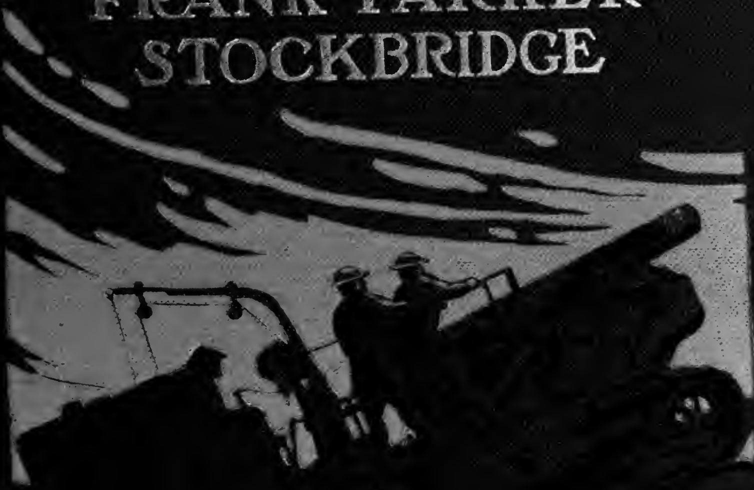
YANKEE INGENUITY IN THE WAR

FRANK PARKER STOCKBRIDGE



YANKEE INGENUITY
IN THE WAR

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A YANKEE SEAPLANE OF THE TYPE THAT FIRST FLEW ACROSS THE ATLANTIC; THE NC-2 RISING FROM THE WATER

YANKEE INGENUITY IN THE WAR

By

FRANK PARKER STOCKBRIDGE

Fully Illustrated
From Official Photographs

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YANKEE INGENUITY IN THE WAR

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To

The Memory of My Father

WINFIELD SCOTT STOCKBRIDGE

to whose own Yankee ingenuity and enthusiasm in the pursuit of knowledge of the natural sciences and in their application I owe my early inspiration and guidance toward the study and appreciation of Man's conquest of the forces of Nature

I dedicate this book

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AUTHOR'S PREFACE

In presenting this report of some of the more striking and inspiring examples of the technical achievements of America that went so far toward the winning of the Great War, the author wishes, first, to point out that the omission of any mention of the great scientific and engineering feats of the Entente Allies, except incidentally, is due not to any desire to disparage the magnificent work of those European masters of pure and applied science whose service in the cause of humanity was surely no less fruitful and even more arduous than that of their American *confrères*. But the whole scope and plan of this book, by its nature, excludes from present consideration all but distinctly American enterprise in this field.

Even within this comparatively narrow range, there is no pretext that the whole field has been covered, or that what has been covered might not have been dealt with more in detail and with greater scientific precision. Eventually that will be done; beyond a doubt the complete history of science in the war, yet to be written, will reveal a thousand wonders much more marvelous than any that have yet been set down. This volume, however, has not been written for the scientist or the technologist, but for the average American, neither skilled nor interested in technical details, but susceptible, the author believes, to the thrill of patriotic pride that comes from the recital of the story of a winning fight against heavy odds.

Since the signing of the armistice there has developed a marked tendency among Americans to disparage our country's part in the war, to accept as true slanderous statements and inuendoes, set afloat by the country's enemies and those traitors of our own people who never really desired the defeat of the Central Powers, and repeated and kept alive by the unthinking who love to roll juicy bits of gossip under their tongues. On every hand one hears it stated, and accepted as fact, that America's whole participation in the Great War was a huge failure; that our military and naval machine failed to function, and that our equipment, from airplanes to submarines, was worthless and insufficient.

If this book shall prove in any slight degree an offset to such falsehoods and distortions of truth and a counterblast to the calumniators of our country and our countrymen's achievements, the author will feel amply repaid for the time and labor that have been expended upon its preparation. It has been a labor of love, in which he has felt the same patriotic pride that he hopes his work may inspire in every true American, and especially in those Americans of the future—the boys of to-day—to whom our country must look for the fulfilment of its great destiny in the reshaping and rebuilding of the world.

