are among the desiderata.

[CONTRIBUTION FROM THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.]

REVIEW OF AMERICAN CHEMICAL RESEARCH.

VOL. III. No. 7.

INORGANIC CHEMISTRY.

HENRY FAY, REVIEWER.

On Hydrocobaltocobalticyanic Acid and Its Salts. BY C. LORING JACKSON AND A. M. COMEY. *Am. Chem. J.*, 19, 271–281.—With the hope of preparing from potassium cobalticyanide compounds analogous to the nitroprussides, a strong solution of potassium cobalticyanide was boiled with strong nitric acid. In less than five minutes the liquid turned red, and the color increased in intensity as the boiling was continued. After boiling about two hours the red solution was converted into a semi-solid gelatinous mass. This product was purified by heating with more nitric acid and washing with water, but as the impurities were removed it began to pass into solution. Essentially all of the cobalt remained in the precipitate, and in the filtrate there was found nitric and hydrocyanic acids, and potassium nitrate. The insoluble jelly was dried *in vacuo* for analysis, when it changed in color from red to a grayish green, but was very hygroscopic, absorbing water readily, at the same time regaining its red color. The solubility seems to vary with the preparation. It usually dissolves slowly, and to a limited extent in cold water, but digestion at 60° C. brings it completely into solution. The composition corresponds to the formula $KH_2Co_2(CN)_{11}.H_2O$. The solution is strongly acid and gives colored precipitates with metallic salts. By mixing a solution of the salt with potassium acetate and alcohol, there is thrown down a pink, flocculent precipitate, which is the dipotassium cobaltocobalticyanide, $K_2HCo_2(CN)_{11}.2H_2O$. Barium cobaltocobalticyanide, $BaHCo_2(CN)_{11}1\frac{1}{2}H_2O$, retains its water of crystallization at 180°C., and is decomposed at 225° C. The silver salt, $Ag_3Co_2(CN)_{11}.H_2O$, is made by adding an excess of silver nitrate to the solution of the monopotassium salt. The zinc salt, $ZnHCo_2(CN)_{11}.3H_2O$, and copper salt, $Cu_3[Co_2(CN)_{11}]_2.4H_2O$, are also described. Free hydrocobaltocobalticyanic acid was obtained by treating hydrocobalticyanic acid with nitric acid, precisely as was done with the potassium cobalticyanide in making the monopotassium salt, which it closely resembles, except that it is less stable and gives off hydrocyanic acid when dried. When potassium hydroxide was added to the solution of the monopotassium salt, it turned dark brown in the cold, and when the liquid was warmed the color deepened to a black, but nothing was precipitated until the solution was boiled. A precipitate of cobaltic hydrate was then formed, but the separation was slow and gradual. If the solution is filtered before precipitation is complete, the yellowish filtrate gives a further precipitate of cobaltic hydroxide on boiling again. Acetic acid added to this solution does not set free hydrocyanic acid. If, after the acetic acid, alcohol be added, it throws out fine white needles, which, on analysis, are shown to be identical with potassium cobalticyanide, but of entirely different crystal habit. A secondary oily product was formed in this reaction, which, on drying, was converted into a yellow solid, the nature of which has not been established. There is a general analogy between these substances and Prussian blue, but they differ essentially, in that in the cobalt compounds all of the cobalt is in the basic portion of the salt.

On the Analogies in Composition of the Salts of Calcium, Strontium, and Barium. By J. H. Kastle. *Am. Chem. J.*, **19**, 281–290.—The author has found that of 280 acids described in chemical literature, 252 show analogies in the composition of their calcium, strontium, and barium salts. Of these acids, the calcium, strontium, and barium salts of 141 have been described. From this number, 34 salts are entirely analogous for the three elements, and 79 show analogies between two of the salts. Of the latter, the analogy existing between the calcium and strontium salts is shown in 30 instances, between the calcium and barium salts in 25, and between the strontium and barium salts in 30 cases. In addition, 139 acids have been found, of which the salt of only two of these metals have been described, but all are stated to be analogous. From these observations the author comes to the general conclusion that *of the calcium, strontium, and barium salts of any acid, all or two of the salts of these metals will be found to be analogous in composition.* This is in opposition to the statement of Lenssen, that there is closer relationship between the strontium and barium than the calcium salts.

On the Action of Ammonia upon Cupriammonium Acetobromide. By Theodore William Richards and Robert Jay Forsythe. *Proc. Am. Acad. Arts and Sci.*, **32**, 239–241.—By passing ammonia gas over cupriammonium acetobromide in a glass tube, placed in a freezing mixture, the substance takes up ammonia corresponding in amount to $3NH_3$. The new substance, $CuBrC_2H_3O_2.5NH_3$, dissolves in water to a deep blue solution, and loses ammonia on exposure to the air passing over into a green compound, $CuBr_2.6NH_3$. This change of color is taken as proof that the ammonia decomposed the original cupriammonium acetobromide, and the decomposition of the addition product may be represented in this way :

$$2Cu(NH_3)_2Br.C_2H_3O_2.3NH_3 = CuBr_2.6NH_3 + Cu(C_2H_3O_2)_2.4NH_3$$

The first of these compounds was already known, and the second was synthesized by passing ammonia over cupriammonium acetate. The analytical data are not exact, owing both to the ease with which the substances lose ammonia, and to their great hygroscopic power.

On Certain Double Halogen Salts of Caesium and Rubidium. BY H. L. WELLS AND H. W. FOOTE. *Am. J. Sci.*, 153, 461–465.—The authors have repeated the work of Remsen and Saunders and Remsen and Brigham, to see whether, by working under widely varying conditions, they could obtain several simpler salts by recrystallizing the complex rubidium antimony chloride, $23RbCl.10SbCl_3$. No variation of composition was detected, although the salt was crystallized from dilute, concentrated and alcoholic hydrochloric acid. The analytical process used in the determination of antimony was checked against the pure salt, $Cs_3Sb_2Cl_9$, containing nearly the same percentage of antimony. The method gave results about 0.25 per cent. too high, and the authors believe that by subtracting this constant error from the amount of antimony found in the analyses of the rubidium salt, it will give results nearer the truth. The results thus obtained agree more closely with the simpler formula, $7RbCl.3SbCl_3$, and this formula is proposed for this salt as well as for the other salts of analogous composition, described by Remsen and Brigham, Herty, and Wheeler. While there is much to be said in favor of the simple formula, it would seem advisable to offer evidence as to the accuracy of the determination of rubidium and chlorine in the salts as well as antimony. In recrystallizing this complex rubidium antimony chloride from very dilute hydrochloric acid, just enough to prevent the precipitation of antimony oxychloride, a new salt having the composition $2RbCl.SbCl_3.SbOCl$ was formed. It crystallizes in sharp, colorless prisms, and can be recrystallized from dilute hydrochloric acid. The work of Remsen and Brigham on the caesium bismuth chlorides was confirmed, and the new salt, $3CsI.2BiI_3$, described. For analysis this salt was dissolved in dilute hydrochloric acid, the bismuth precipitated as sulphide, digested with nitric acid until decomposed, the free sulphur removed by filtration, and the bismuth reprecipitated as carbonate. The caesium was determined as sulphate.

On the Double Fluorides of Zirconium with Lithium, Sodium, and Thallium. BY H. L. WELLS AND H. W. FOOTE. *Am. J. Sci.*, 153, 466–471.—It has been found by a comparison of the double fluorides of zirconium with ammonia, potassium, and caesium, that the types of double salts formed varied with the molecular weights of the alkaline fluorides. A relatively large number of molecules of small molecular weight enter into combination, while those fluorides of higher molecular weight combine with more zirconium fluoride than the others. This was found to be true also in double fluorides of zirconium and lithium. Salts of the 4 : 1 and 2 : 1 type were prepared, but the 3 : 1 type could not be made. The following table shows the symmetrical gradation of types, according to the atomic weight of the alkali metals :

Type.	Lithium salts.	Potassium salt. (Marignac.)	Caesium salts.
4 : 1	$4LiF.ZrF_4.\frac{2}{3}H_2O$	......	......
3 : 1	......	$3KF.ZrF_4$	......
2 : 1	$2LiF.ZrF_4$	$2KF.ZrF_4$	$2CsF.ZrF_4$
1 : 1	......	$KF.ZrF_4$	$CsF.ZrF_4.H_2O$
2 : 3	......	......	$2CsF.3ZrF_4.2H_2O$

The double fluorides of sodium and thallium with zirconium fluoride do not form a symmetrical series which will fall into line with the known other salts. The salt $2NaF.ZrF_4$ was prepared by bringing together two parts sodium fluoride with fourteen parts zirconium fluoride. The following double fluorides of thallium and zirconium were prepared: $TlF.ZrF_4.H_2O$, $5TlF.3ZrF_4.H_2O$, and $3TlF.ZrF_4$. The first salt separates without water of crystallization if the solution is evaporated until crystals begin to form, and then cooled. Two of these thallous salts correspond to recognized types of alkali salts, while the 5 : 3 type is new.

The Oxides of Tungsten. BY EN. D. DESI. *J. Am. Chem. Soc.*, 19, 213–241.—By treating tungstic acid or metallic tungsten with sulphuric and sulphurous acids at various temperatures, under atmospheric pressure and in sealed tubes, oxides of tungsten were isolated corresponding to the formulas WO, W_4O_3, W_2O_3, W_5O_{12}, W_4O_9, W_8O_{14}. By heating ammonium tungstate to a white heat the oxide, W_2O_5 was formed, and it was also obtained by fusing tungstic acid with potassium iodide. Upon fusing tungstic acid with potassium chloride, potassium bromide, metallic sodium or potassium, metallic tungsten was formed. Different oxynitrides of tungsten were prepared by acting upon tungstic acid with ammonium chloride, potassium cyanide, and cyanogen. Tungstic acid can be separated from molybdic acid by dissolving the latter in sulphuric acid, while the former is entirely insoluble.

Recovery of Waste Platinum Chloride.—By H. W. Wiley. *J. Am. Chem. Soc.*, 19, 258–261.—Aluminum turnings are suggested for the reduction of potassium platinochloride to metallic platinum.

Compounds of Metallic Hydroxides with Iodine. By Theodore Rettie. *J. Am. Chem. Soc.*, 19, 333–339.—The author has examined the brown precipitate formed when magnesium sulphate is treated with iodine and potassium hydroxide, and finds that it is not of constant composition, being principally magnesium hydroxide with a variable quantity of iodine. Colored precipitates are formed with zinc and cadmium salts. Glucinum sulphate, and calcium and strontium salts, give precipitates which dissolve on standing.

Variations in the Composition of Red Lead. By Durand Woodman. *J. Am. Chem. Soc.*, 19, 339–341.—If commercial red lead is treated with a saturated solution of lead acetate the lead monoxide is dissolved, leaving the true red lead. The percentage of Pb_3O_4 found in this way varies from 41 to 92 per cent.

ORGANIC CHEMISTRY.

J. F. Norris, Reviewer.

On the Colored Compounds Obtained from Sodic Ethylate and Certain Aromatic Nitro Compounds. By C. Loring Jackson and Martin H. Ittner. *Am. Chem. J.*, 19, 199–217.—By the action of sodium ethylate on fourteen compounds of the general structure CH_3(or COOH)(1)NO_2(3)X(4)NO_2(5) colored bodies analogous to those obtained by Victor Meyer (*Ber.*, 27, 3153) and Lobry de Bruyn (*Rec. Trav. Chim. Pays. Bas.*, 14, 89) from *s*-dinitrobenzoic acid and *s*-trinitrobenzene have been prepared. The colors formed from the toluene derivatives lasted but a few seconds, while those from the benzoic acids were stable for several hours. The colored compound from dinitranisic acid was isolated by precipitation from an alcoholic solution with ligroïn and, after drying *in vacuo*, had the composition $C_6H_2.OCH_3.(NO_2)_2.COONa.C_2H_5ONa$. When heated at 110° it was decomposed and lost a weight nearly corresponding to one molecule of alcohol. The authors offer no structural formulæ for the compounds, but show that the explanation of Victor Meyer, that they are formed by the replacement of one atom of hydrogen in the benzene ring by an atom of sodium, and the addition of a molecule of alcohol of crystallization is rendered improbable by the work of Lobry de Bruyn. The latter proved that *s*-trinitrobenzene is not acted on by sodium in boiling xylene and that its colored derivative has the composition $C_6H_3(NO_2)_3.CH_3OK.\frac{1}{2}H_2O$, in which, if Meyer's explanation is correct, there are both alcohol and water of crystallization. This latter assumption is highly improbable.

On the Action of Chlorcarbonic Ethyl Ester on Formanilide. By H. L. Wheeler and H. F. Metcalf. *Am. Chem. J.*, 19, 217–227.—The authors have studied the action of chlorcarbonic ethyl ester on formanilide, and find that the explanations of the reaction given by Lellmann (*Ber.*, 14, 2512), and Freer and Sherman (*Am. Chem. J.*, 18, 579), are in part incorrect. The following substances were obtained as final reaction-products: Diphenylformamidine hydrochloride, formylphenylurethane, phenylurethane, carbon dioxide, carbon monoxide, and ethyl chloride. The reaction can be explained whether formanilide is, as its name implies, an anilide with the structure $HCO.NHC_6H_5$, or whether it has the imido structure and is phenylimidoformic acid. Its structure cannot, therefore, be determined by the final reaction-products. The oil obtained by Freer and Sherman (*loc. cit.*), and which they state is ethylisoformanilide, proved to be a mixture of formphenylurethane, phenylurethane, and unaltered formanilide. It is also shown that Claisen's argument (*Ann. Chem.* (*Liebig*), 287, 360) for the amide structure of formanilide, based on the relation of its boiling-point and that of its oxygen ester, is not well taken. Formylphenylurethane, $C_6H_5N.CHO.CO_2C_2H_5$, was prepared by the action of chlorcarbonic ethyl ester on ethylisoformanilide. It boils from 149° to 151° at 15 mm. pressure. The above structure was shown to be correct by the action of alkali and of phenyl hydrazine. With the former there was a separation of the lower acid, giving phenylurethane; with the latter, α-formphenylhydrazine was formed.

Naphthalene Tetrabromide, $C_{10}H_8Br_4$. By W. R. Orndorff and C. B. Moyer. *Am. Chem. J.*, 19, 262–270.—But one of the three possible stereochemical modifications of naphthalene tetrabromide was formed by the action of naphthalene on bromine. This was made by cautiously treating naphthalene covered with an ice-cold four per cent. solution of sodium hydroxide with bromine, and allowing the mixture to stand in the cold for several hours. Of the pure product, which melted at 111°, with decomposition after crystallization from chloroform, 7 grams were obtained from 100 grams of naphthalene. A large quantity of α-monobromnaphthalene and 1 : 4 dibromnaphthalene were obtained at the same time. The tetrabromide is insoluble in water, ether, glacial acetic acid, and cold alcohol; soluble in hot water, carbon bisulphide, ligroïn, hot chloroform, and hot benzene. It crystallizes in transparent monoclinic prisms, which become opaque on standing. A full crystallographic study of the compound is given. As the tetrabromide decomposed in all boiling solvents, its molecular weight could not be determined. A determination of the molecular weight of the analogous chloride gave results corresponding to the formula $C_{10}H_8Cl_4$.

Action of Mercaptides on Quinones. BY H. S. GRINDLEY AND J. L. SAMMIS. *Am. Chem. J.*, 19, 290–295.—By the action of sodium mercaptide on dichlordiphenoxyquinone, a compound was obtained analogous to the hemiacetals prepared by Jackson and Grindley (*Am. Chem. J.*, 17, 577) from quinones and sodium alcoholates. The yellow sodium salt formed when six molecules of the mercaptide and one of the quinone were used was so unstable that it could not be analyzed. It decomposed readily in the presence of water forming tetrathioethylquinone, $C_6(SC_2H_5)_4O_2$, which melts at 90°–91°, and gives a hydroquinone melting at 58°. The tetrathioethylquinone, when treated with two equivalents of sodium mercaptide, gives the unstable yellow salt which, in turn, gives the compound tetrathioethylquinone dibenzoyl-dithiobenzoylacetal $C_6(S.C_2H_5)_4(O.CO.C_6H_5)_2(S.CO.C_6H_5)_2$ when treated with benzoyl chloride in alcoholic solution. The substance is not affected by either zinc dust and glacial acetic acid or hydroxylamine hydrochloride.

The Hydrolysis of Acid Amides. BY IRA REMSEN. *Am. Chem. J.*, 19, 319–322.—In a preliminary note which announces that the author has undertaken an extensive investigation of the speed of hydrolysis of the acid amides, the rate of decomposition of the three nitrobenzamides with half normal hydrochloric acid is reported. At the end of 3 hours 3.3 per cent. of the *o*-amide, 80.5 per cent. of the *m*-amide, and 84.5 per cent. of the *p*-amide were hydrolyzed. At the end of 6 hours 6.2 per cent., 94.2 per cent., and 96.9 per cent. of the ortho, meta, and para amides, respectively, were changed.

On Urethanes. BY OTTO FOLIN. *Am. Chem. J.*, 19, 323-352.—From the study of the action of sodium methylate on a number of acid bromamides the author deduces the following conclusion : The reaction

$$RCONHBr + NaOCH_3 = RNHCOOCH_3 + NaBr,$$

is quite as general as the analogous reaction of alkalies on acid bromamides, and should be as useful in the preparation of urethanes, as is the reaction of Hofmann for the amines. The introduction of negative groups into the radical R does not prevent the "Beckmann rearrangement," and in no case was direct substitution of the bromine effected even to a slight extent. The introduction of a positive group in one case had no more influence than that of a negative group. The following compounds were prepared from the corresponding bromamides and are described in detail: Methylphenyl carbamate; methyl-*m*-nitrophenyl carbamate, crystallizing in well-formed octahedra which melt at 147°–149°; methyl-*o*-nitrophenyl carbamate, greenish-yellow crystals, which melt at 53°; methyl-*m*-bromphenyl carbamate, white crystals melting at 84.5°–85.5°. The yield in all cases was nearly quantitative. As it was found impossible to obtain an acid bromamide containing the amido or dialkylamido group in the benzene ring, an analogous amide in the aliphatic series was prepared, carbomethoxy-β-amidopropionbromamide, $CH_3O_2CNHCH_2CH_2CONHBr$, from which the corresponding urethane was formed by the action of sodium methylate. The study of the action of phosphorus pentachloride on a number of aromatic urethanes leads to the following equation, which is general.

$$RNHCO_2CH_3 + PCl_5 = RNHCOCl + CH_3Cl + POCl_3.$$

This reaction and the one given above furnish easy methods for the preparation of chlorformanilides and isocyanates. With free urethane phosphorus pentachloride splits off ethyl chloride and a carbamide chloride is formed, but the reaction is not so simple as with the aromatic urethanes. A simple method of preparation of urethane from potassium cyanate and alcohol is described. Phosgene and urethane, when brought together in molecular proportions, reacted simultaneously in the different ways:

1. $NH_2CO_2C_2H_5 + COCl_2 = ClCONHCO_2C_2H_5 + HCl.$
2. $ClCONHCO_2C_2H_5 + NH_2CO_2C_2H_5 = CO(NHCO_2C_2H_5)_2 + HCl.$
3. $2NH_2CO_2C_2H_5 + COCl_2 = NH_2CONHCO_2C_2H_5 + C_2H_5Cl + CO_2 + HCl.$

The products of the reaction are fully described.

Action of Phosphorus Pentachloride on Aniline and its Salts. BY J. ELLIOTT GILPIN. *Am. Chem. J.*, 19, 352–363.—Trichlorphosphanil, $PCl_3(NC_6H_5)$, was obtained by subliming phosphorus pentachloride and aniline hydrochloride at 170° for six hours. The compound condensed in the cooler part of the vessel as a white coating. It cannot be purified by crystallization, as all solvents decompose it. Concentrated sulphuric acid, alcohol, and ether, cause an evolution of hydrochloric acid; sodium hydroxide changes it to a hard, brittle mass; and water decomposes it into aniline hydrochloride and phosphoric acid. Neither the sulphate nor the nitrate of aniline gave the compound when heated with phosphorus pentachloride. Aniline and phosphorus pentachloride react readily with evolution of hydrochloric acid. The cooled mass is extracted with water, then with small portions of hot alcohol, until, on evaporation, one kind of crystals is obtained, and finally crystallized from boiling alcohol. The resulting compound, chlorphostetranilide, $PCl(NHC_6H_5)_4$, is very stable. It is not decomposed when boiled with water, concentrated alkali, or hydrochloric acid; but when heated with water in a sealed tube at 180°, aniline, aniline hydrochloride, and phosphoric acid are formed. Only a small amount was decomposed when heated in a porcelain tube in a current of oxygen over the blast-lamp for several hours. A compound of the structure $P(OH)(NHC_6H_4SO_3H)_4$, was formed by the action of concentrated sulphuric acid on chlorphostetranilide. Acid lead and barium salts were formed by the replacement of six hydrogen atoms in two molecules of the acid. The three toluidines reacted with phosphorus pentachloride and formed compounds of analogous composition.

On the Preparation of Metabrombenzoic Acid and of Metabromnitrobenzene. By H. L. Wheeler and B. W. McFarland. *Am. Chem. J.*, **19**, 363-367.—The authors offer the following much improved method for the preparation of metabrombenzoic acid: 20 grams of benzoic acid and 6 grams of iron wire are heated in a flask, connected with a return condenser, to 170°, when 48 grams of bromine are added, drop by drop, while the temperature of the bath is allowed to rise slowly to 260°. After purification and distillation, 20 grams of the pure acid were obtained. Perbrombenzene, C_6Br_6, was formed when 5 grams of benzoic acid, 2 grams of iron, and 37.4 grams of bromine were heated in a tube to 225° for 5 hours. Metabromnitrobenzene was prepared as follows: 30 grams of nitrobenzene and 3 grams of iron were heated to 120°, when 60 grams of bromine were added gradually. A 75 per cent. yield was obtained. Paradichlorbenzene reacts readily with bromine in the presence of iron, giving probably 1,4-dichlor-2,5-dibrombenzene, which melts at 148°.

On the Non-Existence of Four Methenylphenylparatolylamidines. By H. L. Wheeler. *Am. Chem. J.*, **19**, 367–374.—Walther (*J. prakt. Chem.*, **55**, 41) has described the preparation of four isomeric methenylphenylparatolylamidines. The author has examined the various methods carefully, and comes to the conclusion that they all give the same body, which melts at 103°.5–104°.5.

The Action of Certain Alcohols on Asym-Metadiazoxylenesulphonic Acid. By W. B. Shober and H. E. Kiefer. *Am. Chem. J.*, **19**, 381–393.—*a*-metaxylidinesulphonic acid, prepared by the method of Jacobson and Ledderboge (*Ber.*, **16**, 193), was diazotized with nitrous fumes. The yield of the diazo compound was 94 per cent. of the theoretical amount. Different portions of the diazo compound were decomposed with methyl, ethyl, and propyl alcohols under varying pressures. In all cases both the hydrogen and the alkoxy reaction took place, the latter to a much larger extent, which increased with increased pressure. *α*-metamethoxyxylenesulphonic acid crystallizes from benzene in needles, and forms potassium, barium, copper, zinc, and sodium salts. Its amide melts at 190°. *α*-propoxyxylenesulphonic acid crystallizes from alcohol in needles, and forms well characterized barium, potassium, and zinc salts. Its amide melts at 146°. By the oxidation of *α*-metamethoxyxylene sulphonamide, an acid of the probable structure $C_6H_2CH_3(1)COOH(3)OCH_3(4)SO_2NH_2(6)+H_2O$ was obtained. The barium and calcium salts were prepared, but did not crystallize well.