The author takes this occasion to express his thanks to the Secretary of War, the Secretary of the Navy, the chairman of the Committee on Public Information and the members of its staff, all of whom, throughout the period of the war and afterward, so freely provided him with the keys and passwords that enabled him to penetrate behind the scenes, as it were, and see for himself what Yankee ingenuity was really accomplishing. He acknowledges his indebtedness, also, to the many officers of the army and navy who so fully and freely aided in every possible way in the collection both of information and of illustrations. He owes a word of appreciation, also, to the editors of *Harper's Magazine*, *The World's Work*, *Popular Science Monthly*, *Motor Life*, *The New York Herald*, *The Sun*, and *The New York Times* for courteous permission granted to include in this volume several chapters and parts of chapters which have previously appeared in the pages of their publications.

FRANK PARKER STOCKBRIDGE.

NEW YORK, *March* 3, 1920.

YANKEE INGENUITY
IN THE WAR

YANKEE INGENUITY IN THE WAR

I

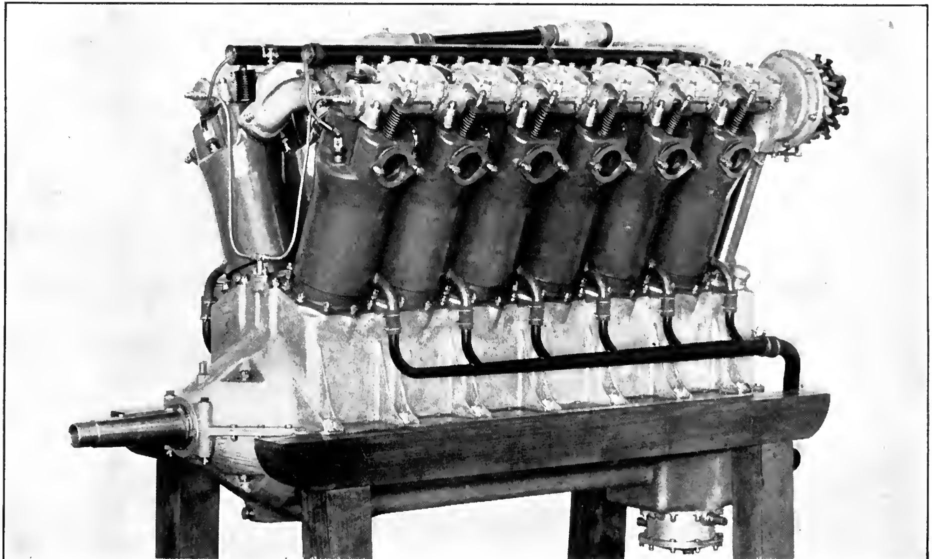
THE MOBILIZATION OF SCIENCE AND INDUSTRY

THE war that came to an end with the signing of the armistice on November 11, 1918, differed from all previous wars principally in that it was a contest of brains much more than it was a contest of brute force. Machines counted for more than men; minds for more than muscle; the only really doubtful question, after the first surprise shock had been successfully resisted by the Allies and the war settled down to a life-and-death struggle, was whether the technical resourcefulness of England, France, Italy, and America, and the ingenuity of the scientists and engineers of these countries, could match and overmatch the scientific and technical resources of the enemy.

The beginning of the war marked the climax of an era of scientific research, discovery, and invention that had made the half-century that ended in August, 1914, the most marvelous chapter in the record of man's conquest of the forces of nature. It was the half-century that gave to the world the electric light, the telephone, the bicycle, the automobile, the motion picture, the phonograph, the X-ray, the wireless telegraph, the airplane, and the submarine. And for forty or more of the fifty years Germany had been cunningly appropriating, adapting, and exploiting these and a thousand other inventions and discoveries, the fruits of the research of the world's greatest intellects, until she had convinced herself and had all but persuaded the rest of the world that she, and she alone, held the master-key that would unlock the treasure-house of science and render its riches available for the service of mankind. So steeped were the Germans in their own conceit that they believed no material resources competent to cope with theirs could be marshaled against them; theirs was the last word in mechanics, in chemistry, in engineering; of what they did not have the rest of the world must be in ignorance.

It is a source of tremendous satisfaction to be able to record the completeness with which Germany's vaunted leadership in the world of science and invention has been overthrown, shattered, and demolished. What literally and actually happened was that Germany was crushed and broken by means of scientific discoveries and inventions so far superior to her own that she could not cope with nor resist them. Germany had for forty years been marshaling her technical resources for the conquest of the world; what Germany did not realize was that, instead of being exhausted, the technical resources of the rest of the world were practically inexhaustible and needed only the stimulus of necessity to be called into action, with overwhelming consequences to those who first provoked the war.

The war was won, in fact, by Yankee ingenuity in



THE LIBERTY MOTOR
The greatest war achievement of Yankee ingenuity and resourcefulness

the application of scientific knowledge and technical skill to military and naval ends. From the very beginning of the struggle in 1914, nearly three years before the United States became a belligerent, the Allies relied upon America for their entire supply of many kinds of munitions of war and for a large proportion of almost all of their essential weapons. When America came into the war our government mobilized, not only an army of fighting-men, but a scientific, technical, and industrial army the like of which had never before been assembled.

We had everything that Germany had and one thing that Germany did not have, the organizing and directing genius of American manufacturers, which had found its highest expressions in peace times in the method of making standardized articles of high quality in huge volume and at low cost, the peculiarly American method known as "quantity production."

When America finally entered the war and threw its gigantic resources into the scale the seat of war shifted from the Hindenburg line to the factories of Bridgeport, Pittsburgh, Detroit, Newark, Cleveland, and a thousand other American cities. The war became a contest of machine power as much as of man power. It was not only a question whether the Allies could hold Verdun, but whether Squantum could build destroyers faster than Hamburg could turn out submarines, Bridgeport produce more cartridges in a given time than Köln. The outcome of the war was the direct result of American quantity production applied to the manufacture of munitions.

Quantity production is the manufacturing method that educates the tool as well as the mechanic and puts the power of a thousand horses and the skill of a thousand brains at the command of a single pair of hands. We have all seen the result; I have tried to tell in these pages something about many of the more interesting and spectacular achievements in the way of quantity production, as well as to describe specific and particular inventions and applications of scientific knowledge that helped us to defeat Germany. But even such an impressionistic picture, painted, as

A THREE-INCH GUN IN ACTION

So rapidly did Yankee artillerymen learn to shoot the three-inch gun that the discharged shell did not reach the ground before the next charge was ready to fire. "Let me see your three-inch machine-guns," a captured German requested. He could not believe they were single-shot guns.

it must necessarily be within the limits of a single volume, in the broadest of brush strokes, cannot convey an adequate sense of how big the job we did really was, how terrific the strain of the battle against time, without at least a peep behind the scenes, as it were.

I went to Detroit in the summer of 1918 to see for myself how American manufacturers were conducting their part of the war. I chose Detroit rather than Bridgeport or Cleveland or Chicago because Detroit is the foremost exponent in its industries of quantity production. I found Detroit performing mechanical miracles. One who could have looked unmoved upon the marvels of creative achievement then already in being must have been lacking in imagination or sensibility, or both.

Probably the business men of Detroit would resent the imputation if one were to call them poets, but if the essence of poetry be the power to conceive grandly and to express grand concepts with rhythmical force, no other term fits them. There was no escaping the sense of titanic fancy, expressing itself in Homeric measures, in the face of what I found these business men doing. Dollars do not drive men to such heights of accomplishment; war, not business, was the source and mainspring of these vast projects and their still vaster execution. Detroit was not thinking or talking of profits. "It is not fashionable to make money out of war," one of her business leaders expressed it. Many expected to come out millions poorer than they went in, and were glad that it was so.