The Preparation of Zinc Ethyl. BY ARTHUR LACHMAN. *Am. Chem. J.*, 19, 410–411.—By using an improved zinc-copper couple in the preparation of zinc ethyl by the process of Gladstone and Tribe (*J. Chem. Soc.*, 1879, 570), the author obtained a yield of 70–90 per cent. in half the time required by the old method. The couple is prepared by passing a stream of hydrogen for 20 minutes over a mixture of 100 parts of zinc dust and 12 parts of copper oxide heated to redness in a combustion tube.

A Simple Test for the Halogens in Organic Halides. BY J. H. KASTLE AND W. A. BEATTY. *Am. Chem. J.*, 19, 412–413. —To test for halogens in non-volatile substances about 1 gram is heated with 5 grams of a mixture of equal weights of copper nitrate and silver nitrate until the latter are reduced to oxides. The resulting mixture is treated with a little water, dilute sulphuric acid, and zinc for 5 minutes, filtered, and tested for halogen with silver nitrate. Volatile substances are heated in an S-shaped tube closed at one end, and the vapors passed over a mixture of the nitrates heated to redness. The method was tested with a large number of substances and was successful in every case.

Notes on Caffein. BY G. L. SPENCER. *J. Am. Chem. Soc.*, 19, 279–281.—The author compares a gravimetric method for the estimation of caffein proposed by himself (*J. Anal. Chem.*, 4, 390) with the volumetric method of Gomberg (*J. Am. Chem. Soc.*, 18, 331), and finds that both give the same result. The volumetric method is to be preferred on account of its wider applicability.

Periodides of Pyridine. BY P. F. TROWBRIDGE. *J. Am. Chem. Soc.*, 19, 322–331.—From a series of experiments on the formation of periodides of pyridine methyl iodide, the author concludes that at ordinary temperatures and with small amounts of iodine, the triiodide is usually formed, and with larger amounts of iodine the pentiodide. When hot saturated solutions were used a heptiodide resulted. Two forms of pyridine hydroiodide are described, $C_5H_5N.HI$ and $C_5H_5N.HI.H_2O$, and periodides containing two, five, and seven iodine atoms. A molecular weight determination in phenol of the unusual periodide containing *two* atoms of iodine showed that its formula is $C_5H_5N.HI.I$.

Modification of the Thalleoquin Test for Quinine. By F. S. Hyde. *J. Am. Chem. Soc.*, 19, 331–332.—It is recommended that very dilute solutions be used in the above test, and a filtered solution of calcium hypochlorite instead of chlorine or bromine water.

G. W. Rolfe, Reviewer.

Allotropy of Sucrose. By F. G. Wiechmann. *J. Phys. Chem.*, 1, 69–74.—The paper records a series of experiments made by the author on an amorphous modification of cane sugar, made by rapidly heating the sugar to boiling, covering the vessel and boiling ten minutes, raising the solution to 176° C., the mass then being rapidly cooled by pouring it on a copper slab. The results point to the conclusion that very minute traces of dissolved inorganic matter tend to cause the sugar to revert to the crystalline form, while, if the sugar is absolutely pure, the amorphous state persists indefinitely.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

A. H. Gill, Reviewer.

On the Butanes and Octanes in American (Ohio) Petroleum. By C. F. Mabery and E. T. Hudson. *Proc. Am. Acad. Arts and Sci.*, 32, 101–118; *Am. Chem. J.*, 19, 243-262.—Hitherto it has been assumed that the butane in petroleum was the normal compound; but the results of this investigation show it to be isobutane, and that its boiling-point is 0° instead of —17°; isopentane of boiling-point 29°–30° was also present. Two octanes were obtained, having a boiling-point of 119.5° and 124°-125°, respectively, and specific gravities at 20° of 0.7243 and 0.7134, respectively. The latter is assumed to be the normal compound, but enough could not be obtained to determine its composition. Diisobutyl could not be detected. Attention is called to the fact that the specific gravity of hydrocarbons from this source is greater than that of the same hydrocarbons synthetically prepared, owing probably to the presence of naphthenes.

The Constituents of Pennsylvania, Ohio, and Canadian Petroleum between 150° and 220°. BY C. F. MABERY. *Proc. Am. Acad. Arts and Sci.*, **32**, 121-176.—The author calls attention to the conflicting statements regarding the constituents of the fractions of American petroleums boiling between 150° and 220°. Some believe them to be naphthenes, while others, on the basis of Pelouze and Cahours' work, consider that they are members of the fatty series; the author's opinion that the higher portions belonged to the C_nH_{2n} series was not sustained. The separation of these bodies presents greater difficulties than those of the lighter portions, as they must be fractionated *in vacuo*. As it was found that cracking did not begin with the Pennsylvania oils until a temperature above 225° was reached, refinery distillates of a gravity of 48°-50° Baumé were used as the initial material. These were fractionated many times—mention is made of forty-five and fifty distillations—and the distillates treated in some cases with fuming sulphuric acid to remove mesitylene. The Ohio and Canadian distillates were obtained from the crude oils by distillation *in vacuo*. The Pennsylvania petroleum contains a decane of b. pt. 163°-164° and sp. gr. 0.7684, another decane, probably the normal, of b. pt. 173°-174°, sp. gr. 0.7486, an hendecane of b. pt. 186°-197°, sp. gr. 0.7662, and a dodecane of b. pt. 214°-216°, sp. gr. 0.7684. Mesitylene, cumol, pseudocumol, cymol, isocymol, durol, isodurol are probably present in small quantities. Ohio Trenton petroleum, within the same limits, contains the same members; the higher specific gravity of the distillates being caused by a larger proportion of aromatic hydrocarbons. The fractions of Canadian corniferous petroleum from Petrolica, boiling between 163° and 173° contain the same constituents. The hydrocarbons collecting between 196° and 214° are of the C_nH_{2n} series. The proportion of aromatic hydrocarbons is greater in Canadian than in Ohio petroleum.

Refractive Power of the Hydrocarbons and Chlorine Derivatives Described in the Preceding Paper. BY C. F. MABERY AND E. T. HUDSON. *Proc. Am. Acad. Arts and Sci.*, **32**, 179-182.—A comparison of the compounds from Pennsylvania petroleum shows a lower refractive index than the same compound from Ohio and Canadian petroleum, as well as a lower specific gravity. The effect of the second chlorine atom in raising the refractive index is also well illustrated.

On the Composition of a South American Petroleum. BY C. F. MABERY AND A. S. KITTELBERGER. *Proc. Am. Acad. Arts and Sci.*, **32**, 185-191; *Am. Chem. J.*, **19**, 374-381.—The oil came from the Magdalena river, in the United States of Columbia, and was dark and thick, and of 0.948 sp. gr. at 20°. It contained a small quantity of sulphur and was peculiar in the instability of its least volatile portions, that boiling from 310°–345° cracking badly on distillation. It may contain naphthenes and possibly some of the benzene series. It resembles the Russian oils.

W. O. CROSBY, REVIEWER.

A Relatively Acid Dike in the Connecticut Triassic Area. BY EDWARD OTIS HOVEY. *Am. J. Sci.*, 153, 287–292.—One of the striking features of the Triassic igneous rocks of the Atlantic border, from Nova Scotia to North Carolina, is their uniformity in appearance and in mineralogical and chemical composition. The only previously noted variations from the monotony of the diabase traps have been rocks of slightly more basic character. But the author has discovered in the Triassic strata near New Haven, and in intimate association with dikes of the normal diabase, two small dikes of distinctly more acid character. One complete analysis ($SiO_2 = 60.13$) is given, and an analysis of the normal Triassic diabase ($SiO_2 = 51.78$) is quoted for comparison. The composition of the new rock indicates that it belongs to the group of keratophyres.

The Granitic Rocks of the Pyramid Peak District, Sierra Nevada, California. BY WALDEMAR LINDGREN. *Am. J. Sci.*, 153, 301–314.—The granitic rocks include granitite, granodiorite, and diorite. The granodiorite is an intermediate or transition type, and the diorite varies in the other direction to augite porphyrite. Complete bulk analyses of the granitite and granodiorite are given, and partial analyses of both these and the other types. From these analyses the proportions of the component minerals are calculated, the potash, soda, and lime feldspars being distinguished. The paper closes with a brief discussion of the general relations and succession of the rocks, which leaves much to be desired as regards the definiteness of the conclusions stated.

On Roeblingite, a New Silicate from Franklin Furnace, N. J., Containing Sulphur Dioxide and Lead. BY S. L. PENFIELD AND H. W. FOOTE. *Am. J. Sci.*, 153, 413–415.—This new species, from a depth of a thousand feet in the great deposit of zinc ores at Franklin Furnace, is of peculiar interest, from the facts that silicates containing lead are very rare, and that this is the first time that a sulphite has been observed in nature. Although the mineral occurs in dense, white, compact masses, it is definitely known that it cannot be a mixture. The average of two very accordant analyses is: SiO_2, 23.58; SO_2, 9.00; PbO, 31.03; MnO, 2.48; CaO, 25.95; SrO, 1.40; K_2O, 0.13; Na_2O, 0.40; H_2O, 6.35 = 100.32 per cent. The nearest approach to a simple ratio is believed to be $SiO_2 : SO_2 : PbO : RO$

$H_2O = 5 : 2 : 2 : 7 : 5$, giving the rather complicated formula $H_{10}Ca_7Pb_2Si_5S_2O_{28}$. The water is driven off at a rather high temperature and is therefore regarded as hydroxyl.

Bacteria and the Decomposition of Rocks. BY JOHN C. BRANNER. *Am. J. Sci.*, 153, 438–442.—The author reviews the various published statements concerning the occurrence of bacteria in rocks and soils and their influence upon the decay of rocks, and finds the following conclusions to be more or less probable. The bacteria found in decayed rocks are chiefly the nitrifying forms, which reduce nitrogenous matter to nitric acid. These are not absolutely dependent upon organic food; that is, they may live in wholly inorganic media, but, in common with all bacteria, they require carbon and nitrogen. They are incapable of separating these elements from the air or water, but can obtain them only from organic bodies and certain salts which occur but rarely, if at all, in ordinary rock formations. Living bacteria are, therefore, practically limited to points near the surface, and to the decayed rocks; they cannot, then, be a primary or important cause of rock decay.

On Wellsite, a New Mineral. BY J. H. PRATT AND H. W. FOOTE. *Am. J. Sci.*, 153, 443–448.—This new species occurs in the Buck Creek Corundum Mine, Clay County, N. C., intimately associated with corundum, albite, and hornblende. The crystallographic and physical features of the mineral show it to be closely related to the phillipsite and harmotome group of zeolites, and this view is fully corroborated by the chemical composition. The average of the two accordant analyses gives: SiO_2, 43.86; Al_2O_3, 24.96; BaO, 5.07; SrO, 1.15; CaO, 5.80; MgO, 0.62; K_2O, 3.40; Na_2O, 1.80; H_2O, 13.35 = 100.01. The ratio of $SiO_2 : Al_2O_3 :$ RO (alkalies and earths) : H_2O is approximately 3 : 1 : 1 : 3, giving the formula $R''Al_2Si_3O_{10}.3H_2O$. Only one molecule of water is given off below 200° C., and regarding this alone as water of crystallization leads to the formula $H_4R''Al_2Si_3O_{12}.H_2O$. A comparison with the other minerals of the phillipsite group, places it at the beginning of the series:

Wellsite	$RAl_2Si_3O_{10}.3H_2O$.
Phillipsite	$RAl_2Si_4O_{12}.4\frac{1}{2}H_2O$.
Harmotome	$RAl_2Si_5O_{14}.5H_2O$.
Stilbite	$RAl_2Si_6O_{16}.6H_2O$.

The analyses of phillipsite vary considerably, and the authors regard 4 : 4 as the most probable normal ratio of $SiO_2 : H_2O$. The minerals then form a regular series in which this ratio is constantly unity. The relations of these minerals to the feldspars are discussed, and the discovery of another member of the series with the $SiO_2 : H_2O = 2 : 2$, is predicted.

Italian Petrological Sketches, IV. The Rocca Monfina Region. By Henry S. Washington. *J. Geol.*, 5, 241–256.—Rocca Monfina is another one of the extinct and composite Italian volcanoes, but in comparison with those previously described by this author, the order of succession of the lavas is reversed: (1), the leucitic, the oldest, which is subdivided into two sub-phases characterized by leucitites and leucite tephrites; (2), the trachytic; (3), the basaltic, which is the youngest. This is also the order of abundance, the leucitic lavas largely predominating. The petrographic descriptions are in several instances accompanied by chemical analyses. These include: (1) leucite tephrite, of which a widely different analysis by vom Rath is also quoted, the two agreeing closely only in the alumina and soda; and (2), biotite vulsinite, a trachytic rock of which two other analyses are quoted for comparison.

The Bauxite Deposits of Arkansas. By J. C. Branner. *J. Geol.*, 5, 263–289.—This is a full and systematic account of these deposits, which are of great extent, and have a large prospective value. Under the head of composition are given, first, four analyses of ferruginous bauxite, the percentage of iron ranging from 54.2 to 66.83, showing that the bauxites grade into impure iron ores. Two analyses of siliceous bauxite are then compared with an analysis of typical kaolin, to show that kaolin is practically another limit of variation. Finally ten analyses of Arkansas, and three of foreign bauxites are given in tabular form for comparison, the purest Arkansas sample yielding SiO_2, 2.00, and Fe_2O_3, 1.66 per cent. The origin of the bauxite deposits is discussed at some length, the author's view being that they are genetically connected with the eruptive syenite of that region.

Hornblende Basalt in Northern California. By J. S. Diller. *Am. Geol.*, 19, 253–255.—This is a study of a water-worn cobble stone, the rock not having been found in place. A complete analysis by L. G. Eakins is given, and three other analyses of hornblende-basalts are quoted for comparison.

On the Genesis of Clay Stones. By H. W. Nichols. *Am. Geol.*, 19, 324–329.—This paper is an application of the modern theories of saturated solutions, to the problem of the clay stone the segregation of mineral substances in the rocks being in general a passage from a more soluble to a less soluble form. Calcium carbonate, for example, changes from aragonite to calcite in the formation of clay stones.

The Anorthosites of the Rainy Lake Region. By A. P. Coleman. *Can. Record Sci.*, 7, 230–235.—Reprinted from *J. Geol.* See *this Rev.*, 3, No. 4.

On the Chemical Composition of Some Kansas Gypsum Rocks. By E. H. S. Bailey and W. M. Whitten. *Kan. Univ. Quart.*, **6**, 29–34.—Twelve analyses of gypsum from four different counties are given, and the proportions of the various constituents as they probably exist in the rock are calculated from each analysis. These show that the material is in the main of a high degree of purity, the majority of the analyses closely approximating the theoretical composition of gypsum. The chief impurities are the calcium and magnesium carbonates.

The Leucite Hills of Wyoming. By J. F. Kemp. *Bull. Geol. Soc. Am.*, **8**, 169–182.—The Leucite Hills, situated in southwestern Wyoming, are surface flows of a highly vesicular leucitic lava. Two analyses are given, one original, and the other quoted from Zirkel, and seven analyses of the leucitic rocks from other regions are also quoted for comparison. The author concludes from the composition and the petrographic features that the rock is best described as leucite phonolite, which shades into leucitites and related types.

Diabase Pitchstone and Mud Enclosures of the Triassic Trap of New England. By B. K. Emerson. *Bull. Geol. Soc. Am.*, **8**, 59–86.—The absorption of large volumes of water and mud by the submarine lava flows has caused the mass to cool as a spherulitic glass, with a minute crackling, which gives it a pitchy luster and a large content of water (4.72 per cent.), thus forming a basic pitchstone, which does not seem to have been described before. A single very complete analysis of the pitchstone, by H. N. Stokes, is given, and this shows that the rock is somewhat more basic ($SiO_2 = 46.86$ per cent.) than the normal diabase.

Erosion at Base-level. By Marius R. Campbell. *Bull. Geol. Soc. Am.*, **8**, 221–226.—This paper supplements the preceding one, being an attempt to apply the principle that silica and aluminous silicates (quartz and clay) are readily soluble in swamp waters, in explaining the sharp line of demarcation observed in many Appalachian valleys between the base-leveled bottoms and the lateral slopes.

"Mineral Soap." By W. C. Knight. *Eng. Min. J.*, **63**, 600–601.—This mineral, which it is proposed to call Taylorite, occurs in the Fort Benton shales of southwestern Wyoming. It is a soft, unctuous clay, with a marked soapy feeling in water, and is associated with gypsum and mirabilite. Four analyses are given, which show it to be essentially a siliceous kaolin, the chief impurities other than silica being ferric oxide and magnesia.

Analysis of a Variety of Ilmenite. By GEORGE M. PEEK. *Am. Chem. J.*, **19**, 232.—The material analyzed is from Bedford County, Virginia. It yielded: TiO_2, 63.31; FeO, 35.99; MgO, 0.82; SiO_2, 1.25 = 101.37. This composition affords approximately the formula $Fe_2Ti_3O_8$, which lies between that of typical ilmenite ($Fe_2Ti_2O_6$) and that of iserite ($Fe_2Ti_4O_{10}$).

"Mineral Tallow" from Danby, Vermont. By L. E. SMOOT. *Am. Chem. J.*, **19**, 233.—This peculiar substance forms a layer two to three inches thick on the walls of a limestone cavern. It is of a soft, smooth, putty-like consistency, and entirely devoid of crystalline structure. Analysis gave 85.38 per cent. of water; and the dried material yielded: CaO, 52.19; MgO, 0.27; CO_2, 41.31; SiO_2, 3.57; org. mat. (by diff.), 2.66; nitrogen, 0.053 = 100.00. The organic matter, which forms about the same proportion as in an oyster shell, is regarded as an essential part of the deposit, the conclusion being that this large amount of calcium carbonate has been secreted by some minute form of life.

Analysis of Dolomitic Marble from Texas, Md. By GEORGE C. BUCK. *Am. Chem. J.*, **19**, 234.—The analysis shows that this valuable marble approximates fairly to a true dolomite.

Analysis of an Alum Water from Lee Co., Va. By L. E. SMOOT. *Am. Chem. J.*, **19**, 234–235.—This water has a strong alum taste, and yielded 3.715 grams per liter of aluminum, iron, and sodium sulphates, the first largely predominating.

Analyses of Infusorial Earth. By F. W. SMITHER. *Am. Chem. J.*, **19**, 235–236.—Three samples were analyzed, from Richmond and King George Cos., Va., and Calvert Co., Md. The second is of exceptional purity, containing 65.83 per cent. of amorphous silica. The chief impurities are quartz and clay, with only traces of lime and magnesia.

Solution of Silica Under Atmospheric Conditions. By C. WILLARD HAYES. *Bull. Geol. Soc. Am.*, **8**, 213–220.—The author states that while it is doubtless true that, considered in its relations to other rock-forming minerals, quartz is one of the most insoluble, some recent observations show that under certain conditions now existing at the earth's surface, quartz is by no means proof against chemical, as well as mechanical, agents of erosion. Various observed cases of the solution of silica are then described, including geodes and quartzose conglomerates and sandstones; and it is attributed to the agency of the humic acids. By the oxidation of the vegetable tissues in the process of decay the humic acids are formed, chiefly humic and crenic. These absorb varying quantities of free nitrogen from the air forming the azo-humic acids, which in turn combine with free silica. The resulting complex acids combine with alkaline carbonates, particularly potassium carbonate, to form easily soluble salts. The author regards the presence of potassium carbonate as probably an essential factor in the process. Thenard has shown that the amount of silica dissolved by azo-humic acid is proportional to the content of nitrogen, varying from 7 to 24 per cent.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

Fourth Annual Report of the Committee on Atomic Weights. Results Published in 1896. BY F. W. CLARKE. *J. Am. Chem. Soc.*, 19, 359–369.—A summary is given of the atomic weight determinations published during the preceding year. The mean results referred to oxygen as 16, are given below. The values adopted by Clarke, in his report of last year, are inserted in parentheses for the sake of comparison.

Hydrogen (THOMSEN, *Ztschr. anorg. Chem.*, 12, 4), 1.0083 (1.0076).

Silver (HARDIN, *J. Am. Chem. Soc.*, 18, 990), 107.928 (107.92).

Nitrogen (HIBBS, *J. Am. Chem. Soc.*, 18, 1044), 14.0117 (14.04).

Arsenic (HIBBS, *J. Am. Chem. Soc.*, 18, 1044), 74.916 (75.09).

Magnesium (RICHARDS AND PARKER, *Ztschr. anorg. Chem.*, 13, 81) .... 24.362 (24.29).

Cadmium (HARDIN, *J. Am. Chem. Soc.*, 18, 990), 112.027 (111.93).

Mercury (HARDIN, *J. Am. Chem. Soc.*, 18, 990), 199.989 (200.0).

Tellurium (CHIKASHIGE, *J. Am. Chem. Soc.*, 69, 881), 127.59 (127.0).

Tungsten (SCHNEIDER, *J. prakt. Chem.*, 53, 288), 184.01 (184.84).

Tungsten (SHINN, *Dissertation*)............184.91 (184.84).

The article closes with a revised table of atomic weights.

The Nature of the Chemical Elements. Argon and Helium in the Periodic Sequence. BY CHARLES SKEELE PALMER. *Proc. Col. Sci. Soc.*, Jan. 4, 1897, 1–10.—The article is extremely hypothetical and visionary. Many of the statements are only verbally intelligible.

Mass Law Studies, II. By S. F. Taylor. *J. Phys. Chem.*, 1, 461–473.—See *this Rev.*, 3, 75.

Solubility and Freezing Point. By D. McIntosh. *J. Phys. Chem.*, 1, 474–492.

On Potassium Lead Iodide. By J. M. Talmadge. *J. Phys. Chem.*, 1, 493–498.

H. M. Goodwin, Reviewer.

Surface Tension of Water and of Dilute Aqueous Solutions. By N. Ernest Dorsey. *Johns Hopkins Univ. Circ.*, 16, 44.—The author employed Lord Rayleigh's method of "ripples" for determining the surface tension of water and aqueous solutions of sodium chloride, potassium chloride, sodium carbonate, potassium carbonate and zinc sulphate, of concentrations varying from 0.05 normal to normal. The method gave results accurate to about one-seventh per cent. The value found for pure water was $T_w = 75.98$ dynes per centimeter, at 0° C. For the solutions employed it was found that the surface tension was a linear function of the concentration, and could be expressed by the formula $T_s = T_w + kC$. The values found for K are given below: NaCl, 1.53; KCl, 2.23; $\frac{1}{2}Na_2CO_3$, 2.00; $\frac{1}{2}K_2CO_3$, 1.77; $ZnSO_4$, 1.86.

Velocity of Silver Ions in Aqueous and Alcoholic Solutions. By W. T. Mather. *Johns Hopkins Univ. Circ.*, 16, 45–46.—Experiments upon the effect of temperatures ranging from 0° to 50° on the transference numbers of silver nitrate and acetate in aqueous solution, confirmed the law well established by Brin, that the value approaches 0.5 with rising temperature. (Both of these salts have already been very carefully investigated by Loeb and Nernst.) In absolute alcohol the transference number for the anion NO_3 was found about 10 per cent. greater than in water, while in a 50 per cent. solution the value was the same. The results are published as preliminary.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. Talbot, Reviewer.

Determination of Potash and Phosphoric Acid in Fodders. By H. W. Wiley. *J. Am. Chem. Soc.*, 19, 320–322.—The procedure described is a modification of the Lindo-Gladding method, and provides for the determination of the phosphoric acid and potash in the same sample, if desired. By this method ten samples may be examined per day without sacrifice of accuracy.

Sodium Peroxide as a Third Group Reagent. By S. W. Parr. *J. Am. Chem. Soc.*, 19, 341–346.—The peroxide throws down from a nitric acid solution of the sulphides of the group, iron, manganese, cobalt and nickel, while the zinc, aluminum and chromium remain in solution, the latter undergoing oxidation to chromate, thus avoiding interference with the zinc. A scheme is given for the further separation of these metals. The procedure proposed in the presence of phosphates, involving the addition of tin, appears to be less satisfactory.

On the Determination of Silica in Blast Furnace Slag. By G. H. Meeker. *J. Am. Chem. Soc.*, 19, 370–374.—The dehydration of the silicic acid by means of concentrated sulphuric acid, instead of by heat, is the essential feature of the procedure, for which both rapidity and accuracy are claimed. The filtrate from the silica thus obtained cannot, however, be utilized for the determination of either aluminum or calcium. The method yields satisfactory results in the presence of spinel.

The Determination of Lead in Lead Ores. By Richard K. Meade. *J. Am. Chem. Soc.*, 19, 374–377; *Eng. Min. J.*, 63, 313.—It is proposed to treat the ore in a platinum vessel with nitric and sulphuric acids, and after the removal of the former, to add hydrochloric acid and expel the excess. The remaining lead sulphate is then filtered and ignited as usual. Other metals forming insoluble sulphates must be absent.

Note on the Separation of Silicic and Tungstic Acids. By James S. de Benneville. *J. Am. Chem. Soc.*, 19, 377–379.—The author points out that silica is not insoluble in ammonia and that the volatilization method, recommended by Arnold (*Steel Works Analysis*), is unquestionably preferable for the separation of these acids.

The Electrolytic Determination of Cadmium. By S. Avery and Benton Dales. *J. Am. Chem. Soc.*, 19, 379–382 and 513.—The authors find that the double oxalate and acetic acid methods for the determination of cadmium are unsatisfactory; the cyanide method yields fair results with relatively large amounts of cadmium, and the formate method yields satisfactory results, provided certain conditions, which they prescribe, are rigidly maintained.

Note on the Volatility of Boric Acid; Separation of Boric and Phosphoric Acid; Estimation of Boric Acid in Foods. By L. de Koningh. *J. Am. Chem. Soc.*, 19, 385–388.—Experimental evidence is offered to show that boric acid is not appreciably volatile with steam, until the solution is evaporated nearly to dryness. Calcium chloride is employed to throw down phosphoric acid, when present, before the titration of boric acid. The use of zinc oxide in food analysis to remove the phosphoric acid is proposed. Its efficiency has not been fully established.

The Volumetric Determination of Lead. BY J. H. WAINWRIGHT. *J. Am. Chem. Soc.*, 19, 389–393.—The procedure proposed is a modification of one already given in *Crookes' Select Methods*. The lead is precipitated by means of potassium bichromate, from an acetic acid solution, using a solution of silver nitrate as an outside indicator. The author claims that the method is rapid and of moderate accuracy. The paper is somewhat confused by the unfortunate use of *carbonate* for *chromate* on pages 390 and 392.

Analysis of Phosphor Bronze, Phosphor Copper, Phosphor Tin, Etc. BY MAX WICKHORST. *J. Am. Chem. Soc.*, 19, 396–398.—The paper presents detailed procedures for the determination of phosphorus in any of the alloys named, and for the complete analysis of phosphor bronze.

Notes on the Estimation of Cyanogen by Silver Nitrate, Using Potassium Iodide and Ammonia as Indicators. BY WILLIAM J. SHARWOOD. *J. Am. Chem. Soc.*, 19, 400–434.—The paper presents the results of an exhaustive study of the reaction between the cyanide and the nitrate under varying conditions. The results can hardly be briefly summarized ; reference must therefore be made to the original article.

Qualitative Separations with Sodium Nitrite in Absence of Phosphates, Etc. BY GILLETT WYNKOOP. *J. Am. Chem. Soc.*, 19, 434–436.—The author finds that iron, chromium and aluminum are precipitated completely by sodium nitrite from a boiling solution containing a small quantity of free acid, while nickel, cobalt, zinc and manganese are not thrown down. The separation seems to be more complete than that effected by the use of barium carbonate.

Table for the Calculation of Analyses. BY EDWARD BARTON AND JOHN NAVARRE MARCOMB, JR. *Kansas Univ. Quart.*, 6, 59–60.

W. H. WALKER, REVIEWER.

Determination of Arsenic in Copper and Cupriferous Solutions. BY TITUS ULKE. *Eng. Min. J.*, 63, 454.—About ten grams of the sample are treated with a mixture made up of equal parts of strong hydrochloric acid and a saturated solution of ferric chloride, and repeatedly distilled. All the arsenic is then found in the colorless distillate as arsenious chloride, and may be determined either by titration with standard iodine solution, or gravimetrically as arsenious sulphide.

W. H. WALKER, REVIEWER.

The Complete Analysis of Chrome Ore. BY A. G. MCKENNA. *Proc. Eng. Soc. Western Pa.*, 63, 180–182.—The dried sample is fused in a nickel crucible (platinum is very easily attacked by this reagent) with an excess of sodium peroxide for a few minutes. This ensures complete decomposition of the ore, after which the sodium chromate formed is dissolved and determined volumetrically with a standard solution of a ferrous salt. The other constituents of the ore are separated and determined by the usual quantitative methods.

PROXIMATE ANALYSIS.

G. W. ROLFE, REVIEWER.

A Recalculation of Wein's Table of Starch Equivalent to Copper Found Based on the Factor 0.92. BY WILLIAM H. KRUG. *J. Am. Chem. Soc.*, 19, 452.—This factor, 0.92, is that suggested by Wiley as the mean between Nägeli's, 0.918, and 0.925 of Ost.

An Analytical Investigation of the Hydrolysis of Starch by Acids. BY G. W. ROLFE AND GEO. DEFREN. *Tech. Quart.*, 10, 133–166.—A revision of an earlier article in the same journal.

The Determination of Reducing Sugars in Terms of Cupric Oxide. BY GEO. DEFREN. *Tech. Quart.*, 10, 167–182.—A revision of an earlier paper.

Improved Method for the Determination of the Specific Gravity of Molasses. BY J. C. BOOT. *La. Planter and Sugar Mfr.*, 18, 415.—The author suggests a modification of Sidersky's method (*Ztschr. für Rübenzucker Indus.*, *1881*, 192) in which a potassium carbonate solution of approximately the same specific gravity as the molasses is used to dilute the latter to the required volume. This obviates the necessity of determining the exact volume of the molasses itself by a separate weighing. The author shows that the error introduced under ordinary conditions is not over one one-thousandth.

F. H. THORP, REVIEWER.

Method of Drying Sensitive Organic Substances. BY C. C. PARSONS. *J. Am. Chem. Soc.*, 19, 388.—The moisture in such substances as soap, wood pulp, and the like, may be determined by dividing the material into small, thin pieces and introducing these directly into a known weight of paraffine oil, which has been heated for some time to 250° C., before using. The mixture is put into a hot closet at 240° C., for a few minutes, and then weighed. The loss is called moisture. The operation seldom requires more than twenty minutes, and no decomposition of the substance takes place under the oil.

W. R. WHITNEY, REVIEWER.

Riegler's Method for Estimating Sugar in Urine. BY HENRY C. C. MAISCH. *Am. J. Pharm.*, 69, 294–296.—The author gives reasons for his adverse criticism of the method for the determination of sugar in urine by means of Fehling solution, pointing out the fact, confirmed by his own experimental investigation, that other reducing bodies than sugars may, by their presence, introduce errors. He recommends the method of Rübner, or Penzoldt's modification. This is a colorimetric test, the sugar being estimated by the depth of color in the precipitate which ammonia produces in the urine after it has been treated with lead acetate solution, and filtered.

Notes on Opium Assaying. BY FRANK X. MOERK. *Am. J. Pharm.*, 69, 343–350.—These notes are valuable additions to the methods for the assaying of opium. The author recognizes the imperfections of all existing methods, and points to the need of more exact processes. Tables are given showing some results and exhibiting variations which are inconsistent with perfect methods, but which make evident the comparative value of the lime-water method.

Analytical Processes and Laboratory Notes. BY CHAS. LAWALL. *Am. J. Pharm.*, 69, 350–352.—Directions for a rapid and accurate method for the determination of caffeine in kola, guarana, coffee, etc., are given. The material is treated with dilute ammonia and shaken out with chloroform. The filtered solution, on evaporation, leaves the fat and alkaloid, from which the fat is extracted with ether and the dried residue weighed. A note concerning the estimation of alkaloids in white hellebore follows, and the article concludes with a discussion of the purity of so-called "C. P." chemicals. The reviewer cannot agree with the author in his opinion concerning the use of "C. P.," and would deprecate the advancement of the idea that the "U. S. P." requirements represent a higher degree of purity than our older well-known "C. P." should. The mark "C. P." ought to indicate such a degree of purity of a preparation that present chemical methods can show no appreciable impurity, and the consequent and necessarily infrequent use of the term "chemically pure" should then be an evidence of its strict propriety.

The Estimation of Menthol in Oil of Peppermint. BY CLEMENS KLEBER. *Pharm. Rev.*, 15, 135.—This paper presents a brief comparison of the author's method for the determination of menthol with that of Kebler, and concludes with a rapid, approximate method, in which a comparison is made of the titration value (in terms of sodium hydrate) of a definite quantity of acetic anhydride with the value of the same quantity after boiling 30 minutes with the oil containing menthol.

TECHNICAL CHEMISTRY.

F. H. THORP, REVIEWER.

Artificial Silk in Germany. BY GEORGE SAWTER. *U. S. Consular Rep.*, **54**, 107–110.—The paper gives a brief description of the Lehner process for the production of artificial silk from wood pulp (see *U. S. Consular Rep.*, **48**, 266), and also of the Seyfert process for its production from cotton yarn. The cotton is treated with a cold solution of caustic soda of 30° Bé., and then dried on a stretcher reel, under strong tension. The yarn is afterwards thoroughly washed, and dyed. The new artificial silk is very strong, non-inflammable, and it is claimed that washing does not injure its lustre.

Quebracho Tanning in Uruguay. BY EDGAR SCHRAMM. *U. S. Consular Rep.*, **53**, 495.—The advantages of quebracho wood as a tanning material and as lumber, are well presented. For use in tanning, the entire log is chipped up to a coarse sawdust and leached in much the same manner that oak bark is treated. It is claimed to be richer in tannins than oak bark.

Photography in Natural Colors. BY FRANK H. MASON. *U. S. Consular Rep.*, **53**, 518–521.—This is a popular account of a new process, invented by M. Chassagne. An ordinary dry plate is treated with an unnamed colorless solution, and then exposed, developed, and fixed in the usual manner, producing a monochromatic negative. Sensitized paper or gelatine film is also treated with the colorless solution and printed by contact, in the usual way. The print appears like an ordinary one, but is said to have acquired the power of selective absorption for dyes, so that if it is passed successively through solutions of red, green, and blue dyes, a proportionate amount of each color is taken up locally, to reproduce the colors of the natural object. No information is given as to the nature of the liquids used.

Manufacture of Phosphor Bronze. BY MAX H. WICKHORST. *J. Am. Chem. Soc.*, **19**, 393–395.—The phosphorus added to bronze to deoxidize the metal may be introduced as phosphorus or as a high phosphorus alloy, called "hardener." This contains six per cent. of phosphorus, with copper and tin in the ratio of eight to one. The "hardener" is made by melting 90 pounds of copper and adding 11 pounds of tin. Seven pounds of phosphorus are put into a dilute solution of blue vitriol, until coated with metallic copper. This protects the phosphorus when it is dried in the air. After drying, the sticks of copper-plated phosphorus are introduced into the melted bronze, two or three at a time, and held below the surface of the metal by a cup-shaped tool. The phosphorus melts and combines with the metal at once, to form "hardener."

On the Manufacture of Dynamite. BY G. E. BARTON. *J. Am. Chem. Soc.*, 19, 500–509.—This paper presents a description of the plant and the method used in the manufacture of dynamite. Two classes of dynamite are recognized: that consisting of nitroglycerol absorbed in wood pulp, or kieselguhr, with various fillers, such as sodium nitrate, etc.; and those called gelatin dynamites, consisting of nitroglycerol, gelatinized with nitrated cellulose. The first class is discussed in this article. The numerous precautions to be taken in arranging and in operating the plant, the tests of materials and yields obtained, are all shown. The treatment of the spent acids is also considered, and recovery by running through a Glover tower is advised. The mixing of the nitroglycerol with the absorbent is best done in a wheel-mill with wooden wheels. For packing the dynamite in the cartridge papers, wooden pack-sticks are best.

The Commercial Preparation of Nitronaphthalenes. BY WILLIAM H. KRUG AND J. E. BLOMÉN. *J. Am. Chem. Soc.*, 19, 532–538.—Nitronaphthalenes are chiefly used in nitroglycerol explosives, to reduce sensitiveness to concussion and to prevent freezing of the dynamite. It also increases the solvent action of nitroglycerol on nitrated cellulose. The nitronaphthalenes used should be as highly nitrated as possible. In order to determine the conditions necessary for the best yield, the authors tried nitrating naphthalene-sulphonic acid under various conditions, and also nitrating naphthalene directly. It was found that the yield of nitronaphthalene decreased proportionally to the degree of sulphonation in the case of α-naphthalene-sulphonic acid. Direct nitration of naphthalene gave better yields, and the best results were obtained by using a mixture of nitric acid 26° Bé., and sulphuric acid, the quantity of the latter depending on the degree of nitration desired. For low melting products, four parts of nitric to one of sulphuric were used; for high melting products, three parts to two. An excess of sulphuric acid chars the product, producing much tar.

BIOLOGICAL CHEMISTRY.

E. H. RICHARDS, REVIEWER.

Dietary Studies. The Food of the Negro in Alabama. BY W. O. ATWATER AND CHAS. D. WOODS. *U. S. Expt. Sta. Bul.* No. 38, 1–69.—This report gives in detail the food consumed by eighteen families living in the neighborhood of Tuskegee, Ala., and is by far the most comprehensive contribution to this vital question for the whole race. The cost per man per day ranged from two and one-quarter to nineteen and three-quarters cents. Ten dietaries cost less than eight cents and seven less than six cents per day, yet only five gave an abnormally low fuel value. As might have been predicted from the experience of employers, the nitrogenous substances were uniformly low. Fourteen of the twenty dietaries (two families were tested in both winter and summer) contained from one-fourth to one-half the required proportion.

Dietaries of the Public Institutions of the City of Boston. BY E. H. RICHARDS AND S. E. WENTWORTH. *Rep. of the Institutions' Dept., City Document 14, 1897,* 206–219.—The authors make a statement of the facts established by their investigation, and recommend certain standards for the different classes of public institutions.

Dietary Studies in New Mexico. BY ARTHUR GOSS. *U. S. Agr. Expt. Sta. Bull.*, No. 40, 1–23.—This Bulletin contains important data not elsewhere found, in the form of analyses of food materials used in the Central American regions, and the dietaries are of more than usual interest in view of our limited knowledge of the food of the Mexicans, both as to quality and cost. Here, as elsewhere, sufficient food seems to be procurable at a cost of from six to nine cents per person daily.

The Fruit Soils of Oregon and the Composition of Oregon Prunes. BY G. W. SHAW. *Reprint from Ore. Expt. Sta. Bull., No.* 45, 1–98.

Removal of Iron from Ground Waters. BY H. W. CLARKE. *J. N. E. Water Works Assoc.*, 11, 277–284.—The author suggests the use of coke as a more efficient filtering material than sand for the removal of iron from certain classes of waters, and in support of this view gives the results of experiments at Provincetown, Mass.

The Iron Removal Plant at Reading, Mass. BY LEWIS M. BANCROFT. *J. N. E. Water Works Assoc.*, 11, 294–300.—The use of lime and alum for the removal of iron from a water which does not yield to simple aeration and filtration, is described, and a table of analyses given.

W. R. WHITNEY, REVIEWER.

Internal Secretion Considered from a Chemico-physiological Standpoint. BY R. H. CHITTENDEN. *Science*, 5, 967–977.—The author treats exhaustively a single internal secretion, that of the rudimentary gland of the neck, the thyroid, known as the seat of the goitre. The effects on the metabolism of persons and animals (both normal and thyroidectomized), brought about by the administration of the gland, or its extracts, are pointed out. These, together with the recognized change produced in the blood and upon the quantity of mucus in different parts of the body, afford sufficient evidence that this vestigial gland produces one or more secretions necessary to the animal body. Concerning the chemical and physiological nature of the principal product, which the author calls "a proteid of peculiar constitution," not much is known. It is peculiar in that "it tends to hold a certain amount of iodine in combination," and yields on decomposition by acids or gastric juices, iodothyrin, a non-proteid, difficultly decomposable compound containing phosphorus and iodine. The physiological action of iodothyrin is further considered, as well as the presence of a relatively high percentage of iodine in the material of the gland.

The Nitrogen-free Extract of Plants and Feeding Stuffs. BY B. TOLLENS. *U. S. Expt. Sta. Rec.*, 8, 641–661.—This article is introduced by a detailed consideration of the constituents of the so-called carbohydrates of food material, and attention is called to the fact that other substances which are not strictly carbohydrates are here classed as such. Uncertainties regarding the proper method of analysis of crude fiber are also pointed out, and some erroneous notions regarding the food value of these constituents are corrected. The author properly recognizes the true value of the well-known Wende extraction method and points out the need for more exact and discriminating procedures.

The Root of Phytolacca Decandra. Part II. BY S. B. FRANKFORTER AND F. RAMALEY. *Am. J. Pharm.*, 69, 281–290.—The paper opens with abstracts of the literature concerning the chemical composition of the root. Of the results of their own investigations, the authors give the percentages of substance extracted by common solvents; a summary of analyses showing the amount of wax, resin, proteids, starch, acid (formic), etc., present; and the results of the study of the sugar extracted. No body of a glucosidal or alkaloidal nature was detected.

On the Occurrence of Strontium in Plants. By HENRY TRIMBLE. *Am. J. Pharm.*, **69**, 296–297.—The author has demonstrated the presence of strontium in several samples of bark and points to the fact that little or no attention has been given to its possible presence in the ashes of plants other than sea plants.

Alfalfa or Lucern; Its Chemical Life History. By JOHN A. WIDTSOE. *Bull. Utah Agr. College*, **48**, 1–73.—The paper presents a thorough discussion of the subject, and is so arranged as to show the composition of successive crops of the lucern. It is supplemented by a discussion of the connection between the analytical results and the value of the material as a fodder.

The Normal Urine. By CHARLES PLATT. *J. Am. Chem. Soc.*, **19**, 382–384.—This paper presents a table showing the mean results of many urine analyses made by the author and by others, and gives the extremes of composition between which the normal urine may lie, including practically all of its constituents.

The Proteids of Lupin Seeds. *J. Am. Chem. Soc.*, **19**, 454–482; **The Proteids of the Sunflower Seed.** *Ibid*, 487–493; **The Proteids of the Cow Pea.** *Ibid*, 494–500; **The Proteid of the White Podded Adzuki Bean.** *Ibid*, 509–512. By T. B. OSBORNE AND G. F. CAMPBELL.

AGRICULTURAL CHEMISTRY.

F. H. THORP, REVIEWER.

Alkali. By B. C. BUFFUM. *Wy. Sta. Bull.*, *No.* **29**, 219–253.—In this paper are given the details of a study of alkali in soil and its effects upon plants. "White alkali" consists principally of sulphates of sodium and magnesium; one per cent. of these salts in the first two inches of surface soil renders it unproductive, except for plants which can inhabit alkali soils. These are sugar-beets, white clover, sages, and alfalfa. A comparison of the temperatures of alkaline and non-alkaline soils was made, but no difference was detected.

The Value of Manure from Animals Fed on Linseed Meal. By H. SNYDER. *Minn. Agr. Expt. Sta. Bull.*, *No.* **47**, 23.—Pigs were fed on linseed meal and potatoes, and produced daily six pounds of urine and two pounds of dung. The total quantity of nitrogen in the two was 0.09 pound, while that in the food was 0.10 pound. A very large part of the nitrogen was thus returned to the soil when the linseed cake was used as feed.

The So-called "Natural Plant Food" a Soft Phosphate. BY A. D. SELBY. *Ohio Agr. Expt. Sta. Bull., No.* 71, 178–184.—An analysis showed "natural plant food," (see this *Rev.*, 3, 41,) to be, in part at least, Florida or Tennessee soft phosphate. A comparison between it and other standard fertilizers with reference to its action in hastening or retarding germination, showed that it retards germination as compared with unfertilized soil, although some of the standard fertilizers exert a still greater retarding action.

Ammonium Thiocyanate as an Impurity in Ammonium Sulphate. BY H. J. WHEELER AND B. L. HARTWELL. *R. I. Agr. Expt. Sta. Rep., 1895*, 281–286.—This is a record of experiments with pure ammonium sulphate, and that containing ammonium thiocyanate, on oats. The results demonstrate the poisonous action of the thiocyanate on such plants.

Analyses of Commercial Fertilizers. *Agr. Expt. Sta. Bull., Vt.*, 58 and 59, and 9th Ann. Rep., *1896*; *Mass. Hatch Sta., No.* 45; *Ky., No.* 68; *R. I. Sta. Rep., 1895*, 39, 287–293; *Mich., No.* 135; *S. C. Sta. Rep., 1895*, 54–63; *Mass. Hatch Sta., 9th Ann. Rep.*, 202–223; *Penn. Dept. Agr. Bull.*, 19; *Cal. Sta. Rep., 1895*, 135–139; *La., Series 2, No.* 45, 56–80; *Penn. Sta. Rep., 1895*, 227–236; *R. I. No.* 40, 71–79; *Wis., No.* 53; *Canada Expt. Farms Rep., 1895*, 206–219.

The Fertilization of Land. BY E. W. HILGARD. *Cal. Agr. Expt. Sta. Rep., 1895*, 123–135.—The effect of crops on the fertility of the soil in California is considered, and the fertilizer requirements studied. The general conclusions reached show that, with the exception of a few localities, the soils of the state contain an abundance of lime, and that acid soils are rare. There is also sufficient potash in most localities, and often an excess. The rainfall being generally deficient, this ingredient is not washed away; but the greater part of California soils are deficient in phosphoric acid, and phosphates are the chief fertilizers now required by the farmers. Nitrogen is generally present, but in some localities may need to be supplied. Next to phosphates, nitrogenous fertilizers are probably most in demand, except in the alkali regions, where an excess of nitrogen is present.

Analysis of Paris Green. E. W. HILGARD. *Cal. Agr. Expt. Sta. Rep., 1895*, 137.—The percentage of arsenious acid is stated for two samples.

Experiments with Soluble, Reverted, and Insoluble Phosphoric Acid. BY E. H. HESS. *Penn. Agr. Expt. Sta. Rep., 1895*, 157–210. —The author concludes that soluble phosphates are too expensive to use on lime soils, where equally good results are obtained with insoluble phosphates; also that ground bone is superior to ground Carolina phosphate rock.

Composition of Wood Ashes Sold in Pennsylvania. By W. Frear. *Penn. Agr. Expt. Sta. Rep.*, *1895*, 224–226.—Analyses of fifteen samples are given, with comments.

Some Pennsylvania Peats. By W. Frear and E. J. Haley. *Penn. Agr. Expt. Sta. Rep.*, *1895*, 148–156.—The value of peat as a fertilizer is shown by the analyses of thirteen samples. Although bulky, it offers a fertilizer well worth consideration; some varieties, however, need composting with lime or with stable manure.