Detroit's story could be duplicated in many cities. Wherever munitions were made men threw themselves and their enterprises wholly and unhesitatingly into the war, placid pastures were changed overnight into clangorous cities. The things Detroit showed me I could have found, or their parallels, in Bridgeport or Newark or Dayton. They would have pointed the same moral, for everywhere the story was the same. Miracles were performed everywhere, but at terrific cost in money, in labor, in strain and effort to make up lost time.

Take, as an example, the case of the Dodge Brothers,

THE AMERICAN THIRTY-FIVE-TON TANK PROPELLED BY A LIBERTY MOTOR, BALANCED ON THE BRINK OF AN EMBANKMENT

merely because their experience and achievement are typical of what occurred everywhere. They have been building automobile engines for years, cars complete for some years. Their big organization is geared to quantity production in all that that implies. When we went to war they went to Washington and offered themselves and their organization. "We can make anything," they said. "What do you need?"

Washington didn't know what it needed that the Dodge Brothers could make. It was autumn before they were sent for.

"Can you make recoil mechanisms for one-hundred-and-fifty-five-millimeter howitzers?" the War Department asked.

"Yes," said the Dodge Brothers. "What are they?"

"They are something like this," replied the War Department, showing them a French piece, "only we've improved them. Here are our drawings. You work from these. Give us so many thousand by such a date."

They did not wait to ask questions, but hurried back to Detroit to evolve a plant out of nothing, to create designs for machines and build them.

That was on November 1, 1917. In early June, 1918, I went through their ordnance plant and saw them turning out the first of the finished pieces. Let me try to convey a faint impression of the miracle the Dodge Brothers had worked in the intervening seven months.

First you must realize that the recoil mechanism of a modern field-gun or howitzer is not only one of the most ingenious devices ever conceived in the mind of man, but it must be more accurately fashioned to precise dimensions than any other object of its size and weight. To make one you take a ton and a half of steel in a single billet eight feet long. Lengthwise of this you bore four holes from about three to more than four inches in diameter; two run all the way through, two half-way. Then you shape the outside of the billet, carving it down at some places to a thin wall around the holes, leaving it in a rigid mass at other points. You hew out of its side a recess the size of a soap-box. You fashion grooves and lands, channels and projections, on various surfaces. By this time you have six hundred pounds of metal left; the rest has gone into the scrap-heap. Now you must finish this, grind it smooth, polish it inside and out, and when it is all done every dimension must register to within one two-thousandth of an inch; the bore and the line of the eight-foot holes, the angles of the recess, the thickness of the walls, must be accurate to the infinitesimal fraction of a hair!

The Dodge Brothers owned a vacant piece of pasture-land on the outskirts of Detroit; and there they decided to erect their plant. They could only guess at the size, for they couldn't tell offhand how many or how large the machines and tools would have to be and there was not a second to lose. It is a saying in Detroit that they have but three seasons—July, August, and winter. Unless the building could be put up before the heaviest frosts it must wait till spring—and our army needed six-inch guns. So the Dodge Brothers staked out twelve acres and on November 19th began to lay a foot of concrete over the whole of it; they couldn't get a contractor to accept the job. With the thermometer most of the time many degrees below zero, there was finished in four months a huge building, 850 by 600 feet, steel-framed, brick-walled, concrete-roofed; roads were graded and trolley lines extended, a new electric-power substation built—a million dollars or so of the Dodge Brothers' own money spent merely for the housing of a plant that so far existed only in the mind's eye, for a factory building is not yet a manufacturing plant.

Machinery was scarce and hard to get. One officer of the company spent three months and five and a half million dollars buying machinery and getting it moved toward the new plant. To bore the four holes in one operation a machine had to be devised. Mechanical engineers and draftsmen worked it out, and seventy-two machines were built—huge devices costing many thousands each. Nobody stopped to estimate cost; speed was what counted. Then came the most delicate and difficult work of all, the designing and making of the tools, the actual cutting-heads for fashioning the steel into shape. All the machinery does is to serve as the mechanical hands to hold and operate the cutting-tools. Every tool must be drafted to the exact size and shape of the cut to be made in the steel, then fashioned from high-speed steel by the highest paid and most skilful mechanics, the toolmakers. I saw a milling-machine cutting-head in operation that cost nearly one thousand dollars in labor alone, and there were dozens exactly like it. This tool performs only one of the forty or fifty operations necessary to fashion the rough billet into the recoil-mechanism bed.