Origin, Value, and Reclaimation of Alkali Soils. By E. W. Hilgard. *U. S. Dept. Agr. Yearbook*, *1895*, 103–122.—Among other subjects discussed in this article are "the influence of irrigation on the movement of alkali," and the "composition of alkali salts."

Inspection of Paris Green. By W. C. Stubbs. *La. Agr. Expt. Sta. Bull.*, *No.* 45 (*2nd Ser.*).—Analyses of eight samples are given.

Investigation on the Foraging Powers of Some Agricultural Plants for Phosphoric Acid. By L. H. Merrill and W. H. Jordan. *Maine Sta. Rep.*, *1895*, 10–18.—This paper is a continuation of the study of the fertilizing value of insoluble, as compared with soluble phosphates. Among other conclusions it is stated that young plants feed chiefly on soluble phosphates, while with older plants the insoluble forms are assimilated. The solubility of phosphate in ammonium citrate is not considered a true measure of the availability of phosphoric acid to the plants. Certain varieties of plants appear better able to assimilate insoluble phosphates than do others.

G. W. Rolfe, Reviewer.

The Occurrence of Raffinose in American Sugar-Beets. By W. E. Stone and W. H. Baird. *J. Am. Chem. Soc.*, **19**, 115–124.—The paper presents a discussion bearing upon the occurrence of raffinose in beet-sugar, in which are given the results of the researches of the authors on Nebraska beet-root molasses. They find by a modification of the Kodyl-Sheibler method that raffinose is present. The authors also note the remarkable fact that raffinose in very small amounts changes the character of cane-sugar crystals, so that they closely resemble those of pure raffinose. They illustrate this by photo-micrographs.

The Sugar-Beet. By H. W. Wiley. *Farmers' Bull. U. S. Dept. of Agr., No.* 52, 1-47.—The paper is intended to give concise information in a popular way on the raising of sugar-beets, a comparison of the different varieties, and the effect of climate, soil, fertilizers, irrigation, etc., on the quality of the beets. Methods of cultivation and manufacture, as well as data on the cost are also given. A number of statistical tables on the world's sugar production are added.

[Contribution from the Massachusetts Institute of Technology.]

REVIEW OF AMERICAN CHEMICAL RESEARCH.

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INORGANIC CHEMISTRY.

Henry Fay, Reviewer.

A Study of Ferric Hydroxide in Precipitation. By Vernon J. Hall. *Am. Chem. J.*, 19, 512–525.—To ascertain whether the reaction between ferric chloride, potassium hydroxide and potassium sulphate takes place according to the equation

$$Fe_2Cl_6 + 6KOH + 4K_2SO_4 = Fe_2(OH)_6 + 6KCl + 4K_2SO_4,$$

and to learn whether the precipitation is affected by occlusion, solutions of each of these compounds were prepared and carefully standardized. Precipitation of the ferric hydroxide from solutions, each containing the same amount of iron, were made with eight, six, five, four, three, and two molecules of potassium hydroxide, and the resulting precipitate and filtrate analyzed for potassium and sulphuric acid. All of the potassium and sulphuric acid should appear in the filtrate if the reaction proceeds according to the equation. Using six molecules of potassium hydroxide none of the sulphuric acid was found in the precipitate, but 0.48 per cent. of the potassium (K_2O) was carried down. On diminishing the amount of potassium hydroxide below six molecules none of the potassium was found in the precipitate. On the other hand, 11 per cent. of sulphuric acid (SO_3) appeared in the precipitate at five molecules, 11.5 per cent. at four, and 9.53 per cent. and 5.52 per cent. at three and two molecules, respectively. When the amount of potassium hydroxide was increased to eight molecules, more potassium was carried down in the precipitate, while all of the sulphuric acid appeared in the filtrate. It appears from these results that potassium sulphate as such is not carried down in the precipitate, but that the ferric hydroxide has the power of decomposing it. In a second series the reaction

$$2FeCl_3 + 6KOH = 2Fe(OH)_3 + 6KCl$$

was tested in the same way, by analyzing the precipitate and filtrate for potassium and chlorine to see what effect the potassium chloride had upon the precipitation of ferric hydroxide. With six molecules the chlorine was undisturbed; at points short of complete precipitation the amount of chlorine in the precipitate decreases as the amount of the hydroxide passes from five and one-half molecules to five, and so on. In a third series the same reaction as in the first series containing potassium sulphate was tested, to see how much chlorine was carried down. From the results it appears that the ferric hydroxide acts on the potassium sulphate in preference to the potassium chloride. The author concludes that the facts observed are inconsistent with the theory of adhesion, but that they are characteristic of chemical action.

Corrosive Sublimate in Calomel. By LYMAN F. KEBLER. *Am. J. Pharm.*, 69, 338–340.—The author has found that calomel occasionally contains corrosive sublimate, but according to the most rigid tests all calomel, with a single exception, examined during several years, has not contained over 0.00001 per cent. of corrosive sublimate.

Notes on Lucium. By WALDRON SHAPLEIGH. *J. Franklin Inst.*, 144, 68–70.—The author has shown that the precipitate with sodium thiosulphate, on which great stress is laid as a reaction for "lucium," can be produced by heating a concentrated solution of the double sulphates of the yttrite group and potassium, and that the precipitate is due to the heat alone and not to the presence of the thiosulphate. One kilogram of monazite sand was worked over, following the directions set forth in the patent of M. Barrière without obtaining any earth corresponding to the reactions of "lucium."

The Action of Iodine on Solutions of Stannous Chloride. By S. W. YOUNG AND MAXWELL ADAMS. *J. Am. Chem. Soc.*, 19, 515–525.—By treating iodine with excess of stannous chloride solution, there is formed stannic iodide with subsequent formation of stannous iodide, and other products, probably producing a state of equilibrium, which varies with the quantities used and the temperature of the reaction.

The Ferrocyanides of Zinc and Manganese. By G. C. STONE AND D. A. VAN INGEN. *J. Am. Chem. Soc.*, 19, 542–547.—Both zinc and manganese form different salts in neutral and acid solutions, the composition of the salts varying according as the ferrocyanide or the metallic salt is in excess. It was found impossible to titrate the excess of ferrocyanide unless the conditions are always maintained absolutely the same. Among the indicators cobalt gave the best results.

On the Ferrocyanides of Zinc and Manganese. BY EDMUND H. MILLER AND J. A. MATHEWS. *J. Am. Chem. Soc.*, 19, 547–558.—The precipitates formed by potassium ferrocyanide and zinc or manganese chlorides are double ferrocyanides, the composition of which varies with the increase or decrease of one of the constituents. The precipitate formed in a dilute hydrochloric acid solution of zinc chloride by potassium ferrocyanide has the composition represented by the formula $Zn_3K_2(Fe(CN)_6)_2$, which confirms the accuracy of the ordinary method for the quantitative determination of zinc and manganese.

METALLURGICAL CHEMISTRY.

H. O. HOFMAN, REVIEWER.

Heat Requirement of the Silver-Lead Blast Furnace. BY L. S. AUSTIN. *Eng. Min. J.*, 63, 634–635.—The author starts with a certain charge consisting of foul slag, bedded ore, siliceous ore, roasted ore, fine dust, oxidized lead ore, and limestone, to be melted with 15 per cent. coke, calculates the resulting products, slag, matte and speiss and base bullion, assumes the composition and temperature of the escaping gases and calculates how the coke charged will be used up. He finds that nearly 82 per cent. of the heat value of the fuel is consumed in the formation of the slag and the reduction of carbon dioxide to monoxide.

Standard Practice in Bessemerizing Copper Mattes. BY C. W. PARSONS. *Eng. Min. J.*, 63, 481–483.—This is the first article on the subject giving full practical details of the manner of working.

The Present Status of Pyritic Smelting. BY H. LANG. *Eng. Min. J.*, 64, 37–38.—This is a defense of the work done by the author at Keswick, Cal. The points of interest in the lengthy article are that in the absence of alumina the single silicate of iron forms the most desirable slag; that the concentration of copper in matte is governed principally by the amount of silica present; and that an excess of silica causes accretions to form and particles of quartz to be mechanically suspended in the slag, while a lack results in the production of a low-grade matte. While in the absence of alumina, slags with about 30 per cent. silica were satisfactory, with alumina the percentage of silica ran from 20 to 40 per cent. The author claims, as a result of his work: (1) Charges with not more than 33 per cent. of sulphide can be smelted with 2½ per cent. coke, making a high concentration; (2) the slags can be made as clean as those from matting copper ores; and (3), as stated above, silica governs, to a great extent, the degree of concentration.

The Peletan-Clerici Process at the De Lamar Mill, Idaho. By D. B. Huntley. *Eng. Min. J.*, **64**, 155–156.—This is an illustrated description of a plant and process which aims to extract by electro-amalgamation, gold and silver from ore to which a small amount of potassium cyanide has been added. The essential parts of the plant are two classes of agitators, 5 upper ones, 8 feet in diameter and 8½ feet deep, receiving through a launder the pulp from the stamp batteries and Huntington mills, and discharging at intervals into 10 lower ones, 8 feet 8 inches in diameter and 4 feet deep, and holding 2½ tons of ore, into which the thick pulp is discharged to be electro-amalgamated. A lower agitator has on the wooden bottom a copper plate forming the cathode, while the vertical shaft, geared from above and having 4 arms bearing sheet-iron plates (4 feet long, 14 inches wide, and ½ inch thick) forms the anode. The pulp in the amalgamator (which has been charged with 600 pounds quicksilver, covering the bottom ½ inch) receives from 2½ to 3 pounds potassium cyanide and 6 pounds of salt per ton of ore and is treated for 11½ hours, the shaft making 20 revolutions per minute, the current being of 10 volts (amperage not given). The amalgam formed is removed twice a month and worked in the usual way. The ore is a decomposed quartz porphyry carrying from 0.25 to 0.50 per cent. concentrates, the valuable mineral is partly oxidized gold- and silver-bearing iron sulphide, from ⅔ to ⅘ of the value of which is gold. By raw amalgamation it yields from 40 to 50 per cent. precious metal, the use of salt and blue stone somewhat increases the extraction and the new process takes out about 80 per cent. of the values.

Roasting Previous to Cyaniding. By W. MacGregor. *Eng. Min. J.*, **64**, 187–188.—The author advocates that, in treating gold ores by the cyanide process, the question of roasting should receive more consideration than it does at present, as there would be a higher extraction of gold, a lower consumption of cyanide, the ores would filter more rapidly, the solutions become less charged with soluble salts, and the use of lime or soda ash as neutralizer would become unnecessary. In experimenting, laboratory tests should be supplemented by small working tests, with from 1 to 10 tons of ore. Stress is laid on roasting the ore absolutely dead. In order to see if an ore has been dead-roasted in large scale work the author recommends the following procedure: Take from 100 to 250 grams of ore, place it in a beaker with some 200 cc. of water, stir and filter, and add slowly to the filtrate cyanide solution of the same strength as the working solution. If no cloudiness appears, the ore is fitted for cyanide treatment; if a brown coloration results, the cyanide consumption will be high; if a blue coloration soon becoming a bluish-green precipitate, the ore is badly roasted.

A Plant for Parting Low-Grade Bullion. By F. Gutzkow. *Eng. Min. J.*, 64, 218.—This paper gives an illustrated description of a plant and an outline of the practical details for carrying out the author's new process noticed in *this Rev.*, 3, 101.

Changes in Cyanide Mill Solutions. By Ph. Argall. *Biennial Rep. Colo. School Min.*, *through Eng. Min. J.*, 64, 246. The subjoined analyses show how little change a mill solution from roasted ore undergoes, if carefully handled, the normal strength being kept up by the addition of fresh cyanide.

	Solution.			
	Before precipitation.	After precipitation.	After six months' use.	After eighteen months' use.
KCN	0.501	0.451	0.535	0.410
HCN	0.061	0.079	0.017	0.021
Total simple cyanides	1.302	1.335	1.470	1.445
$KyFe(CN)_6$	0.098	0.117	0.018	0.026
KCNS	0.212	0.207	0.058	0.057
Zn	0.316	0.360	0.368	0.388
CaO	0.085	0.082	0.172	0.172
Au (oz.)	1.15	0.037	1.81	0.03

During the six months 11,000 tons of ore were treated, during eighteen months, 26,000 tons.

Limitation of the Cyanide Process. By Ph. Argall. *Biennial Rep. Colo. State School Min.*, *through Eng. Min. J.*, 64, 246.—The cyanide process is used only for oxidized ores containing gold in a fine state of division; if coarse gold is present, this has to be recovered by amalgamation either before or after cyanide treatment. Copper ores are soluble in dilute cyanide solutions, the copper accumulating up to a certain point when it is thrown down in the zinc boxes. Skey proved the solubility of chalcopyrite and copper glance, as well as that of sulphide of antimony. He believes that very small amounts of sulphur decrease the dissolving power of cyanide for gold; the author did not find this to be the case in working on a large scale. Galena is soluble in cyanide, but does not interfere with the solution of gold; blende and pyrite are insoluble.

The Accumulation of Amalgam on Copper Plates. By R. T. Bagliss. *Trans. Am. Inst. Min. Eng.*, 26, 33–38, 1039–1051.—The paper calls attention to the differing quantities of gold and silver found in the amalgam daily collected, the hard amalgam accumulating on the copper plates and the copper plates themselves at the gold mill of the Montana Mining Co., Marysville, Mont. The ore treated has a quartz ore gangue, contains argentiferous native gold in a very fine state of division, active silver in wire and leaf form, sulphides of iron and copper, and traces of lead, arsenic, antimony, and zinc; it assays one-half ounce gold and from 7 to 12 ounces silver per ton. The ore is stamped in a battery through a 30-mesh sieve, amalgamated on apron plates and passed over a Frue Vanner having an amalgamated distributor; the tailings are subsequently amalgamated in pans. An apron plate, of one-eighth inch rolled copper plate and electroplated with one ounce of silver to the square foot, was taken out after being in constant use for three years and ten months, the amalgam scale (ranging in thickness from sixteen-hundredths to one-sixteenth inch) removed by striking back and front and by scraping with a chisel. The amalgam recovered from the plate (8 feet long and 54 inches wide) weighed 160 pounds avoirdupois, yielded 38 per cent. bullion of 993.9 fineness, *viz.*, gold 431.4 and silver 562.5, representing a value of $8,340.54. In another case a plate yielded $11,000.00. The retorted amalgam from the daily clean-ups was 985.4 fine, *viz.*, gold 541.5 and silver 443.9; that from the accumulated scale 993.9, *viz.*, gold 431.4 and silver 562.5; that from the amalgamated copper plate on the Frue Vanner 982.5, *viz.* gold 380.5 and silver 602.0; the cleaned apron plate, when run into a bar, had absorbed 8.96 ounces gold and 9.62 ounces silver. Thus in regard to total fineness, the order of the amalgams was: accumulated scale (993.9), daily clean-up (985.4), Vanner plate (982.5), and in regard to the ratio of gold and silver, daily clean-up (123 : 100), absorbed by copper plate (93 : 100), accumulated scale (76 : 100), and Vanner plate (63 : 100). The author believes that chemical and not mechanical causes, as suggested in the discussion, must furnish the explanation for the excessive accumulation of scale and for the variations in the values of the different amalgams.

Notes on the Handling of Slags and Mattes at Western Works. By W. Braden. *Trans. Am. Inst. Min. Eng.*, **26**, 38–53.—The paper is an illustrated description of the different methods in use for separating the increasing amounts of matte formed in the treatment of silver-lead ores, and of disposing of the slag produced by blast furnaces, the capacity of which has been nearly doubled in the last five years.

The Volatilization of Silver in Chlorodizing Roasting. By L. D. Godshall. *Trans. Am. Inst. Min. Eng.*, **26**, 53–62.—This paper is a reply to Mr. C. A. Stetefeldt's criticism (*this Rev.*, 1, 331) of the author's "A Review of the Russell Process," which appeared in *Proc. Colo. Sci. Soc.*, 4, 306–322.

Notes on the Walrand-Legenisel Steel-Casting Process. By H. L. Hollis. *Trans. Am. Inst. Min. Eng.*, 26, 134–138.—In making steel for casting, open-hearth metal must be employed if sound castings are to be obtained. The process in question supplements the Bessemer operation in such a way as to permit the making of castings directly from the converter. It does this by adding ferro-silicon, containing from 10 to 12 per cent. silicon, to the converter at approximately the time when the flame drops and then making an after-blow. The result is a steel strongly superheated (on account of the high calorific power of silicon), free from blowholes (as the product of combustion is a slag and not a gas), very fluid and one which permits the making of intricate castings down to a fraction of a pound in weight. The paper outlines the mode of working used at the Legénisel and Cruizot works in France, at the works of Hagen, Prussia, and those of the Potter and Hollis Foundry Co., Chicago, Ill. The advantages of the process are that, the converter being small (600–1500 pound charges), the cost of installation is low, that, being heated up in about one hour, the plant need not be working continuously, that the process is cheap, that it furnishes cheaply small quantities of steel of the desired composition of such fluidity that small intricate castings can be made and that green sand can be used, if the castings are not to be machined. It is claimed that the same results can be obtained in a basic converter by substituting high-phosphorus iron for ferro-silicon.

The Effect of Additions of Titaniferous to Phosphoric Iron Ores in the Blast Furnace. By A. J. Rossi. *Trans. Am. Inst. Min. Eng.*, 26, 144–149.—The author shows by a number of fusions carried on in graphite crucibles that the tendency of titanium to throw the carbon in pig iron into the combined state is modified by the presence of phosphorus, the effect being the greater the larger the percentage of phosphoric acid in the mixture. He believes that by mixing titaniferous and phosphoric ores in the correct proportions, two classes of ores, of little value at present, can be smelted in the blast furnace, furnishing a foundry iron sufficiently strong for most purposes.

The Sulphuric Acid Process of Treating Lixiviation Sulphides. By F. P. Dewey. *Trans. Am. Inst. Min. Eng.*, 26, 242–263.—This paper, which was read simultaneously before the American Chemical Society and the American Institute of Mining Engineers, was discussed in *this Rev.*, 2, 99.

Action of Blast Furnace Gases upon Various Iron Ores. By O. O. Laudig. *Trans. Am. Inst. Min. Eng.*, 26, 269–278. Discussion by F. E. Bachman and R. H. Sweetser. *Ibid*, 1061–1071.—These experiments were undertaken to find out if it is possible to determine by laboratory experiment what processes go on in the blast furnace. Different iron ores, thirty-three in number, representing magnetite, different kinds of hematite, limonite, iron and steel scale, flue and puddle cinder were tested in sizes ranging from one-eighth inch to that passing through a 100-mesh sieve. The samples were separately heated in a small iron vessel for three hours to a temperature of about 432° C., first in a current of air that had been passed through caustic potash, pyrogallate of potash, and sulphuric acid, and then in a current of blast furnace gas, the composition of which [CO_2 7.4, CO 31.0, and CO_2 7.8, CO 27.0] gave the proportions of one CO_2 to 4.19 and 3.16 CO, respectively. The deposited carbon in the gas-heated sample having been determined, the weight of the air-heated ore deducted from the gas-heated ore (minus its carbon) gave the weight of the oxygen lost. Full details of the manner of experimenting are given. Nearly all the ores, with the exception of scales, cinders, and magnetites, after treatment showed a considerable increase in bulk, those depositing the most carbon showing the greatest. Thus Mesabi ores deposited 21.61 per cent. carbon, soft hematites 13.82, hard hematites 7.52, blue ores 3.08, cinders and scales 0.38, and magnetites hardly any. Carbon deposition and reduction bore no direct relation to each other, as was expected, except that when there was a large carbon deposition, there was also a large amount of oxygen lost. The mechanical effect of deposited carbon is to disintegrate the ore, thus opening the pores for the action of the carbonic oxide, and work in the blast furnace showed that ores absorbing the largest amount of carbon required the least amount of fuel per ton of iron. Ores that are easily reduced without carbon deposition must be very porous. The carbon-deposition has little to do with the carbon contents of the pig iron. Mr. Bachman, in his discussion, attributes the troubles occasioned by the use of fine Mesabi ores to their great increase in bulk, *viz.*, twice the original volume after the carbon has been burned off and four or five times taking carbon and ore together, as they choke up the interstices between the lumpy coke and limestone. In order to do satisfactory work, he says, it is necessary to have a charge which would make enough slag to give a regular-working furnace and take up all the sulphur without giving more than 2 per cent. in the cinder, and an ore-mixture which will give up its oxygen rapidly and uniformly at the lowest temperature, each ore to deposit enough carbon to thoroughly disintegrate it, to convert all the carbon dioxide of the flux to carbon monoxide and to remove all the oxygen from the ore that is not taken up by the carbon monoxide.

The Occurrence and Behavior of Tellurium in Gold Ores, more Particularly with Reference to the Potsdam Ores of the Black Hills, South Dakota. By Frank Clemes Smith. *Trans. Am. Inst. Min. Eng.*, **26**, 485–515, 1103–1108.—The chemical part of this paper refers to the assay, the roasting, and metallurgical treatment of tellurium gold-silver ores. In assaying, the author found that work in the crucible gave higher results than that in the scorifier, the charge—ore 0.25, sodium bicarbonate 1.00, litharge 2.00, argol 0.10, assay tons—giving the highest results with the Blue and Red Potsdam ore of the Black Hills, analysis of which gave: Blue ore, SiO_2 68.748, Al_2O_3 3.072, Fe 13.289, S 11.728, $CaSO_4\ 2H_2O$ 0.833, CaF_2 0.784, P_2O_5 0.842, and in ounces per ton Te 4.03, Au 0.325, Ag 1.055. Red ore, SiO_2 84.45, Al_2O_3 4.07, Fe_2O_3 7.28, CaO 0.85, MgO 0.25, SO_3 3.71, and in ounces per ton Te 8.426, Au 0.576, Ag 2.875. The tellurium mineral, which is sylvanite, was found to be very evenly distributed in both classes of ore.

In cupelling, it was found that the loss by absorption and volatilization increased with the percentage of tellurium. Selenium had an effect similar to that of tellurium.

In roasting, very rich tellurium gold ore assaying as high as 180.66 ounces gold and 2041 ounces silver per ton, losses of 14.06 ounces gold and 29.46 ounces silver per ton were encountered, while with Potsdam ore (22.80 ounces gold and 3.16 ounces silver per ton), the loss was 0.04 ounces gold and 0.32 ounces silver per ton, and with Cripple Creek (Colo.) ore (109.6 ounces gold and 667.71 ounces silver per ton) it was 3.60 ounces gold and 38.21 ounces silver per ton. The average loss in roasting Potsdam ores, ranging from 0.72 to 5.20 ounces gold and from 0.87 to 58.52 ounces silver per ton, was after 20 minutes, 5.281 per cent. gold and 4.074 per cent. silver, and after 60 minutes 11.446 per cent. gold and 8.438 per cent. silver.

The author suggests that the treatment of the gold precipitate obtained in chlorinating works might be modified and the tellurium saved. Ordinarily the precipitate is roasted and then melted with fluxes, causing loss of all the tellurium and a considerable percentage of gold. By treating the slimes with nitric acid, all loss may be avoided and the tellurium recovered from the solution.

The Use of the Tremain Steam Stamp with Amalgamation. By E. A. Sperry. *Trans. Am. Inst. Min. Eng.*, **26**, 545–553. —A description of the results obtained at the Cross mill, Gunnison County, Colo., with the stamp, the use of which is very limited in milling gold ores.

The Cyanide Process in the United States. By G. A. Packard. *Trans. Am. Inst. Min. Eng.*, **26**, 709–721.—The author, who has had considerable experience in the cyaniding of ores visited the leading works of the country, and reviews the present state of the process. The gold ores treated are low-grade, have with a few exceptions a siliceous gangue, and contain small percentages of base metal. With silver ores some good results have been obtained, although the time required and the large consumption of cyanide, as a rule, exclude this class of ores. Chlorination is a rival of cyaniding, and on account of the higher extraction of gold is more used, where proximity to a railroad permits the transportation of the large amount of chemicals required, *e. g.*, at the Golden Reward Mill, Deadwood, S. D., 35 versus 2½ pounds per ton. Amalgamation can compete with the cyanide process only when very finely divided gold ores are to be worked in pans. Then follow the practical details of the method of leaching, the manner of precipitating, the consumption of reagents, and the cost.

Solution and Precipitation of the Cyanide of Gold. By S. B. Christy. *Trans. Am. Inst. Min. Eng.*, **26**, 735-772.—This paper is a systematic study of the subject embodying a summary of the researches made by the author since 1891, and requires an extended review. As to the solution of gold in potassium cyanide, MacArthur held that Elsner's equation was wrong, while MacLaurin's investigations proved it to be correct and further showed that the rate of solubility went through a maximum in passing from concentrated to dilute solutions, which fact is explained by the decrease of solubility of oxygen in cyanide with the concentration of the latter. The author verified the necessity of the presence of oxygen, showing that with a limited air supply the solution stopped when the oxygen had been exhausted, and began again when it was supplied. He reasons that in the cyanide solution the oxygen and potassium cyanide may be present without acting one upon another until the gold is introduced, starting the reaction, when nascent cyanogen attacks the gold. The necessity of the presence of oxygen being proved, experiments were made with other oxidizing agents than the oxygen of the air, such as potassium chlorate, nitrate, permanganate, and ferricyanide as well as with the peroxides of barium, manganese, lead, and sodium. They all proved effective, potassium ferricyanide and the peroxides of sodium and manganese more so than the others. If cyanogen bromide be added to potassium cyanide, there are formed potassium bromide and cyanogen and this in the presence of gold and an excess of potassium cyanide gives potassium aurocyanide. It was found more convenient to add dilute bromine water to a cyanide solution than to use cyanogen bromide. It is essential in the use of these reagents that in the presence of an excess of potassium cyanide, they shall not be added faster than the cyanogen set free can combine with the gold; if this rule is not observed, the free cyanogen will be converted into paracyanogen and oxidized products which, being ineffective, simply diminish the amount of active reagent. Bromine and cyanogen bromide can be replaced by chlorine and iodine and their respective cyanogen compounds. Comparing chlorine, bromine and oxygen, weight for weight, 1 gram chlorine causes the solution of 2.45 grams gold, 1 bromine 5.52 gold, and 1 oxygen 24.5 gold; experiments proved that oxygen gave as good, if not better, results than chlorine and bromine, if properly applied, although the latter was more convenient, being more readily soluble in water. With low-grade ores and dilute solutions no additional oxidizing agent is required, if the solution be well aerated, unless the ore or the water contains some reducing agent; with rich ores and correspondingly stronger solutions, an artificial oxidizer may be of distinct advantage. The author experimented upon the solubility of sulphide, telluride, and antimonide of gold. As the sulphide cannot be produced in the dry way, sulphide prepared in the wet way served as a basis of the experiments. It was found to dissolve readily, more quickly in a concentrated than in a dilute solution. In the solution there was always found to be present potassium sulphide and sulphocyanate and in most cases suspended sulphur, which makes it probable that beside the potassium aurocyanide, there are formed in the solution potassium sulphide and free sulphur, the former acting upon the gold sulphide gives potassium aurosulphide and the sulphur set free from both reactions combines wholly or in part with potassium cyanide to sulphocyanate. Tellurides of gold and silver dissolve with the greatest difficulty, the probable reason for this being that the affinity of potassium for tellurium is much smaller than that of sulphur and that the tendency of tellurium to form tellurous acid retards the oxidation and thereby the solution. Antimonide of gold behaved in a way similar to telluride, white oxide forming in solution. In the study of the precipitation of gold from cyanide solutions the author found that the generally accepted statement that upon acidifying a solution of potassium aurocyanide with sulphuric acid a yellow precipitate of aurocyanide separated was only true when the solution had been evaporated down and become concentrated and that metallic gold was separated from this salt only by the strongest hot sulphuric acid. He believes that a compound $HAuCy_2$, aurocyanhydric acid, similar to the ferro- and ferri-cyanhydric acids is formed. Before accepting the existence of the new gold compound, he had thought that in an acidified cyanide solution the gold was kept dissolved by the liberated hydrocyanic acid and experimented to find, whether in driving off the hydrocyanic acid the gold could not be separated and at the same time the acid be recovered by passing over potash or lime, which readily absorb it. Upon acidifying a one per cent. solution no trace of hydrocyanic acid appeared, yet, when it was kept for weeks near caustic potash, this was found to have absorbed nearly all the acid. In order to accelerate the process, air and then the steam with air were blown through the solution, the hydrocyanic acid of which was reduced in 3 hours from 1 to 0.003 per cent. By using absorption towers, steam can be dispensed with in large scale work and if sufficient time be given, the absorption towers may not be necessary. From 80 to 90 per cent. of the acid was recovered in the laboratory experiment. In case a stock solution contained alkaline sulphides, these would have to be removed previous to acidifying by treatment with lead carbonate or sulphate. But even when the hydrocyanic acid had been reduced to 0.01 per cent., the solution containing as much as 0.1 per cent. of gold remained clear and the usual precipitants, oxalic acid, sulphurous acid, hydrogen sulphide, etc., failed to throw down any gold. An excess of silver nitrate, however, precipitated the gold completely, while lead and quicksilver nitrates did it only in part. Oxidizing agents, such as potassium permanganate, peroxides of manganese, and lead in acid solution facilitated the precipitation. In precipitating gold by filtering through charcoal, the author found that its power was very limited, as it took up not more than 0.2 per cent. gold, although within this limit it acted completely and promptly, but the presence of free potassium cyanide lowered the capacity; acidification raised it. The difficulty of recovering the gold from the charcoal puts it out of consideration for practical use. Precipitation with mercuric chloride was satisfactory only in the absence of free potassium cyanide and when the solution was brought to a boil, then a yellow cyanide of gold fell out which at a low red heat turned to pure gold. The mercury can be recovered from the filtrate by adding the requisite amount of potassium sulphide, and thus the cyanide in solution regenerated. Under-precipitation does no harm, as the solvent is used over again. For the reasons stated above, this precipitant can come into play only under very limited circumstances. As one of the requisites of all ore to be suited for the cyanide process is that it shall contain little or no soluble copper compounds, it seemed to the author that they might be used as precipitants. In immersing sheet-copper in a solution with 0.33 gram of gold, a light-yellow precipitate began to form in the liquid and only very little of it on the copper; after 3 days 75 per cent. of the gold had been precipitated, and after 11 days only 0.011 gram remained in solution. This, of course, was too slow for practical work. Experiments with copper sulphide stirred into the solution showed that if this was neutral and alkaline, two-thirds, and if acidulated with sulphuric acid, the whole of the gold was thrown down in a few hours. Cupric sulphide obtained in the wet way, precipitating one-fifth of its weight of gold, acted better than cuprous sulphide prepared in the dry way. Removal of free hydrocyanic acid, if in excess of 0.1 per cent., assisted the precipitation. From the precipitate the gold sulphide was dissolved with potassium sulphide after making alkaline. The gold from the solution could be recovered by electrolysis and the cupric sulphide freed from gold be ready to be used over again. Instead of stirring the copper sulphide into the solution this may be filtered through the sulphide; the author prefers the first procedure. Preparing cupric sulphide in the acidified solution by adding cupric sulphate and then hydrogen sulphide worked as satisfactorily as stirring in the sulphide. Provided the free hydrocyanic acid had been removed, 1 pound of copper as sulphate will precipitate 3.11 pounds of gold. In precipitating with copper compounds it was found that no copper whatever went into solution; this pointed to the solution that the precipitate was mainly a salt of the aurocyanhydric acid, either cuprous aurocyanide or the corresponding sulpho salt. The author then experimented with cuprous chloride and found that a white precipitate containing all the gold formed at once, the metallic copper present as cuprous chloride precipitating twice its weight of gold. All the cuprous salts were found to be effective, even cuprous cyanide. As the precipitate obtained by cuprous hyposulphite is soluble both in potassium cyanide and sodium hyposulphite, a complete precipitation can only be had from an acidified solution. The method employed by the author was to add sulphuric acid to the solution, to remove the hydrocyanic acid by aëration after, or by fine sulphate before acidifying, and then to precipitate with cuprous chloride prepared by adding salt to a cuprous sulphate solution and saturating with sulphurous acid. The precipitate, $CuAuCy_2$, is insoluble in dilute acids, readily so in potassium cyanide; the gold is easily extracted. The author then criticizes the de Wilde process. This consists (1) in leaching the ore with a 0.05 per cent. potassium cyanide solution containing about the same amount of soda or lime, (2) in recovering the excess of alkaline cyanide by neutralizing the free alkali and precipitating with ferrous sulphate, and (3) in precipitating the gold as aurous cyanide with cuprous cyanide, formed by introducing sulphurous acid and adding cupric sulphate. He found that the precipitate of ferrous cyanide was very bulky, took weeks to filter, and was constantly changing in composition, and argues that it is not an easy matter to extract the cyanide from the precipitate. While the precipitation of gold is sharp and complete, it takes a long time to form and to settle. He, therefore, prefers his method of making the cuprous salt outside of the solution with concentrated reagents, which works more quickly. In reviewing the precipitation of gold, by means of electricity, from a dilute solution with insoluble anode, the author argues that the great resistance can only be overcome by very large electrode surfaces and energetic artificial circulation, and that if all the gold is to be precipitated, this cannot be done without destroying most of the cyanide. Another disadvantage observed by the author is that gold is not only deposited on the cathode but also on the anode, and that a gold-bearing precipitate settles out from the electrolyte. An acidulated solution worked better than one that was neutral or alkaline, but the cyanide was destroyed unless special precautions were taken. The difficulties can be overcome, as in South Africa (see *this Rev.*, **2**, 102) but it requires great technical skill. The method in common use for precipitating gold is by means of metallic zinc, although it has the disadvantage of great consumption of zinc, unnecessary destruction of cyanide, loss in working the precipitate and the failure of the zinc in certain cases to throw down any gold at all. The excess of the consumption of zinc in practice over what is required theoretically (1 oz. Zn : $\frac{1}{8}$–$\frac{1}{16}$ oz. Au *vs.* 1 oz. Zn : 6.2 oz. Au) is explained by the solvent effect of the free alkali, the excess of potassium cyanide and the oxygen dissolved in the water ; the failure of zinc sometimes to precipitate gold is attributed to polarization and to the formation of a film of zinc cyanide in the absence of free potassium cyanide. The ordinarily accepted reaction,

$$2AuKCy_2 + Zn = K_2ZnCy_4 + 2Au,$$

does not explain the different phenomena. The author suggests that in the absence of free potassium cyanide the reaction is

$$4KAuCy_2 + 4Zn + 2H_2O = 2ZnCy_2 + ZnCy_2.2KCy + ZnK_2O_2 + 4H + 4Au,$$

and in the presence of free potassium cyanide,

$$2KAuCy_2 + 3Zn + 4KCy + 2H_2O = 2Au + 2(ZnCy_2.2KCy) + ZnK_2O_2 + 4H.$$

He then discusses the recovery of potassium cyanide from strong solutions of zinc sulphate, the precipitation of aurous cyanide by means of zinc chloride and oxychloride, gives the advantages of the method with cuprous salts and outlines the mode of operation. He concludes his splendid paper with some satisfactory results that he obtained in treating high-grade ores, while previously the process had been applied only to those of a low tenor and predicts a far greater field for the process than it occupies to-day.

Notes on the Cyanide Process. By J. E. Clennell. *Univ. Sci. Press*, 74, 256. This is an open letter addressed to Professor Christy reviewing the paper just abstracted, the criticisms being based on large-scale work and laboratory experiments made in South Africa.

Laboratory-Tests in Connection with the Extraction of Gold from Ores by the Cyanide Process. By H. Van F. Furman. *Trans. Am. Inst. Min. Eng.*, 26, 721–734.—The paper gives full details of the methods in common use to determine by preliminary treatment, whether an ore is suitable for the process or not, and to control the work in the mill. It embraces the character of ore; size to which it should be crushed; question of preliminary roasting; strength of solution; time of leaching; rate of percolation; testing of water to be used in the mill; determination of acidity; test for the consumption of cyanide; test for percentage of extraction; determination of the cause of cyanide-consumption; of the free potassium cyanide in solution; of the free hydrocyanic acid in solution; of the total simple cyanides in solution; of the ferro-, the ferri-, and the sulpho-cyanides in solution; of the zinc and lime in solution and of the gold and silver in solution. A useful abstract can not be made without reproducing nearly the entire paper.

The Value and Use of Aluminum, Manganese, and Silicon in the Brass Foundry. By F. J. Davis. *Aluminum World*, 3, 141–142.—The alloy of copper with from 10 to 11 per cent. aluminum is one of the strangest known, its tensile strength ranging from 80,000 to 90,000 pounds per square inch. It also has a high elastic limit, but a low percentage of elongation (5 per cent. in one inch). The presence of silicon increases its strength and hardness, but decreases its ductility. Of the brasses the one containing 3.50 per cent. aluminum, 33.3 per cent. zinc, the rest being copper, is the best and strongest, having a tensile strength of from 75,000 to 85,000 pounds per square inch. The addition of 0.1 per cent. silicon to melted copper before pouring makes the bath more fluid and gives clean and solid castings free from blow-holes. Silicon acts in a similar way upon brass and tin bronze mixtures. Two silicon-copper alloys (bronzes) are commonly used to-day, *viz.*, the alloy of 5 per cent. silicon and 95 per cent. copper, which is strong and tough, having a tensile strength of 75,000 pounds per square inch and 8 per cent. ductility, and the alloy of 3 per cent. silicon and 97 per cent. copper, which has a tensile strength of about 55,000 pounds per square inch and from 50 to 60 per cent. ductility. If more than from 5 to 5½ per cent. silicon be added to the copper it becomes brittle. Of the manganese bronzes free from iron, the one having the composition Cu 53, Zn 42, Mn 3.75, Al 1.25, makes a very strong and tough alloy, suited for propeller wheels, gears, etc., and for mining screens, as it is not attacked by acid mine waters. The alloy, Cu 67.25, Mn 18.50, Zn 13.00, Al 1.25 forms a good substitute for German silver.

Notes on Malleable Cast Iron. By G. C. Davis. *Am. Manuf.*, 60, 728, *and Iron Age*, 59, No. 19, 5.—From the examination of a large number of malleable castings the author comes to the following conclusions as to what their composition should be. Silicon should range from 0.60 to 0.90 per cent. ; if it runs below 0.50 per cent. the casting will be too tough ; if above 1 per cent., too brittle ; sulphur from 0.04 to 0.12 per cent. ; phosphorus from 0.15 to 0.22 per cent., a higher percentage making the casting brittle ; manganese from 0.20 to 0.40 per cent. ; the percentage of carbon varies with the cross-section of the casting and the time of annealing—thus, castings one-eighth inch thick to show 0.15 per cent. carbon, three-sixteenths—0.64 carbon, five-sixteenths—1.03 carbon, nine-sixteenths—1.58 carbon. The carbon is sometimes more completely removed than these figures indicate. The author obtained his samples for the determination of carbon by breaking the casting, filing across the fracture and collecting the filings on a sheet of paper.

ASSAYING.

H. O. Hofman, Reviewer.

An Improved Muffle. By A. S. Dwight. *Trans. Am. Inst. Min. Eng.*, 26, 992–994.—This muffle, devised by Mr. H. F. Wierum, assayer of the Colorado Smelting Co., Pueblo, Colo., has two sets of horizontal ribs on the inner sides, running from front to back, which serve to support a loose slab of burned fireclay used to regulate the heat of the different parts of the muffle.

Silver Losses in Cupellation. By L. D. Godshall. *Trans. Am. Inst. Min. Eng.*, 26, 473–484.—The silver losses in cupellation are due to absorption by the cupel and volatilization. The author has determined the combined loss from these two sources and studied the effects of a variable quantity of silver, of the weight of the lead button and the nature of the cupel. While the investigation is of much value as far as the commercial assay is concerned, it would have been of greater scientific interest if the temperatures had been measured and the speed of the air-current passing through the muffle determined.

GENERAL AND PHYSICAL CHEMISTRY.

A. A. NOYES, REVIEWER.

On the Permeation of Hot Platinum by Gases. BY WYATT W. RANDALL. *Am. Chem. J.*, 19, 682–691.—After giving a brief review of the previous work done on the permeation of metals by gases, the author describes the apparatus used in his own experiments. This consists of a platinum tube closed at one end, fitted into a hard-glass tube, and connected at its protruding open end with a Töpler pump and a sparking tube for examining the spectrum. The hard-glass tube and the platinum tube within it are heated to a white heat, a high vacuum is produced in the latter, and carefully dried hydrogen or other gas to be tested is passed through the outer tube. It was found that hydrogen passed through the platinum, though only very slowly, the pressure within the tube (total volume 100 cc.) increasing at the rate of a millimeter in 3–5 minutes. The spectrum indicated that the hydrogen which had passed through the platinum was perfectly pure. On the other hand, when the platinum tube was surrounded with dry air, the vacuum within could be maintained indefinitely. Like oxygen and nitrogen, methane seemed to have no power whatever of permeating the metal.

The Atomic Mass of Tungsten. BY WILLET LEPLEY HARDIN. *J. Am. Chem. Soc.*, 19, 657–676.—The author has investigated the methods commonly employed in determining the atomic weight of tungsten, consisting in the reduction of its trioxide by hydrogen, and in the reoxidation of the metal by ignition in the air. The results are given of sixty-four determinations made with the material from different sources. From the discordant results obtained, the author concludes that the method is unsatisfactory, and that this may be due to the action of the substance on the vessel in which it is ignited, to loss mechanically or by volatilization, or to the presence of nitrogen as impurity, all of which sources of error were demonstrated to be actually present.

Mass Law Studies, III. BY S. F. TAYLOR. *J. Phys. Chem.*, 1, 542–546.—See *this Rev.*, 3, 75, 122.

Solubility of Solids in Vapors. BY J. M. TALMADGE. *J. Phys. Chem.*, 1, 547–554.—The author has determined at different temperatures the partial vapor-pressures of naphthalene and camphor in their saturated solutions in ether, acetone, methyl alcohol, and ethyl alcohol. He concludes from his experiments that the partial pressures are different for the different solvents, and that in the case of camphor at least the values are greater than those belonging to the pure substance at the same temperatures. However, as no check determinations are given, it is impossible to judge of the accuracy of the results. Those in the case of naphthalene in ether differ enormously from those of Benedict, previously obtained in the same laboratory. See *this Rev.*, 3, 75.

Comment on the Note of R. Franchot Entitled "Nascent Hydrogen." By D. Tommasi. *J. Phys. Chem.*, 1, 555.—A claim for priority.

Note. By Wilder D. Bancroft. *J. Phys. Chem.*, 1, 556.—Remarks on the preceding note.

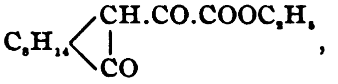
On the Speed of Reduction of Ferric Alum by Sugar. By J. H. Long. *J. Am. Chem. Soc.*, 19, 683–698.—The author determines the rate at which sugar reduces ferric alum by measuring the increase in electrical conductivity which the mixed solutions undergo, and comparing this with that of solutions containing the reaction-products at known concentrations. The results show that the velocity of the reaction is proportional to the amount of sugar present. The author assumes that very little sugar is used up by the reduction, and that therefore its amount remains practically constant during each series of experiments, so that the concentration of the ferric salt alone varies; and he calculates accordingly the constants of the first order. These are found to increase with the progress of the reaction, the acceleration being attributed to the free acid gradually produced by the reaction. The theoretical equation which should express this effect is not that given by the author, but the following one: $\frac{dx}{dt} = (K + K'x)(A - x)$, in which K' is a second constant representing the increase in the reaction-constant K, caused by acid of unit concentration.

Early American Chemical Societies. By H. Carrington Bolton. *J. Am. Chem. Soc.*, 19, 717–732.—The article is a description of three chemical societies founded in the United States in 1792, 1811, and 1821, respectively.

ORGANIC CHEMISTRY.

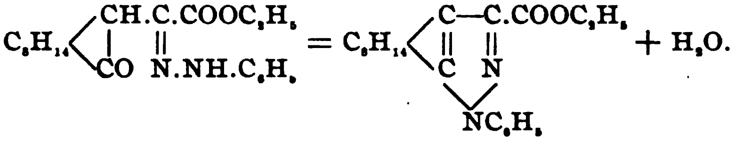
J. F. Norris, Reviewer.

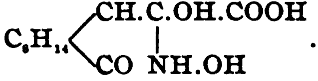
The Action of Ethylic Oxalate on Camphor (II). By J. Bishop Tingle. *Am. Chem. J.*, 19, 393–410.—In order to throw some light on the structure of the 1, 3-diketones and keto-acids, the author has undertaken a further study of ethyl camphoroxalate, which was prepared by him a few years ago (*J. Chem. Soc.*, 57, 652). Although the results do not establish the correctness of the carbonyl or hydroxyl formula, they are published in order to reserve the field. Ethyl camphoroxalate,



$$C_8H_{14}\left\langle\begin{array}{l}CH.CO.COOC_2H_5\\ |\\ CO\end{array}\right. ,$$

is best prepared by the action of sodium on a mixture of camphor and ethyl oxalate dissolved in ligroïn. It does not form a copper salt, is quickly decomposed when heated, and in presence of alkali is rapidly hydrolyzed. A hydrazone is readily formed which loses water and gives ethyl camphylphenylpyrazolecarboxylate,



From the latter ester the acid can be easily formed. Camphoroxalic acid can be boiled with concentrated alkali without decomposition. With hydroxylamine at ordinary temperature, in presence of acid sodium carbonate, it yields an addition-product, $C_{12}H_{16}O_4.NH_2OH$. The formation of this favors the hydroxyl formula for the free acid since it is scarcely to be expected that hydroxylamine would yield an addition-product with a substance containing two carbonyl groups. The formula of the compound is, consequently,  $C_8H_{14}\left\langle\begin{array}{l}CH.C.OH.COOH\\ \qquad\;\; |\\ CO\;\; NH.OH\end{array}\right.$. The correctness of this view is further established by the production of camphylisoxazole, , when the compound containing hydroxylamine is heated. The preparation and properties of the above bodies are described in detail.

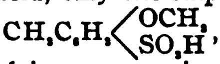
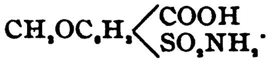
On the Molecular Rearrangement of the Oximes by Means of Certain Metallic Salts. By William J. Comstock. *Am. Chem. J.*, 19, 485–492.—Cuprous chloride, cuprous bromide, and antimony trichloride effect the Beckmann rearrangement of the oximes. When a cold concentrated solution of benzaldoxime in dry benzene was treated with cuprous chloride, the latter dissolved and an addition-product separated, crystallizing in colorless needles. Its formula was $(C_6H_5CH.NOH)_2CuCl$, but the antioxime was changed into its stereoisomer. When a benzene solution of the addition-product was boiled, cuprous chloride precipitated and benzamide was obtained from the filtrate. By a study of the action of cuprous chloride and bromide on benzaldoxime, cinnamaldoxime, oenanthaldoxime, acetoxime, acetophenoneoxime, and benzophenoneoxime, it was shown that the formation of addition-products of the formula, $(\text{Oxime})_2 + CuCl$ or $CuBr$, is general. The rearrangement into amide, or substituted amide, by boiling a solution of the cuprous-halide-oxime is not, however, a general reaction and when effected is not a smooth one. When the solution is boiled, there is usually, to some extent, a regeneration of aldehyde or ketone. When a saturated aqueous solution of benzaldoxime or acetoxime was treated with a solution of cupric chloride, the cuprous addition-product separated. A part of the acetoxime was split into acetone and hydroxylamine, which was oxidized to nitrous acid by the cupric chloride. Benzophenoneoxime was changed to benzanilide by antimony trichloride.