Have I made it clear what quantity production involves in money, time, brains, and labor before a single finished article can be turned out? It took seven months and seven million dollars before the first recoil mechanism could be delivered. Yet its manufacture involved no new principles, no methods with which Detroit (and I include all American manufacturers) had not been perfectly familiar for years.

What the Dodge Brothers did hundreds, possibly thousands, of other American manufacturers did in as many other items of the vast number of things that had to be made to carry out our war program and equip our fighting forces.

Through this sort of co-operation, there has come about a better understanding between the government at Washington and the business men of the nation. Washington has a clearer comprehension of the difficulties and the problems of the business man, and the business men of the country have acquired new knowledge and respect for Washington's point of view and ways of doing things, and for the men of science who played so important a part in our war preparations. In a hundred different fields of applied science, business men who had spent their lives in particular lines of industry found, when they undertook to do war work for the government, that the methods they had found good enough for business purposes were not good enough for government purposes, but had to be adapted, refined, and improved to meet specifications drawn up by the scientific experts from the universities and research laboratories, who had been called into the service of the nation, put into uniforms, and given the opportunity to make practical application, in uncounted instances for the first time, of the principles which their research and experiments had demonstrated to be in advance of current knowledge in the trade.

At first the theories of the business man and the facts of the scientists, who are seldom concerned with theories, but who do insist upon facts, frequently clashed. The scientists were in uniform, however, with bars and oak leaves and eagles on their shoulders, and when they gave orders they had to be obeyed.

And before very long a good many thousands of "practical" men began to discover that a lot of the things they had always done had been done very badly indeed; that a lot of things they had always maintained couldn't be done could be done, and were better than the old ways. They began to have a new respect for the men whom they had formerly addressed somewhat contemptuously as "professor," but whom they now saluted as "captain"!

The whole wonder-story of our country's scientific and technical war achievements may never be told; fragments of it will continue to be told, piecemeal, for a generation to come. In the perspective of history these things that American industry, inventiveness, and ingenuity accomplished in the brief space of eighteen months will rank with our most glorious achievements by land and sea; they were no less essential to the winning of the war and hardly less heroic. The full disclosure of these things, many of them among the most carefully guarded military and naval secrets while hostilities were in progress, will furnish also the final convincing, clinching proof that German claims to scientific and technical leadership are based on nothing but egotism and moonshine.

Enough can now be told to make it clear that we have taken forward steps in the application of science to the uses of humanity, forced by the pressure of war necessity, that might not have been taken in fifty or a hundred years of the slow and orderly processes of peaceful development. We cannot measure the cost of the war in dollars and cents alone, but, on the other hand, its profits, great as they are in their spiritual values, have material aspects in the new tools and instruments which have been put in the hands of man a generation or two earlier than they otherwise might have been available for his use; the methods and processes by means of which life may be made easier and better, even though these methods and processes were devised under the stress of conflict to make the taking of life easier and swifter; the new knowledge of ourselves and our resources, our possibilities and our limitations, too costly to seek out in time of peace, but which, once disclosed by the emergency of war, is of imperishable and incalculable value in rendering easier and more swift the progress of the race toward the goal of the ultimate absolute liberation from every form of bondage, physical as well as spiritual, of every human being.

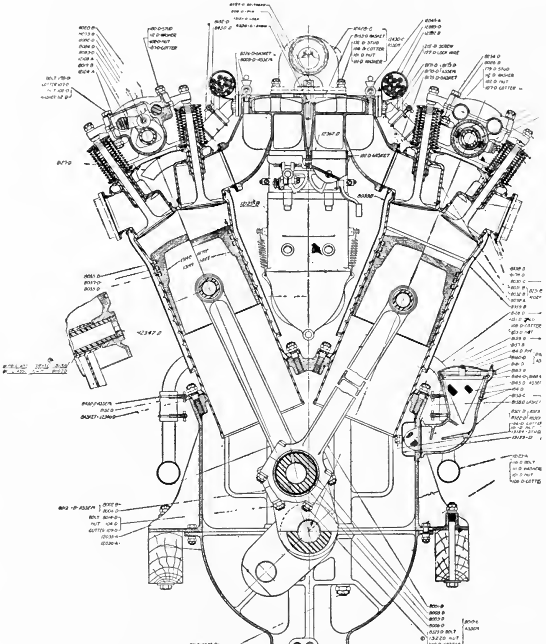
II

THE LIBERTY MOTOR

BEYOND question America's biggest single war achievement in the application of scientific knowledge and technical resources and methods is the development and production of the Liberty motor. In spite of all that has been written and said about this wonderful engine, it is probable that the full extent and importance of what was accomplished in its production can never be grasped except by the technical men who took part in the work. Let me try to visualize what this war production meant.

On the day the armistice was signed there had been built and delivered 15,131 twelve-cylinder Liberty motors. The total horse-power developed at Niagara Falls is about one million. These Liberty motors had the power of six Niagaras—6,052,400 horse-power!

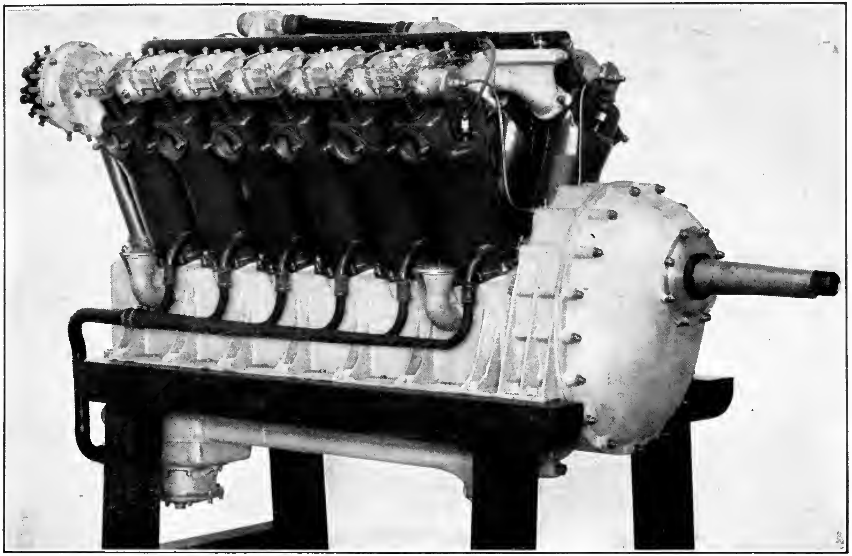
Engine production at this speed, unprecedented as it was, was not fast enough. Not only our own Air Service, but the aviation corps of Great Britain, France, and Italy were clamoring for Liberty motors, and when the armistice was signed orders had been placed for 51,100 Liberty twelves and 8,000 Liberty eights, as part of a total program of 95,993 aviation engines which the United States would have contributed before the end of 1919! Engine production was going on at the rate of 200 complete Liberty



WORKING DRAWINGS OF THE LIBERTY MOTOR, SHOWING DETAILS OF THE INTERNAL CONSTRUCTION OF THIS WONDERFUL ENGINE twelves daily when the war was stopped. By April it would have reached 10,000 a month, with no limit in sight.

All this was accomplished in eighteen months. On May 29, 1917, the first drawings of the design of the Liberty motor were made. On July 4, 1917, the first engine built from these designs was flown. Less than nine months later six great plants were producing Liberty twelves in ever-increasing volume. In between there was a heartbreaking interval of preparation for quantity production that literally strained the industrial and technical resources of the nation. Everything was new. There was a blank sheet of paper on which could be written either success or failure.