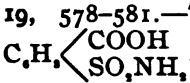
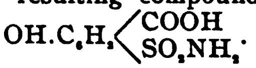
The Action of Urea and Primary Amines on Maleic Anhydrides. By Frederic L. Dunlap and Isaac Phelps. *Am. Chem. J.*, **19**, 492–496.—In a former article (*Am. Chem. J.*, **18**, 333) a method was described for the preparation of imides by the action of urea on the anhydrides of dibasic acids. It was shown that the formation was to be explained by the addition of urea to the anhydride to form an acid which, when heated, decomposed, yielding an imide, carbon dioxide, and ammonia. Maleüric acid, $HOOC.CH{=}CH.CO.NH.CO.NH_2$, has now been prepared in this way, but when heated it did not yield sufficient imide for identification. Following the method of Anschütz (*Ber. d. chem Ges.*, **20**, 3214) the following compounds have been prepared by the action of primary amines on maleïc anhydride: *p*- and *o*-tolylmaleämic acids $HOOC.CH{=}CH.CO.NHC_6H_4CH_3$, and α- and β-naphthylmaleämic acids, $HOOC.CH{=}CH.CO.NHC_{10}H_7$.

On the Isomeric Chlorides of *p*-nitro-*o*-Sulphobenzoic Acids. By Ira Remsen and G. W. Gray. *Am. Chem. J.*, **19**, 496–512.—The results obtained in the investigation of the chlorides of orthosulphobenzoic acids (*Am. Chem. J.*, **17**, 309, 311, 330, 347; and **18**, 791, 794, 809, 818) have led the authors to undertake a study of the corresponding chlorides of *p*-nitro-*o*-sulphobenzoic acid. With the latter acid the separation of the isomeric chlorides is easier. This is effected as follows: A chloroform solution of the mixed chlorides, prepared by the action of phosphorus pentachloride on the acid potassium salt, is allowed to evaporate spontaneously, when the symmetrical chloride, $C_6H_3NO_2\left\langle\begin{matrix}COCl\\SO_2Cl\end{matrix}\right.$, crystallizes in monoclinic (?) pinacoids and basal planes. When no more crystals can be obtained, the solvent is evaporated off and the resulting oil dissolved in petroleum ether, from which the unsymmetrical chloride, $C_6H_3NO_2\left\langle\begin{matrix}CCl_2\\SO_2\end{matrix}\right\rangle O$, crystallizes in fine white needles or plates. The action of ammonia is analogous to that on the chlorides of orthosulphobenzoic acid. The symmetrical yields the ammonium salt of the imide, $C_6H_3NO_2\left\langle\begin{matrix}CO\\SO_2\end{matrix}\right\rangle N.NH_4$, and the unsymmetrical the ammonium salt of a cyan acid, $C_6H_3NO_2\left\langle\begin{matrix}CN\\SO_2ONH_4\end{matrix}\right.$. From these ammonium salts the corresponding silver, potassium, barium, calcium, magnesium, and zinc salts were prepared. The methyl and ethyl salts of the sulphinide and the free paracyanbenzenesulphonic acid, with its chloride and amide are described.

A Study of the Action of the Nitrate and Sulphate of Paradiazotoluene on Methyl Alcohol under Various Conditions. BY WILLIAM E. CHAMBERLAIN. *Am. Chem. J.*, 19, 531–547.—From a study of the action of methyl alcohol on the sulphate and nitrate of paradiazotoluene the conclusion is drawn that under atmospheric pressure the alkoxy reaction takes place almost entirely. With the nitrate, lowering of temperature and pressure favors the hydrogen reaction, whereas, under the same conditions, the sulphate gives a better yield of the alkoxy product. When the decompositions were effected in the presence of sodium methylate, potassium hydroxide, potassium carbonate, or zinc dust, the hydrogen reaction alone took place. When zinc oxide was used the temperature of reaction was higher and both hydrogen and the methoxy group were introduced. It follows, therefore, that the presence of alkaline substance to neutralize the acid set free and a low temperature favor the hydrogen reaction. When paradiazotoluene was decomposed with methyl alcohol some dinitroparacresol was formed. This was shown to be due to the action of the nitric acid set free upon the chief reaction-product, paracresol methyl ether, nitration and saponification taking place at the same time. This saponifying action of dilute nitric acid is unusual and took place only during nitration, as dinitrocresol ethyl ether was not saponified by long boiling with dilute nitric acid.

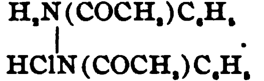
The Reaction of the Salts of Nitrodiazobenzene and the Diazobenzoic Acids with Methyl Alcohol. BY GEORGE F. WEIDA. *Am. Chem. J.*, 19, 547–561.—The following facts were established by a study of the decomposition with methyl alcohol of the diazo compounds obtained from the three nitranilines and the three aminobenzoic acids. Orthonitrodiazobenzene sulphate yields nitrobenzene as the only reaction-product that can be isolated; para- and metanitrodiazobenzene nitrates yield mostly nitrobenzene, and some nitranisol. The salts of the diazobenzoic acids all yielded as the principal product of reaction the ethereal salts of the corresponding methoxy acids; with the nitrate of the ortho acid some nitrosalicylic acid, with the sulphate of the ortho acid some methyl benzoate, and with the nitrate of the para acid some free anisic acid are obtained.

A Study of the Action of Methyl Alcohol on the Sulphate of Orthodiazotoluene. BY WILLIAM BROMWELL. *Am. Chem. J.*, 19, 561–578.—The author comes to the following conclusions from a study of the action of methyl alcohol on the sulphate of orthodiazotoluene: (1) Orthodiazotoluene sulphate is decomposed by methyl alcohol at a lower temperature than the corresponding para compound. (2) When decomposed under atmospheric pressure it gives almost exclusively the alkoxy reaction. (3) Whether decomposition takes place slowly at the temperature of the room or rapidly at a temperature near the boiling-point of the alcohol, the yield of the methoxy product is the same. (4) When orthomethoxytoluene is treated with cold concentrated sulphuric acid, only one sulphonic acid is formed, which has the formula  $CH_3C_6H_3\left<\begin{matrix}OCH_3\\SO_3H\end{matrix}\right.$, and which forms well-characterized barium, calcium, magnesium, zinc, copper, lead, sodium, and potassium salts. (5) Methoxytoluenesulphonic acid forms a chloride and an amide which is oxidized by potassium permanganate to the acid  $CH_3OC_6H_3\left<\begin{matrix}COOH\\SO_2NH_2\end{matrix}\right.$.

On the Action of Potassium Hydroxide on Orthomethoxysulphaminebenzoic Acid. BY CHARLES WALKER. *Am. Chem. J.*, 19, 578–581.—The methoxysulphaminebenzoic acid,  $CH_3O.C_6H_3\left<\begin{matrix}COOH\\SO_2NH_2\end{matrix}\right.$, obtained by Bromwell (preceding review) was fused with potassium hydroxide, in order to establish its constitution. This was not determined, as the sulphamine group remained intact, the resulting compound being orthoxysulphaminebenzoic acid,  $OH.C_6H_3\left<\begin{matrix}COOH\\SO_2NH_2\end{matrix}\right.$. Its barium, calcium, sodium, and silver salts were prepared. When heated with hydrochloric acid in a sealed tube salicylic acid was obtained.

Aluminum Alcoholates. By H. W. Hillyer. *Am. Chem. J.*, 19, 597–603.—In a former paper the author showed (*Am. Chem. J.*, 19, 37) that aluminum alcoholates were formed by the action of aluminum on alcohols in the presence of certain anhydrous chlorides. When absolute alcohol is poured on chipped aluminum and either platinic, mercuric, or stannic chloride added, hydrogen is evolved and a rapid deposition of metal takes place with rise in temperature. A large amount of aluminum is dissolved, and a pasty reaction-product, an alcoholate, is formed. The addition of a saturated solution of hydrochloric acid in alcohol produces the same effect as the metallic chloride. The best yields are obtained when a small amount of an alcoholic solution of stannic chloride is added to the absolute alcohol containing the aluminum. Methyl alcohol acted as above, but the resulting compound could not be isolated, as it decomposed on distillation. Considering the fact of the evolution of hydrogen rather than a hydrocarbon, and the presence of aluminum in solution in a form not the chloride, the reaction can best be explained as follows: $2Al + 6CH_3OH = 2Al\,(OCH_3)_3 + 3H_2$. Aluminum propylate was isolated by fractional distillation and analyzed. Amyl alcohol also furnished a volatile compound, but aluminum isopropylate decomposed before distillation. The nascent hydrogen formed in this reaction furnishes a method of reduction in the entire absence of water.

Behavior of Chloral Hydrate with Ammonium Sulphide. By Joseph Lesinsky and Charles Gundlich. *Am. Chem. J.*, 19, 603–606.—A precipitate of unknown composition was formed by the action of yellow ammonium sulphide on a solution of chloral. By varying the concentrations of the solutions the color of the precipitate varies from pink to yellow and changes to brown or black on heating. The time required for precipitation decreases as the temperature increases. The authors propose to study the reaction more carefully and to use it in testing the purity of chloral hydrate.

On Halogen Addition-Products of the Anilides. By H. L. Wheeler, Bayard Barnes, and J. H. Pratt. *Am. Chem. J.*, 19, 672–682.—Wheeler and Walden (*Am. Chem. J.*, 18, 85) showed that the anilides form perhalides, and it was concluded that the compounds are analogous to the perhalides of caesium and ammonium. In order to test the correctness of this view a crystallographic study of some organic and inorganic perhalides has been made. As ammonium triiodide is analogous to the perhalides of the alkali metals and shows no crystallographic analogy to the derivatives of the anilides it is concluded that it differs from the latter in structure. The view is strengthened by the fact that all of the organic perhalides are formed from salts containing two molecules of the anilide and one of the halogen acid. Perhalides from the 1 : 1 salts have not been prepared. The most probable structure of the salt $(CH_3CO.NHC_6H_5)_2.HCl$ is  $\begin{array}{l} H_2N(COCH_3)C_6H_5 \\ | \\ HClN(COCH_3)C_6H_5 \end{array}$. The perhalides are thought to be addition-products of compounds with this diammonium structure. Another striking difference between the alkali and anilide perhalides is the ease with which the latter can be obtained containing two halogens. A large number of salts and mixed perhalides of acetaniline and methyl metanitroacetanilide were prepared and studied crystallographically. It is shown incidentally that formanilide forms the salt $(HCO.NHC_6H_5)_2.HCl$, and therefore acts like a true anilide, whereas, if it had the imido structure, the hydrochloride should be a 1 : 2 salt.

On Some Malonic Acid Derivatives. By Richard S. Curtiss. *Am. Chem. J.*, 19, 691–702.—Ethylanilido malonate, $C_6H_5NH.CH(COOC_2H_5)_2$, was formed when bromethyl malonate was treated with aniline. It gives a crystalline compound with hydrochloric acid gas, a sodium salt with sodium ethylate, a bromine addition-product, and reduces ammoniacal silver nitrate in the cold. When oxidized with mercuric oxide ethyldianilido malonate, $(C_6H_5NH)_2C(CO_2C_2H_5)_2$, is formed. The same compound was prepared from dibromethyl malonate and aniline. Sodium ethylate and dibromethyl malonate gave a complex mixture from which ethyl diethoxymalonate $(C_2H_5O)_2C(CO_2C_2H_5)_2$ was isolated by fractional distillation.

The Action of Nitric Acid on Triphenylmethane. By E. S. Smith. *Am. Chem. J.*, 19, 702.—In an attempt to make trinitrotriphenylmethane by the action of fuming nitric acid on triphenylmethane, triphenylcarbinol was obtained. It was impossible to discover the exact conditions necessary, as repetition of the work always yielded the usual nitro derivatives.

Halides and Perhalides of Pyridine. By P. F. Trowbridge and O. C. Diehl. *J. Am. Chem. Soc.*, 19, 558–574.—This is a continuation of a paper recently reviewed (*this Rev.*, 3, 112). Reference must be made to the original article for a description of the large number of compounds prepared.

ANALYTICAL CHEMISTRY.

ULTIMATE ANALYSIS.

H. P. TALBOT, REVIEWER.

A Modification of the Permanganate Method for the Determination of Iron. BY HAMILTON P. CADY AND ALFRED P. RUEDIGER. *J. Am. Chem. Soc.*, 19, 575–581. The reducing action of hydrochloric acid upon potassium permanganate during an iron titration may be prevented by the introduction into the solution of mercuric sulphate. The mercury ions at once tend to unite with the chlorine ions of the hydrochloric acid to form mercuric chloride, and this slightly ionized compound does not influence the permanganate. The results which the authors obtained by this modification of the permanganate process are satisfactory.

Notes on the Determination of Insoluble Phosphorus in Iron Ores. BY CHARLES T. MIXER AND HOWARD W. DUBOIS. *J. Am. Chem. Soc.*, 19, 614–619.—The authors determine the soluble phosphorus in a solution of the ore obtained by treatment with hydrochloric acid (sp. gr. 1.10). The insoluble residue is filtered, dried, and ignited for a short time at a red heat, after which the remaining phosphorus may be readily extracted by dilute acid. Analyses of the insoluble residues indicate that the phosphorus is probably in combination with alumina.

A Further Communication on the Estimation of Phosphoric Acid by Titration of the Ammonium Phosphomolybdate Precipitate with Standard Alkali. BY B. W. KILGORE. *J. Am. Chem. Soc.*, 19, 703–711.—Two main objections have been raised to the adoption of this method as an official procedure; *viz.*, insufficient proof of its applicability to various sorts of fertilizer material, and the difficulty in removing all the acid from the precipitate. The first objection the author meets by presenting satisfactory analyses of a wide variety of materials, made by this procedure; the supposed difficulty in washing the precipitate the author believes to be apparent rather than real.

The Exact Dilution of Liquids by Formula. BY CHAS. D. HOWARD. *J. Am. Chem. Soc.*, 19, 587.

W. H. WALKER, REVIEWER.

A New and Rapid Method for the Qualitative Separation of Iron, Aluminum, Chromium, Manganese, Zinc, Nickel, and Cobalt. BY ALEXANDER RAMSAY CUSHMAN. *Am. Chem. J.*, 19, 606–607.—This separation is based upon the behavior of the above metals with bromine water, first in the presence of strong aqueous ammonia, by which the iron, manganese, chromium, and aluminum are separated from the zinc, nickel, and cobalt, and later in the presence of an excess of potassium hydrate, which separates the iron and manganese from the aluminum and chromium. The further separation and identification of the metals is carried out in the main according to well-known procedures. No provision is made for the detection of the alkaline earth phosphates, which may be thrown down with the ammonium sulphide precipitate, and this the reviewer thinks must seriously limit the general application of the method.

The Actual Accuracy of Chemical Analyses. By F. P. Dewey. *Trans. Am. Inst. Min. Eng.*, **26**, 370–379.—This paper does not consider ways and means for the increase of analytical accuracy, nor the question of what could or should be attained in this direction; it is an extensive résumé of the results exhibited in actual every day practice, and does not admit of a brief review.

Titration of Sodium Thiosulphate with Iodic Acid. By Claude F. Walker. *Am. J Sci.*, **154**, 235–242.—The nature of the reaction between thiosulphuric acid and iodic acid is here studied to determine the expediency of using one acid in standard solution for the direct titration of the other. It has been stated that when sodium thiosulphate is titrated with iodic acid, the reaction takes place according to the equation:

$$6Na_2S_2O_3 + 6HIO_3 = 3Na_2S_4O_6 + 5NaIO_3 + NaI + 3H_2O.$$

Under these conditions no free iodine will be liberated until all the thiosulphate has been oxidized; the first drop of iodic acid in excess, however, will liberate iodine according to the equation:

$$5NaI + 6HIO_3 = 5NaIO_3 + 3H_2O + 3I_2,$$

thus furnishing an end-point. The results of many titrations made during this investigation are tabulated and show that the reaction does not always take place according to the above equations, but that "it is so indefinite in its nature and so dependent for its completeness on conditions of time, dilution, and mass that its direct application as a means of standardizing solutions must remain impracticable."

ASSAYING.

H. O. HOFMAN, REVIEWER.

The Assay by Prospectors for Auriferous Ores and Gravels by Means of Amalgamation and the Blow-Pipe. BY W. H. MERRITT. *Trans. Am. Inst. Min. Eng.*, **26**, 187–192.—The method recommended by the author is similar to that used by Leonard (*this Rev.*, **2**, 75); it is the one taught in the prospector-classes of the School of Mines, Kingston, Ont. The ore having been sampled down to 2 pounds is ground to pass a 40 or 60-mesh sieve, transferred to a mortar which has been charged with water, 1 ounce quicksilver, and a small amount of sodium amalgam, and rubbed with a wooden pestle. The pulp is transferred to a pan, and quicksilver concentrates and tailings are separated. The amalgam is retorted in a small cup-shaped vessel of Russia-iron, the quicksilver condensed in a hollowed-out potato, the spongy bullion from the cup mixed with lead, fused on charcoal and cupelled on a clay pipe, and the relative proportion of gold and silver estimated by the color. The balance used is one with a sliding weight weighing from 0.1 to 0.5 grain and costing $3.00. By taking as much as 2 pounds of ore for a test, the values of ores running as low as $3.60 in free-milling gold can thus be approximately determined. The paper closes with a detailed description of the apparatus required and its cost.

GEOLOGICAL AND MINERALOGICAL CHEMISTRY.

W. O. CROSBY, REVIEWER.

On the Identity of Chalcostibite (Wolfsbergite) and Guejarite, and on Chalcostibite from Huanchaca, Bolivia. BY S. L. PENFIELD AND A. FRENZEL. *Am. J. Sci.*, **154**, 27–35.—This paper is the record of an elaborate chemical and crystallographic investigation based upon all the available material from various sources; and the authors have conclusively demonstrated that we have in this rare sulphide of antimony and copper but one mineral species, for which the chemically descriptive name chalcostibite has priority.

Native Iron in the Coal Measures of Missouri. BY E. T. ALLEN. *Am. J. Sci.*, **154**, 99–104.—Three occurrences of the native iron, in as many different counties, are described. It was found in each instance in drilling through the Coal Measure sandstone, at depths of 35, 37, and 51 feet. The iron appears to occur in more or less continuous masses in the solid rock, offer-ing great resistance to the drill, and the samples obtained consist chiefly of fragments detached from these masses in drilling, the largest weighing 45 grams. The analyses show: iron, 97.10 to 99.39; silica (originally from the sandstone), 0.31 to 1.65; phosphorus, 0.13 to 0.207; and traces of carbon. These irons are undoubtedly of terrestrial origin, and were certainly not derived from the drills. They are characterized by exceptional softness, and are attributed to the reducing action of the carbonaceous matter of the enclosing formation. The complete absence of nickel, so characteristic of meteoric irons, confirms this theory of their origin.

On Bixbyite, a New Mineral, and Notes on the Associated Topaz. BY S. L. PENFIELD AND H. W. FOOTE. *Am. J. Sci.*, **154**, 105–108.—The bixbyite, named after the discoverer, occurs sparingly on the border of the desert in Utah, and is attributed to fumarole action. The mineral is isometric, metallic, brilliant-black, with black streak, hardness 6 to 6.5, and specific gravity 4.945. The average of two analyses gave: SiO_2, 1.21; Al_2O_3, 2.53; Fe_2O_3, 47.98; TiO_2, 1.70; MnO, 42.05; MgO, 0.10; available oxygen, 4.38; total, 99.95. The silica and alumina are regarded as impurities. Neglecting these, two formulas are possible: R_2O_3, where $R = Fe$, Mn, and a little Ti; or $FeO.MnO_2$. The latter best accords with the isometric crystallization, and suggests relationship to the isometric species perofskite, $CaO.TiO_2$, and after further discussion of the analyses the conclusion is reached that the mineral really is $FeO.MnO_2$, in which small quantities of MgO and MnO are isomorphous with FeO and a little TiO_2 with MnO_2. In other words, it is a ferrous salt of manganous acid, H_2MnO_3, corresponding to braunite, $Mn.MnO_3$. The associated topaz is described crystallographically, but was not analyzed.

Note Concerning the Composition of Ilmenite. BY S. L. PENFIELD AND H. W. FOOTE. *Am. J. Sci.*, **154**, 108–110.—The existence of a molecule $R^{II}O.R^{IV}O_2$ in bixbyite and perofskite brings to mind the views concerning the composition of ilmenite. One of these is that the mineral is $RO.TiO_2$ ($R = Fe$ and Mg); the other, that it is R_2O_3, or an isomorphous mixture of Fe_2O_3 and Ti_2O_3. Crystallographically, ilmenite is not intermediate between hematite and artificial Ti_2O_3, as the second formula would require; and the formula fails to account for the MgO in almost all the ilmenites that have been analyzed. Rammelsberg found 13.71 per cent. MgO in an ilmenite from Warwick, N. Y.; and this high value having been questioned, the analysis was repeated by Foote, and 15.97 per cent. MgO obtained. In the two analyses the ratio of $RO_2 : RO$ is very close to 1 : 1, thus indicating the existence of the molecule $RO.TiO_2$, where $R = Fe$ and Mg.

Igneous Rocks of the Leucite Hills and Pilot Butte, Wyoming. By Whitman Cross. *Am. J. Sci.*, 154, 115–141.—This paper is a detailed petrographic description of leucitic lavas occurring in the forms of plugs or volcanic necks and surface flows, and the author differentiates what has hitherto been regarded as one type under the names *Wyomingite*, *Orendite* and *Madupite.* Chemical analyses of these types, together with analyses of some of their constituent minerals, and of the leucitic lavas of Montana (leucitite and missourite), are given in tabular form and are remarkable for their complexity, more than twenty-five elements occurring in determinable amounts. In the discussion of the analyses it is noted that TiO_2, Cr_2O_3, BaO, and Fl are found chiefly in the phlogopite, that the sulphuric acid indicates the occurrence of noselite in the rock, and that these lavas are exceptionally rich in P_2O_5. The most striking fact revealed by the analyses is the almost identical chemical constitution of two rocks, one rich in leucite and free from sanidine (wyomingite), the other with predominant sanidine (orendite). The conclusion that the chemical composition of a magma does not alone determine whether leucite or sanidine shall be formed, but that this is controlled by conditions of consolidation, is unavoidable. From the analyses the proportions of the component minerals in each rock are computed ; and after a discussion of the classification, nomenclature, and magmatic relations of these lavas, the paper concludes with an account of some interesting inclusions, and the action of the magma upon them. A rather unique, though quite incidental, mineralogical feature of these masses of lava is the occurrence in sheltered cavities and recesses of notable developments of nitre, which proves, on analysis, to be potassium nitrate in some cases and sodium nitrate in others. Although the nitric acid is most probably of organic origin, the potash and soda are supposed to have been derived directly from the adjacent volcanic rock.

GENERAL AND PHYSICAL CHEMISTRY.

H. M. Goodwin, Reviewer.

Relations between the Melting-Points and the Latent Heats of Fusion of the Metals. By Joseph W. Richards. *J. Franklin Inst.*, 143, 379–383.—In 1893 the author pointed out that the latent heat of fusion of most metals is approximately one-third of the total heat required to heat them from —273° to their melting-points. As more recent observations have confirmed this relation, the author has collected all data bearing on this subject, and he points out the limits within which the rule apparently holds true. With the exception of bismuth, tin, gallium, and aluminum, the agreement is striking. The first two of these metals Pictet also found to be exceptions to his rule that the absolute melting-point of an element is inversely proportional to its coefficient of expansion, a, and to the cube root of its atomic volume, V; that is, $T = \frac{4.5}{a\sqrt[3]{V}}$. Aluminum, too, is known to be anomalous in many of its properties.

If the specific heat be assumed nearly constant from —273° to 100°, then the total heat contained in an atomic weight of any metal at its melting-point will be approximately $6.4T$ (Dulong and Petit's Law). Hence, according to the author's relation between latent heat and total heat, the latent heat of fusion (L) of one atomic weight of a metal will be $2.1\ T$. Combining this with Pictet's formula given above, we get $L = \frac{9.5}{a\sqrt[3]{V}}$. Using Pictet's values of $a\sqrt[3]{V}$, the agreement between the computed and observed values of L is (with the exception of aluminum) within the limits of error of the data used for comparison.

On the Second Differential Coefficients of Gibb's Functions ζ. The Vapor Tensions, Freezing- and Boiling-Points of Ternary Mixtures. By W. Lash Miller. *J. Phys. Chem.*, 1, 633–642.—The author discusses the physical interpretations which μ may have in the equations

$$\left(\frac{d\mu_1}{dm_2}\right)_{t,p,m_1m_3\ldots\ldots} = \left(\frac{d\mu_2}{dm_1}\right)_{t,p,m_2m_3\ldots\ldots} = \text{etc.},$$

these equations being delivered by partial differentiation of Gibbs ζ function, the order of differentiation being immaterial. The phenomena with ternary mixtures, observed by McIntosch, Bancroft, and others, are shown to be in agreement with conclusions to be drawn from the above relations.

The Specific Gravities of Water Solutions of Formic Acid. By Geo. M. Richardson and Pierre Allaire. *Am. Chem. J.*, 19, 149–151.—A table is given showing the specific gravity of seventy-one formic acid solutions varying in concentration from pure acid to a 0.6 per cent. solution. The determinations were made with a picnometer at 20° C. Special attention was given to the purity of the acid.

Some Boiling-Point Determinations. By H. J. Steuber. *J. Phys. Chem.*, 1, 643–646.—The effect of the addition of sodium chloride and of sugar on the boiling-point of mixtures of alcohol and water was studied. In all cases a rise of boiling-point was observed, but this was less than that observed in water alone. The effect of the presence of alcohol was less, the greater the concentration of the solution with respect to the dissolved salt.

A New Method of Determining the Specific Heat of Liquids. By Robert L. Litch. *Phys. Rev.*, 5, 182–185.—The rise of temperature produced by a coil of wire placed in the liquid in the calorimeter is exactly compensated by the addition of a quantity m of cooler liquid of known temperature T_0 (approximately 0° C.). This is easily affected in a slightly modified form of Waterman's Calorimeter (see *this Rev.*, 3, 19). The heat H generated in the calorimeter is determined from measurements of the current, resistance, and time. The specific heat is then calculated from the equation $S = \frac{H}{m(T-T_0)}$, where $T-T_0$ is the difference between the temperature of the added liquid and that of the calorimeter. Preliminary results on water are given. These indicate a slight decrease in the specific heat between 18.8° and 21.2°. Further experiments are to be made with two calorimeters containing heating coils in series, the first calorimeter containing a liquid of known specific heat, and the second the liquid under examination. This latter method has the advantage of eliminating measurements of current and time.

Radiation in a Magnetic Field. By A. A. Michelson. *Astro-Phys. J.*, 6, 48–55.—The author has examined the phenomenon discovered by Zeeman with his very sensitive interferometer, and finds that in general the effect of the magnetic field is to separate rather than broaden the lines, and that the phenomenon is not of the nature of a reversal. Thus with sodium, the lines are doubled in a field up to about 2,000 C. G. S. units, the separation being nearly proportional to the strength of field. Beyond this point the components become broadened as well as separated with increased strength of field. The broadening effect was noticeable only when the pencil of light was at right angles to the field. The red cadmium line gave similar but even more pronounced results. The green and blue cadmium lines, and the green line of mercury, on the other hand, were both separated and broadened. The hydrogen, lithium, and thallium lines were but slightly affected by the magnetic field.

Changes in the Wave-Frequencies of the Lines of Emission-Spectra of Elements, Their Dependence upon the Elements

Themselves and upon the Physical Conditions under which They are Produced. By W. J. Humphreys. *Astro-Phys. J.*, 6, 169–233.—The principal results of this interesting investigation, carried out with the exceptional facilities for spectroscopic research of Prof. Rowland's laboratory, are embodied in the following summary: "1. Increase of pressure causes all isolated lines to shift towards the red end of the spectrum. 2. This shifting is directly proportional to the increase of pressure. 3. It does not depend upon the partial presence of the gas or vapor producing the lines but upon the total pressure. 4. The shift of the lines seems to be nearly or quite independent of temperature. 5. The lines of bands (at least of certain cyanogen and aluminum oxide bands), are not appreciably shifted. 6. The shifts of similar lines of a given element are proportional to the wave length of the lines themselves. 7. Different series of lines (as described by Kaysen and Runge) of a given element are shifted to different extents. When reduced to the same wave-length these shifts are to each other approximately as 1 : 2 : 4, respectively, for the principal first and second subordinate series. 8. Similar lines of an element, though not belonging to a recognized series, are shifted equally (when reduced to the same wave-length), but to a different extent than those unlike them. 9. Shifts of similar lines of differentsubstances are to each other, in such cases, as the absolute temperature of the melting-points of the elements that produced them. 10. The shifts of similar lines of different elements are to each other approximately as the products of the coefficients of linear expansion and cube roots of the atomic volumes of the respective elements (in the solid state) to which they are due. 11. Analogous or similar lines of elements belonging to the same half of a Mendelejeff group, shift proportionally to the cube roots of their respective atomic weights. 12. The lines of these substances, which in the solid form have the greatest coefficients of linear expansion, have the greatest shifts. The converse is also true. 13. The shift of similar lines is a periodic function of atomic weight, and consequently may be compared with any other property of the elements, which itself is a periodic function of their atomic weights." These conclusions are drawn from a careful study of a great many photographs of the arc spectra of the metals taken under varying conditions. The arc was enclosed in an air-tight box, the pressure in which could be varied and measured. A six-inch concave grating of twenty-one and a half feet focal length, ruled with 20,000 lines to the inch, was used. The author suggests several hypotheses of a kinetic nature to account for the shifting of the lines observed.

On the Conditions Required for Attaining Maximum Accuracy in the Determination of Specific Heat by the Method of Mixtures. By F. L. O. Wadsworth. *Am. J. Sci.*, **154**, 265–283.—This author gives a precision discussion of the formula for calculating specific heat by the method of mixtures, with special reference to the cooling correction as determined by the methods of Rumford, Jamin, Regnault, and Holman. This is followed by the description of a method by which the correction for radiation is wholly eliminated. It is essentially a perfection of Rumford's method, in which the temperature of the surroundings is so determined and adjusted before the experiment that the maximum temperature reached is that which the calorimeter would have attained had no loss by radiation occurred. Two preliminary series of measurements on the rate of cooling are necessary for the determination of the proper initial temperature of the surroundings. A modification of Regnault's apparatus is also described, by which the hot body is transferred in a little car sliding upon rails from the heater to the calorimeter, where it is dropped in by means of an ingeniously contrived trap. A convenient method of filling an ice calorimeter with water is described, and the advantage is pointed out of placing the calorimeter in a bottle containing partially frozen distilled water.

TECHNICAL CHEMISTRY.

F. H. Thorp, Reviewer.

System of Tanning in India. By K. E. Talati. *Leather Manufacturer*, **8**, 43.—This short article describes the crude process as carried on near Bombay. The hides are "limed," but not "bated." Ten days or more are required for liming, unhairing, and fleshing the skins. The tanning proper is done with a decoction of *acacia auriculata*, or turwar bark. The extract, at 12° Bk., is made with cold water, and the skins lie in the liquor ten days. They are then treated with stronger liquor for twelve days more. After removal from the bark solution, the hides are steeped four days in myrabolans liquor, made with hot water. They are then wrung and oiled with sesame oil or ground-nut oil; and are dried in the air.

New Method of Chrome Tanning. By Wm. M. Norris. *Leather Manufacturer*, **8**, 38–39.—The article is an abstract by the inventor of U. S. Patent No. 588,874. Metallic zinc is added to the reducing bath of sodium thiosulphate or sodium bisulphite. The free acid in the bath attacks the zinc and the hydrogen liberated converts the sulphurous acid into hyposulphurous acid, a more powerful reducing body.

Producing Fancy Leathers. By H. C. Standage. *Leather Manufacturer*, **8**, 22–23, 44–45.—This is a general description of the process of making Morocco and imitation Morocco leathers.

The Influence of the Gravity of Glycerine on the Yield of Nitroglycerine. By W. E. Garrigues. *Proc. Eng. Soc. Western Pa.*, 13, 265.—The author wished to determine whether variations of two or three units in the third decimal place of the specific gravity of glycerine, has any effect on the yield of nitroglycerine, when calculated from the actual quantity of glycerine nitrated. A series of experiments on four samples of glycerine of 1.2623, 1.2613, 1.2600, and 1.2572 sp. gr., respectively, where the percentage of glycerine varies from 99 to 97, show that the small quantity of water present has no practical effect on the yield of nitroglycerine. All samples were nitrated with the same acid mixture and under exactly similar circumstances. He concludes that with commercial glycerine above 1.257 sp. gr. or 97 per cent. glycerine, the value is exactly according to its percentage of strength. The details of the experiment are fully explained. The author also demonstrates that the yield may be influenced by the method of separating the acid and nitroglycerine. If separated by settling only, the yield is less than if the charge is "drowned" in an excess of water. But since the latter method gives a milky product, he intimates that the apparent increase may be due to absorbed water. The method of determining the specific gravity of glycerine by the use of the picnometer is also explained.

Softening Agents for the Production of Asphalt Cement for Paving and other Purposes. Chemical Constitution of Residuums and Malthas, and Its Relation to Water Action. Solubility of the Asphalt Hydrocarbons in Heavy Petroleum Oil. By Clifford Richardson. *Municipal Eng.*, 12, 343; 13, 1, 67.—These papers form a series of popular articles, containing some tables of the properties and composition of asphalts, malthas, and residuums.

How to Analyze Clay. By Holden M. Ashby. *Brick*, 7, 57, 113, 148.—This is a series of illustrated articles on the methods of analysis employed for clay. The articles are copyrighted and appear to be abstracts from notes prepared by the author for the use of students or others desiring instruction in chemical analysis as applied to clay alone.

Nitrosylized Blast Furnace Slag as an Addition to Hydraulic Cement. By A. D. Elbers. *Eng. Min. J.*, 63, 661, 364, 454. —To make "nitrosylized" slag, finely ground slag is moistened with weak nitric acid, water is added after the acid has become neutralized, and the leached mass is dried. Each 100 pounds of slag requires one-half pound of 60 per cent. (N_2O_5) acid and 30 pounds of water. The object is the removal of calcium sulphide from the slag. The "nitrosyl" (NO ?) set free by the action of the acid on the slag, is absorbed by the ferrous silicate in the slag, thus, it is supposed, rendering its silica more "disposed to sever its connection with the ferrous oxide and to become gelatinous when acted upon by the dissolved lime." It also prevents the formation of ferric hydrate, since the iron is rendered soluble and is washed away, while gelatinous silica deposits on the surface of the slag particles. Briquettes of slag, which had been treated thus, were tested in various ways; the author concludes, from the results, that ordinary and inferior Portland cements may be mixed with such slag, without diminishing their strength, but only small quantities should be added to high grade cements.

Composition and Formation of Tank Residues in Electrolytic Copper Refineries. By Edward Keller. *J. Am. Chem. Soc.*, 19, 778–782.

The Chemistry of the Pottery Industry. By Karl Langenbeck. *J. Franklin Inst.*, 143, 321.—The article represents a lecture given before the Institute. A few analyses are tabulated.

W. R. WHITNEY, REVIEWER.

The Manufacture and Applications of Lactic Acid. By A. A. Claflin. *Am. J. Pharm.*, 69, 599–604.—The paper contains extracts from the note-book of a chemist engaged in the manufacture of lactic acid. The process is the fermentation of glucose by the bacillus acidi lacti, which the author, by inadvertently omitting the prefix micro, describes as "averaging in length 2–2.5 millimeters." A saccharine solution containing 7.5 to 11 per cent. saccharine matter, of which 10–15 per cent. is advantageously cane sugar, is employed. The solution should also contain albuminoid matter and preferably a quantity equal to about 8 per cent. of the saccharine matter. After sterilization the solution is impregnated with the bacillus at 45°, below which temperature the fermentation takes place. Milk of lime is added from time to time to counteract the increasing acidity of the solution. To obtain the purest lactic acid, the calcium lactate is crystallized from the solution after the glucose is almost completely fermented, and the acid is obtained by distilling the salt with sulphuric acid.

Formaldehyde. By O. I. Affelder. *Proc. Eng. Soc. Western Pa.*, 13, 350–362.—This paper is divided into three parts entitled preparation, reactions, and determination. In the first part modifications of the method of Tollens are described. The methyl alcohol vaporized with air was passed through a heated iron pipe instead of glass, as described by Tollens. A table is given showing the effect of varying the rate of the air current which passes through the methyl alcohol. The maximum yield of aldehyde occurred when 0.7 cubic foot of air passed per hour. The effect of various temperatures of the iron pipe was also studied. It was found that below 250° C. little or no aldehyde is formed. At 350° a maximum is reached. A description of lamps to be used in forming aldehyde by combustion of the alcohol, with or without the use of gas, is given. The article is concluded with a very complete collection of the qualitative tests and methods of quantitative analysis of formaldehyde.

A. H. GILL, REVIEWER.

Certain Phenomena of Gas Explosions. BY W. H. BIRCHMORE. *Am. Gas Light J.*, **67**, 563–565.—The article deals with the explosion or combustion of mixtures of air and hydrogen, air and detonating gas, and air and acetylene. The experiments took place in a tube instead of a bulb; and in the case of the acetylene they are instructive as showing how the Paris explosion may have taken place. The article is written in a popular style and gives no experimental data.

Anhydrous Ammonia for Ice Machines. BY H. FAUROT. *Am. Gas Light J.*, **66**, 728.—The author recommends the testing of the liquid ammonia used for refrigeration. The common gaseous impurities are air and the constituents of illuminating gas. These can be detected by discharging the ammonia into water and analyzing the insoluble gases. The liquid impurities are water and oils; these are detected by allowing 50 cc. of the liquid to evaporate in a tube with a narrow graduated bottom, the volume of the residual liquid being noted. The boiling-point of commercial ammonia should not be higher than —28.6° F.

G. W. ROLFE, REVIEWER.

Spontaneous Combustion of Molasses. BY J. T. CRAWLEY. *J. Am. Chem. Soc.*, **19**, 538–542.—An account is given of an investigation into a curious case of spontaneous combustion of a tank of molasses at an Hawaiian sugar-house. The author found that fully eighty per cent. of the sugars in the molasses, besides most of the gums and mucilages, had been destroyed. He can give no satisfactory explanation of the cause of combustion, but is inclined to believe that the decomposition of the non-sugars may have much to do with it.

On the Use of Silico-Fluorides in Sugar Refining. By Walter Mills. *La. Planter and Sugar Mfgr.*, 19, 188–189.—The author attributes the failure of hydrofluosilicic acid as a refining agent to its inverting action ; and he recommends the use of the ammonium salt, which is free from this drawback and which, moreover, precipitates lime salts as well as the alkalies. The experiments of the author show that 34.8 per cent. of the ash is removed by this agent.

BIOLOGICAL CHEMISTRY.

W. R. Whitney, Reviewer.

The Action of Certain Bodies on the Digestive Ferments. By Frank D. Simons. *J. Am. Chem. Soc.*, 19, 744–754.—The bodies referred to are the common coloring matters, flavoring extracts, and preservatives. Among the most interesting results may be mentioned the discovery that peptic digestion is greatly retarded by picric acid, tropaeolin ooo, and metanil yellow, less so by salicylic acid and oil of wintergreen, and that pancreatic digestion is retarded by Bismarck brown, cinnamon, and formol.

The Amount and Properties of the Proteids of the Maize Kernel. By Thomas B. Osborne. *J. Am. Chem. Soc.*, 19, 525-532.—This is a continuation of the work of Chittenden and Osborne on the maize kernel. The article contains descriptions and analyses of the four fractions into which they had divided the proteid matter.

The Caffein Compounds of Kola. By J. W. T. Knox and A. B. Prescott. *Pharm. Rev.*, 15, 172–176; 191-196.--The recent literature of oak tannins is considered at length, after which a description of the methods used in preparing the free kola tannin, and of some of its chemical properties, is given. The second part of the paper contains the results of analyses of the kola tannin, its bromine and acetyl derivatives, and its several anhydrides. The methods of preparation of these compounds and their properties are given.

The Tannin of Castanopsis. By Henry Trimble. *Am. J. Pharm.*, 69, 406–408.—This relates to the nature of the tannin in the bark of a group of trees intermediate between oaks and chestnuts in character. The tannin of the American Quercus densiflora and the Castanopsis chrysophylla of this group were shown to be identical with the oak tannin. As the chestnut tannin differs from these, and is identical with galltannin, the above intermediate group partakes of the nature of oaks. A table giving the analyses of ten of these barks accompanies the article.

Aralia Nudicaulis. BY W. C. ALPERS AND B. J. MURRAY. *Am J. Pharm.*, 69, 534–543.—This paper is a treatise on the wild sarsaparilla. Qualitative tests for tannin, sugar, alkaloids, etc., are described. Alkaloids and glucosides were not found. Tannin, starch, a volatile oil, and a resin were found. The results of a proximate quantitative analysis of the drug are given.

The Important Constituents of Taraxacum Root. BY L. E. SAYRE. *Am. J. Pharm.*, 69, 543–546.—This portion of the author's continued work on Taraxacum is devoted to the bitter principle and to the analysis of the drug and of its ash.

The Tannin of Ceriops Candolleana. BY HENRY TRIMBLE. *Am. J. Pharm.*, 69, 505–506.—This tree is common in India, being a small evergreen of the mangrove genus. Its bark is unusually rich in tannin, one dried sample containing 31.56 per cent. The tannin was shown to belong to the same class as the oak bark tannins.

Some Products of the Tuberculosis Bacillus. BY E. A. DE SCHWEINITZ AND M. DORSET. *J. Am. Chem. Soc.*, 10, 782–785. —From bacillus cultures the authors have isolated a crystalline compound of melting-point 161°–164°. It is an acid soluble in ether, alcohol, and in water, and its analysis corresponds nearly to that of teraconic acid ($C_7H_{10}O_4$). It is evidently that product of the tuberculosis germ which produces the necrosis peculiar to these bacilli.

On the Presence of Amylolytic Ferment and Its Zymogen in the Salivary Gland. BY C. W. LATIMER AND J. W. WARREN. *J. Exptal. Medicine*, 2, 465–273.—Chloroform water and sodium fluoride solutions were used to extract the salivary glands of dogs, cats, rats, mice, oxen, sheep, and opossums. The extract was tested for amylolytic power; it was then acidified with acetic acid, and after ten minutes neutralized. The resulting solution was tested with starch paste for the zymogen. Many of the extracts contained the active ferment (ptyalin), many also the ptyalinogen, but no classification seems possible. No quantitative work was attempted.

On the Presence of Milk-Curdling Ferment (Pexin) in the Gastric Mucous Membrane of Vertebrates. BY J. W. WARREN. *J. Exptal. Medicine*, 2, 476–492.—With chloroform water extracts the presence of a milk-curdling ferment in the stomachs of many vertebrates has been shown. This the writer calls pexin and its forerunner pexinogen. Active ferments were found by him in the extract from the ox and calf only. Fifty-three stomachs from thirteen different vertebrates gave pexinogen, which was made active as a ferment by acidification of the extract by acetic acid and subsequent neutralization.

Note on the Influence of "Peptone" on the Clotting of Milk by Rennet. BY F. S. LOCKE. *J. Exptal. Medicine*, 2, 492-499.—The previous work on this subject has been done with peptones having an alkaline reaction. To this alkalinity the author thinks the action of the peptone, in delaying the coagulation by rennet, should be ascribed, although attempts to obtain a peptone which did not cause this delay were futile.

Algae and Antiseptics. BY R. H. TRUE. *Pharm. Rev.*, 15, 152–153.—This is practically a continuation of work done by Kahlenberg and True on the connection between the toxic action of acids, bases, and salts, and the condition of electrolytic dissociation of the agent. In this case the author has undertaken a study of the effects of acids and phenols upon the common spirogyra, and has determined the maximum dilutions fatal to this algae. With hydrochloric and sulphuric acids this dilution was found to be 800 and 1600 liters per gram-molecule, respectively, which seems to confirm the opinion that the toxic action of the acids is to be accredited to the hydrogen ions. With hydrochinone the toxic power was greatly increased by the spontaneous alteration in this phenol in its dilute solutions. This is to be further investigated.

G. W. ROLFE, REVIEWER.

The Distribution of Galactan. BY J. B. LINDSEY AND E. B. HOLLAND. *Mass. Agr. Coll. Ann. Rep.*, 34, 192–196.—The authors describe their method, which is that perfected by Tollens and others, based on the estimation of the derived mucic acid, and publish a large number of results, which show that galactan, while extensively distributed, is present in considerable quantity only in the leguminous plants. The greatest percentage was found in clover and lupin seeds, the amount in the latter exceeding 14 per cent.

SANITARY CHEMISTRY.

E. H. RICHARDS, REVIEWER.

The Filtration of Water. BY EDMUND B. WESTON. *Municipal Eng.*, 13, 199–207.—The author considers the "American system of filtration" to be "mechanical filtration aided by the application of chemicals," in distinction from sand filtration, a process which was imported from Europe. He estimates the cost of the latter to be considerably more than that of the former, and questions the expediency of incurring this extra cost to obtain the increase of 1.5 per cent. of efficiency in the removal of bacteria which he concedes to the best European practice.

Mechanical Filtration of the Public Water Supply of Lorain, Ohio. By C. O. Probst. *Ohio Sanitary Bull.*, 1, 100–120.—This report gives the conditions under which were made the tests of the Jewell filters, in purifying the water of Lake Erie, which is contaminated at the intake by the water from Black River. The results show that the use of 2.5 grams of alum per gallon and a rate of 100,000,000 gallons per acre per 24 hours appears to affect a sufficient purification.

Milk: Its Value as a Food and Studies which Suggest a Different Method of Sale. By E. B. Voorhees and C. B. Lane. *N. J. Agr. Sta. Bull.*, 123, 1–19.—The authors give the results of a year's study of the composition of the milk of a herd and of individual cows as affected by food and external conditions, and show that uniformity can be maintained, and suggest that consumers should be educated to consider that a definite relation between price and food value can be established.

The Composition of Prepared Cereal Foods. By E. E. Slosson. *Wyoming Expt. Sta. Bull.*, 33, 71–84.—Analyses of twenty-one of the common "Breakfast Foods" are given. The results with thirteen preparations of wheat are shown in the following table:

	Fat. Per cent.	Protein. Per cent.	Calories per gram.	Cost.
Maximum	3.72	16.60	4689	15.8
Minimum	1.20	9.37	3993	4.3
Average	1.85	12.44	4215	9.5

The author concludes that "there is more variation in price than in composition." He might have added that the cost bore no relation to the food value or the palatability. In the six samples of preparations from oats, there is even less variation in composition, but more in price. Oatmeal, in bulk, is bought for 2.5 cents per pound, while 12.8 cents is paid for a brand very slightly richer. Another supposed advantage of the package foods is taken away by the author's statement "that the claims for quick cooking are generally fallacious."

Soy Beans as Food for Man. By C. F. Langworthy. *U. S. Dept. Agr. Farmers' Bull.*, 58, 20–23.—In addition to a table giving nineteen selected analyses of the soy bean grown in different countries, the author describes ten modes of preparing it for food, mostly by fermentation, and gives the composition of the products. It is claimed that the soy bean contains no starch, and that when the cellulose is broken down by bacterial action, the nitrogen is well assimilated; it is also stated that these products replace meat in the Japanese dietary.

Human Food Investigations. BY HARRY SNYDER. *Univ. Minn. Agr. Expt. Sta. Bull.*, 54, 37–90.—The author summarizes valuable work on the character and composition of the nitrogenous constituents of wheat as affecting the light porous loaf of the bread made from the different varieties, and shows that the prolonged fermentation of the dough causes certain losses in both the starchy and nitrogenous constituents. He does not, however, discuss the most important corollary: Is not the bread so much improved in flavor as to offset this small loss? Digestibility experiments were made with bread from whole wheat, bakers' flour, and patent spring wheat flour. The results showed that all were well assimilated. In the case of potatoes, the starch is the most perfectly digested, while the nitrogenous portion is less available than in most vegetable substances. Experiments were also made in regard to the loss of food value by the different ways of cooking. Potatoes lose a large per cent. of the nitrogen when pared and soaked in cold water before cooking; but, as might have been predicted, very little of the starch is lost (except in the parings, which, however, may amount to 30 per cent. by weight, as has been determined repeatedly in the New England Kitchen). As the author has shown that the nitrogen is of small moment in the potato, one is puzzled to discover why so much stress is laid on this loss. The escape of the mineral salts is a more serious matter. The losses incurred in the cooking of carrots and cabbages are next considered, and shown to be very large, amounting to some 30 per cent. of the total food value, and the conclusion is that only by the use of the water in which the vegetables are cooked can all this value be recovered. The rest of the *Bulletin* gives in a concise form a summary of the main facts upon which the "*Rational Feeding of Men*" may be based. Tables of composition of food substances are reprinted from the *U. S. Dept. Agr. Bulletins*.

The Value of a Bacteriological Examination of Water from a Sanitary Point of View. BY E. K. DUNHAM. *J. Am. Chem. Soc.*, 19, 591–605.—The author discusses both the methods of determining the presence of pathogenic forms of bacteria in potable water, and the interpretation of the results. He concludes that the method proposed is capable of giving information of value, especially when supplemented by the determination of the presence or absence of sufficient organic matter to furnish food for the continued growth of the organisms.

W. R. WHITNEY, REVIEWER.

The Constitution of Milk with Special Reference to Cheese Production. BY S. M. BABCOCK. *Wis. Agr. Expt. Sta. Bull.*, 61, 1–21.—This is a comprehensive treatment of the subject, but it contains little that is really new.

Tainted or Defective Milks: Their Causes and Methods of Prevention. BY H. L. RUSSEL. *Wis. Agr. Expt. Sta. Bull.*, 62, 1–27.—The sources of contamination are considered, the effects on the value of the milk for various purposes are pointed out, and methods for preventing or remedying the evils are suggested.

Composition of Full Cream Cheese. BY WM. FREAR. *Pa. State College, School Agr., Bull.* 2, 1–16.—This paper summarizes experiments made in several states to determine the average composition of full cream cheese, and the variation in composition likely to arise from differences in the quality of the milk from which it is made. Briefly, the results are as follows: Green cheese of less than 32 per cent. fat is seldom produced from average factory milk; a green cheese loses about 5 per cent. in weight during one month's curing; and a reduction in the fat-content of the cheese is not likely to occur from the minor accidental variations in processes of manufacture or in differences of composition of unskimmed factory milk.

AGRICULTURAL CHEMISTRY.

W. R. WHITNEY, REVIEWER.

On the Influence of Vegetable Mould on the Nitrogenous Content of Oats. BY H. W. WILEY. *J. Am. Chem. Soc.*, 19, 605–614.—The author concludes from the investigation of the effects of various soils on the composition of oats grown in them, that humus soils greatly increase the nitrogen content of the cereal, this increase being chiefly in amid nitrogen. Three forms of fertilizers employed on humus soils caused about an equal increase in the quantity and alteration of the quality of the crop.

Physical Effects of Various Salts and Fertilizer Ingredients upon a Soil as Modifying the Factors which Control its Supply of Moisture. BY J. L. BEESON. *J. Am. Chem. Soc.*, 19, 620–649.—This article contains descriptions of apparatus and methods employed in studying, under varying conditions of composition, etc., the rate of percolation of water through soils, its evaporation from them, their water-holding capacity, and their rate of saturation.

The Composition of Humus. BY HARRY SNYDER. *J. Am. Chem. Soc.*, **19**, 738–744.—Analyses of different kinds of humus made by the decomposition in soils of various kinds of organic matter are given. The results make evident the fact that the chemical similarity between the different varieties is no greater than a consideration of their derivations would warrant; and they make necessary the indefinite postponement of an accurate chemical classification of these different forms of humus.

A Study of Alfalfa and Some Other Hays. BY W. P. HEADDON. *Col. Agr. Expt. Sta. Bull.*, **39**, 1–34.—This contains comparative analyses of alfalfa crops of different years and different cuttings of the same year, together with their relative digestibilities, as measured by acid pepsin solutions. Clover, pea vines, and upland hays are also subjected to the same methods of investigation. The results are well summarized on the concluding page, and the paper must be recognized as an important contribution to our knowledge of fodders. The author's remarks concerning criticisms adverse to the class of investigations of which this paper is a good example, may have considerable significance in Colorado; but the value of scientific study in the comparatively fertile field of agricultural chemistry is elsewhere rapidly receiving the appreciation due to it.

Burdock as a Vegetable. BY INAZO NITOBE. *Am. J. Pharm.*, **69**, 416–420.—The author discusses the use of the luppa or burdock root as an article of food and gives a table in which its composition is compared with that of other vegetables. In Japan, in 1888, about 36,000 tons of this root were produced for home consumption.

F. H. THORP, REVIEWER.

Electrical Method of Determining the Moisture Content of Arable Soils. Electrical Method of Determining the Temperature of Soil. Electrical Method of Determining the Soluble Salt Content of Soil. *U. S. Dept. Agr. (Division of Soils) Bulls.*, **6, 7, 8.**

Fertilizers. *Hatch Expt. Sta. Bull.*, **48**; *Purdue Univ. Special Bull., May, 1897; N. H. Agr. Expt. Sta. Bull.*, **43**; *N. Y. Agr. Expt. Sta. Rep., 1895*, 156–229; *N. Y. Agr. Expt. Sta. Bull.*, **116**; *N. C. Agr. Expt. Sta. Bull.*, **136**.

Some Notes Concerning the Nitrogen Content of Soils and Humus. BY E. FULMER. *Wash. Agr. Expt. Sta. Bull.*, **23**.—This bulletin contains determinations of nitrogen, phosphoric acid, potash, lime, iron oxide, and organic matter, in 53 soil samples.

G. W. ROLFE, REVIEWER.

Sugar Beets. BY W. W. COOKE AND WILLIAM P. HEADDON. *Col. State Agr. Coll. Bull.*, 36, 1–23.

A Review of Oregon Sugar Beets. BY G. W. SHAW. *Ore. Agr. Expt. Sta. Bull.*, 44, 1–49.—These bulletins are excellent examples of the work which many of the official experiment stations are doing out of deference to a generally awakened interest in the possibilities of beet sugar manufactured in this country. The experimental results of the investigations on the production and yield of the sugar beet in Colorado and Oregon are, as far as they go, favorable to the industry. Both reports give much practical information of a general nature as to cultivation. The Oregon report also goes into the manufacture and cost of production of the sugar, and will doubtless be of value in correcting the fallacious ideas so prevalent as to the conditions requisite for success from a business standpoint.

ANALYTICAL CHEMISTRY.

PROXIMATE ANALYSIS.

A. H. GILL, REVIEWER.

The Detection of Foreign Fats in Lard and Butter. BY C. B. COCHRAN. *J. Am. Chem. Soc.*, 19, 796–799.—Two cubic centimeters of the melted fat are introduced into 22 cc. of fusel oil contained in a glass-stoppered graduate, and the mixture is warmed to about 40° C. and allowed to cool slowly to 16° or 17° C. for two or three hours. A crystalline deposit forms, which is filtered off, recrystallized from ether, and examined microscopically. The method is capable of detecting five per cent. of beef fat. The amount of deposit which is formed and the melting-point of the sample may furnish a basis of estimation of the quantity of admixture.

Volatile Oils and Their Assay. BY E. KREMERS. *Pharm. Rev.*, 15, 196–198.—The article is an introductory one dealing with the changes produced in the oils upon standing and by distillation.

Notes on Several Fatty Oils. BY F. A. SIEKER. *Pharm. Rev.*, 15, 112–113.—The oils described are those of the Saw palmetto, pumpkin seed, and croton oil. Saw palmetto oil is soluble in alcohol as well as ether and petroleum ether; it has a specific gravity of 0.9138 at 15° C., and a cold test of 14°. The iodine value is 42–43, and the saponification numbers are 212.5

to 217; it does not solidify when subjected to elaidin test. Pumpkin seed oil is of a reddish-yellow color, soluble in ether, petroleum ether, and carbon disulphide, but insoluble in alcohol. Its specific gravity is 0.9231 at 15° C; its iodine value, 118–119; and its saponification number 195. It is not solidified by the elaidin test. Croton oil is of a yellow color and is soluble in the usual solvents. Its specific gravity at 15° C. is 0.9445; its iodine value, 107–108; and its saponification number, 192–196.

The Chemistry of Food Adulteration. By Henry Leffmann. *J. Franklin Inst.*, **144**, 133–137.—This paper is an abstract of an address on the methods of expressing analytical results in food analysis.

G. W. Rolfe, Reviewer.

The Exact Estimation of Total Carbohydrates in Acid Hydrolyzed Starch Products. By Geo. W. Rolfe and W. A. Faxon. *J. Am. Chem. Soc.*, **19**, 698–703.—The authors compute by a graphical method from the specific gravity factors for hydrolyzed starch products of all possible specific rotatory powers. The actual specific gravity factors of sixteen hydrolyzed starch samples were obtained by evaporation to dryness, by method of Lobray de Bruyn and Van Laent. They were found as a whole to agree closely with the calculated values. A formula is given by which the total carbohydrates in any solution of the kind can be quickly estimated, when the specific rotatory power, obtained by the factor 386, is known.

The Phloroglucin Method for the Estimation of Pentsoans. By J. B. Lindsey and E. B. Holland. *Mass. Agr. College Ann. Rep.*, **34**, 197–199.—The authors describe the method devised by Councler and perfected by Kruger and Tollens, and give six determinations of seeds and fodders, together with six parallel determinations by the usual phenyl hydrazin method. The results are concordant, and the authors recommend the phloroglucin process on account of its greater simplicity.

F. H. Thorp, Reviewer.

A Comparison of the Methods for Determination of Glycerol. With Notes on the Standardizing of Sodium Thio-Sulphate. By W. E. Garrigues. *Proc. Eng. Soc. Western Pa.*, **13**, 271.—Minute directions are given for the three standard methods of analyzing spent soap lyes, with certain modifications, by the author. The processes examined were (*a*) Benedikt and Zsigmondy's oxidation process, with alkaline permanganate; (*b*) Benedikt and Cantor's acetin process; (*c*) Hehner's oxidation process with acid bichromate solution. The author concludes that crude glycerol is best determined by the acetin process, and soap lyes by the bichromate method. The proper conditions must be observed in standardizing the thiosulphate and in determining chromic acid; the process recommended is as follows: '25 cc. of chromic acid solution are mixed with 10 cc. of a ten per cent. potassium iodide solution and five cc. of strong hydrochloric acid. Let the mixture stand ten minutes and then dilute with 150 cc. of water, and titrate the iodine, stoppering and shaking violently between the addition of the last few drops of thiosulphate, to dissolve any iodine in the precipitated iodide of starch. This is essential to accurate work. There is no benefit to be obtained in using lead acetate with lyes or crude glycerine, since the sulphuric acid is sufficient to clarify them. But in candle glycerine, a little lead may be used to precipitate organic matter.

Asphalt Examination. By H. Endemann. *Municipal Eng.*, 13, 6.—This is a short article on a method of analysis proposed by the author for the separation of petrolene and asphaltene. A number of analyses are given; and a method of calculating the amounts of asphalts of different quality, which must be combined to produce a standard grade is fully explained.

Determination of Potash and Phosphoric Acid in Fodders. By H. W. Wiley. *J. Am. Chem. Soc.*, 19, 320–322.—This article describes an improvement on the usual method, whereby time is saved.

W. R. Whitney, Reviewer.

The Rapid Estimation of Uric Acid in Urine. By E. H. Bartley. *J. Am. Chem. Soc.*, 19, 649–656.—After a comprehensive review of many methods employed for uric acid determination, the author describes one of his own. This consists of a titration with silver nitrate solution in the warmed urine after the addition of ammonium and magnesia mixture. The end-point is determined by testing a drop of the solution for silver by sodium sulphide, from time to time, during the titration. Comparative results obtained by Ludwig's and by the author's method are given.

APPARATUS.

A. H. Gill, Reviewer.

A Recent Assay Balance. By L. S. Austin. *Proc. Col. Sci. Soc.*, *1897*, 1–6.—The article describes what would seem to be an unusually delicate balance.

Some New Forms of Apparatus. BY A. E. KNORR. *J. Am. Chem. Soc.*, 19, 817.

An Electrical Laboratory Stove. BY M. D. SOHON. *J. Am. Chem. Soc.*, 19, 790.

Mechanical Arrangement for Fat Extraction Apparatus. BY G. J. VOLCKENING. *J. Am. Chem. Soc.*, 19, 735.

Method of Drying Sensitive Organic Substances. BY. C. C. PARSONS. *J. Am. Chem. Soc.*, 19, 388.

A New Form of Condenser for the Distillation of Liquids having Low Boiling-Points. BY E. E. EWELL. *J. Am. Chem. Soc.*, 19, 398.

A New Apparatus for Sulphur Determinations in Iron and Steel, and a Useful Form of Wash-Bottle. BY R. K. MEADE. *J. Am. Chem. Soc.*, 19, 581.

A Simple Fat Extractor. BY V. J. HALL. *J. Am. Chem. Soc.*, 19, 586.

An Apparatus for Collecting Samples of Water. BY GEORGE C. WHIPPLE. *Eng. Record*, 35, 515.—The apparatus is designed to collect water from considerable depths. For the method of operation reference must be made to the original article.

A Simple and Efficient Boiling-Point Apparatus for Use with Low- and with High-Boiling Solvents. BY HARRY C. JONES. *Am. Chem. J.*, 19, 581–597.—The author discusses the various forms of apparatus in use, and suggests a modification of Hite's apparatus, in which the condensed solvent is not returned directly into the boiling solution. The apparatus consists of a tube about one-fourth filled with glass beads, on which rests a platinum cylinder. The thermometer is immersed in the solvent inside the cylinder, which serves to separate the condensed solvent and boiling solution. The results obtained seem to be very satisfactory.

METALLURGICAL CHEMISTRY.

H. O. HOFMANN, REVIEWER.

Ferric Sulphate in Mine Waters and Its Action upon Metals. BY L. J. W. JONES. *Proc. Col. Sci. Soc.*, June 15, 1897.—The author analyzed a muddy mine water, which strongly corroded the pumps and other iron parts. The filtered mud gave: Fe_2O_3, 53.57; Al_2O_3, 2.87; SiO_2, 10.85; SO_3, 11.46; H_2O, 21.14. The filtered water in 1,000 parts: SiO_2, 0.043800; NaCl, 0.013450; Na_2SO_4, 0.311720; K_2SO_4, 0.155480; $Al_2(SO_4)_3$, 0.019787; $ZnSO_4$, 0.122440; $MnSO_4$, 0.427140; $MgSO_4$, 0.467460; $CaSO_4$, 0.636290; $Fe_2(SO_4)_3$, 0.603360; $FeSO_4$, 0.009337; $CuSO_4$, 0.1918010; total, 3.002065. Free sulphuric acid was absent; the corrosive action on iron was due, in part, to cupric sulphate, and the solvent power for copper to ferric sulphate. As a result of a number of experiments, bronze pipe was used in the mine and this has stood for over two years.

Composition and Formation of Tank Residues in Electrolytic Refineries. By E. Keller. *J. Am. Chem. Soc.*, 19, 778–782.—The author compares the composition of anode coppers with that of the tank residues obtained during a given time at one of the leading electrolytic copper refineries of the country, and draws deductions as to the degree of concentration of silver (gold) in the residue, and the amount of the original contents of the anodes which went into solution and remained in the residue. He also calls attention to the fact that selenium is present in Montana coppers to a much greater extent than is generally believed.

Practical Workings of Chlorination. By T. G. Taylor. *Min. Sci. Press*, 75, 48.—The article is a description of the work done at the Champion mine, Nevada City, Cal.

Apparatus for Extracting Gold and Silver from Ores by the Cyanide Process. By A. S. Cooper. *Min. Sci. Press*, 74, 542–543.—A sheet-iron conical drum, closed at both ends and having spiral blades, revolves on a horizontal axis. It receives ores and solutions at the larger end and discharges them at the smaller one.

Notes on the Action of Potassium Zinc Cyanide Solutions on Gold. By W. J. Sharwood. *Eng. Min. J.*, 64, 396, 426, 460, 461.—The author gives a summary of what has been published on the subject with all the necessary references, discusses the value of the different equations proposed from a thermochemical point of view, and describes in detail his own experiments, embodying over two hundred and fifty observations, to which the reader is referred for details. The conclusions arrived at are: (1) The gold-dissolving power of a solution of potassium zinc cyanide increases rapidly with increased excess of oxygen, presence of oxygen being the most essential condition. (2) It increases somewhat with strength of solution, but this effect is small. (3) It increases with a rise of temperature. (4) Gold dissolves in the solutions without forming any precipitate at first, but after a certain proportion of gold has dissolved, a white precipitate begins and continues to form, gradually coating the metal and retarding further action. The amount of precipitate is not proportional to that of the gold dissolved, being relatively less when the amount of solvent is large; it consists of a somewhat variable mixture of cyanide and oxide of zinc. (5) The solvent action of the double cyanide solution is less than that of a solution of simple potassium cyanide containing the same amount, or half the amount, of cyanogen in equal volumes. (6) It is increased by addition of caustic alkali, other conditions remaining the same, and the increase is greatest in solutions to which oxygen has the freest access. (7) The considerable increase in solvent power observed when caustic potash is added (always provided that oxygen is accessible), coupled with the superior effect of free potassium cyanide, is good evidence that some free potassium cyanide is formed upon such addition, and, therefore, that in dilute solutions (such as 0.3 to 0.6 per cent. or 0.80 to 0.40 gram molecule per liter) potassium zinc cyanide is partially decomposed by caustic alkali, in accordance with the principles of chemical equilibrium between substances in solution.

Cyanide Mill Solutions. By PH. ARGALL. *Eng. Min. J.*, **64**, 393.—This note is a correction of a typographical error in a previous paper (*this Rev.*, 3, 139). In the table there given, in place of: KCy 0.501, 0.451, 0.535, 0.410; read KCy 0.501, 0.491, 0.505, 0.505.

The Edison Concentrating Works. By C. KIRCKHOFF. *Iron Age*, No. 18, **60**, 1–8.—The larger part of this paper is an illustrated description of the magnetic concentration plant of Edison at the Ogden Mines, N. J. The magnetite concentrates are converted into briquettes containing: Fe 67–68, SiO_2 2–3, Al_2O_3 0.4–0.8, Mn 0.05–0.10, CaO, MgO, S traces, P 0.028–0.033, resinous binder 0.78, H_2O none. In trial runs made in the blast furnace of the Crane Works, Catasauqua, Pa., the normal product of 100–110 tons of pig was increased to 138.5 tons. This was due to the richness of the ore, which, however, caused not only an increased output of pig but a decrease in the amount of limestone required and a larger number of charges. It was also found that the fuel consumption was lowered. The following analyses give the character of the pig produced:

Date.	Percentage briquette on charge.	Tons of pig produced.	Si.	P.	S.	Mn.
Jan. 5....	25	104	2.750	0.830	0.018	0.500
" 6....	37.5	124.5	2.620	0.740	0.018	0.350
" 7....	50	138.5	2.572	0.580	0.015	0.200
" 8....	75	119	1.844	0.264	0.022	0.200
" 9....	100	138.5	1.712	0.147	0.038	0.185

The Value of Physical Tests. By S. S. KNIGHT. *Am. Manufacturer*, **61**, 585–586.—The paper is a strong plea that chemical work in the iron foundry shall be on the same footing with physical testing, which is so frequently made the sole standard. In his arguments the author brings forward several facts of general interest. He shows by analyses and physical tests that the adage "the shrinkage in iron varies inversely as the silicon" is absolutely wrong, the fact being that it varies directly as the sulphur, manganese, combined carbon and titanium and inversely as the silicon and phosphorus. How absolutely necessary chemical work is in a foundry is illustrated by an interesting set of determinations, showing that the first tap of a day from the cupola was uniformly softer than that of any others made later during the day; *e. g.*: Silicon in metal from first tap was 2.739, 2.891, 2.624 per cent., and from the fourth tap, 2.102, 2.007, 1.992 per cent.

A Preliminary Thermo-Chemical Study of Iron and Steel. BY E. D. CAMPBELL AND F. THOMPSON. *J. Am. Chem. Soc.*, 19, 754–766.—This paper comprises the results obtained by the authors in trying to determine whether carbon was the sole cause for the variations in the heat of solution of steels subjected to different heat treatments. They summarize the work done by Troost and Hautefeuille in 1875, and Osmond in 1885, and give the results of their own work, which is brought together in four tables representing the influence on the heat of solution of chemical composition, annealing, quenching, tempering, and reheating, and of reheating on the tensile strength of cold-drawn wire.

Semi-Steel. BY C. KIRCKHOFF. *Iron Age*, No. 3, 60, 13.—The basis of this metal is a low-carbon steel to which are added special irons which make the product homogeneous, solid, strong, and tough. It has twice the strength and elasticity of cast iron, can be used in seventy-five per cent. of the work for which steel castings are commonly used, and costs about half the price.

ASSAYING.

H. O. HOFMAN, REVIEWER.

A Modified Method of Fine Silver Assay. BY A. E. KNORR. *J. Am. Chem. Soc.*, 19, 814–816.—The author has combined the Gay-Lussac and Volhard methods of assaying fine silver, by precipitating the bulk of the silver with a standard salt solution in the usual way and finishing the assay with potassium sulphocyanate, of which 1 cc. will precipitate 1 mg. silver. As indicator he uses 5 cc. of a solution of ferric ammonic alum.

Assaying Gold and Silver. BY J. B. ECKFELDT. *Min. Sci. Press*, 75, 4, 29, 49.—These articles give an outline of the modes of procedure at the United States Mint at Philadelphia.

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