When the United States declared war on Germany on April 6, 1917, there had not been made in America a single high-powered aviation engine suitable for use under war conditions. There were several manufacturers producing low-powered engines suitable for training-'planes; a great many of these engines had been built and placed in American-built training-'planes made for the British and Canadian governments. One American company was just getting under way on a contract with the French government for the production of the Hispano-Suiza motor, one of the best European types of aviation engine, but developing only 150 horse-power. Another American company was prepared to build the nine-cylinder rotary Gnome engine, a type which had been popular for exhibition flying before the war, and which could be used on advanced training-'planes. We had nothing in America, however, to compare with the British Rolls-Royce, the high-powered Hispano-Suiza or the Lorraine-Dietrich of the French, the Italian Bugatti



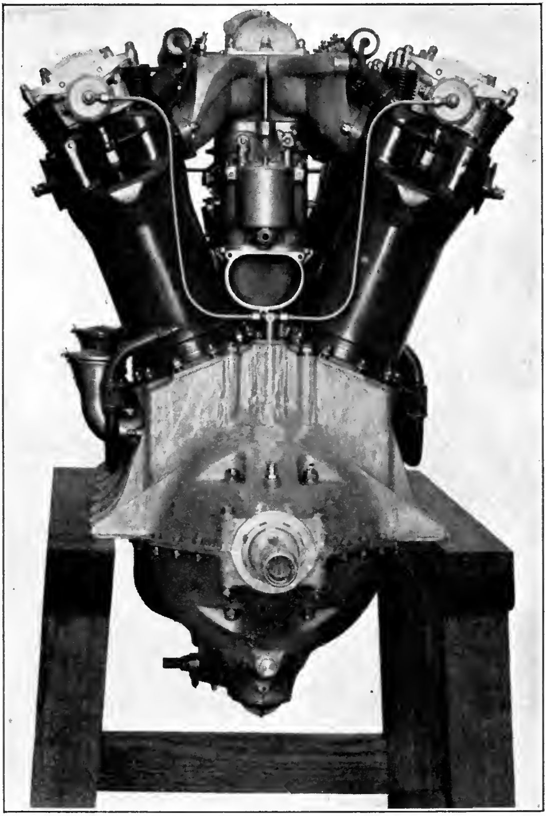
THE TWELVE-CYLINDER LIBERTY MOTOR, MODEL B

This is the type manufactured for the navy. It differs from the army type in having less compression between piston and cylinder heads, and also in that it is geared down to the propeller shaft and revolves only 1,400 times a minute. In the army machine the propeller is attached directly to the main crank-shaft, which makes 1,800 r.p.m. The NC-4 which made the first flight across the Atlantic had Liberty Model B motors.

and Fiat, or even the German Mercedes. We did not even know what was needed, either in airplanes or aviation engines, to meet the conditions as they then existed on the western front. Aviation was then a part of the work of the Signal Corps of the army. The books of the Signal Corps showed that in the nine years between the first public flight of a heavier-than-air machine and our entrance into the war only 118 'planes of all types had been delivered to the army; most of these had been destroyed or were obsolete in pattern. Sixty-six engines had been ordered; fifty-four had been delivered. The army had practically no material, personnel, or experience in the designing, producing, or use of aeronautical equipment.

The first thing we had to do was to ascertain the needs. A commission of officers and civilians was sent to Europe to study the engines used by the Allies. A survey was made to find out what was being done by American manufacturers in the building of aviation engines for European governments with the idea that such production could be increased for the benefit of the United States. But while these two investigations were going on it was decided to marshal the engineering talent and facilities available in America to design and develop a suitable engine of our own.

It was found that the time that had been required to adapt American manufacturing methods to the production of such European engines as the Hispano-Suiza and Gnome indicated the impossibility of adopting a European design in the hope of any considerable production under two or three years. It was a much more logical and practical undertaking to design an American engine, with reference in the construction

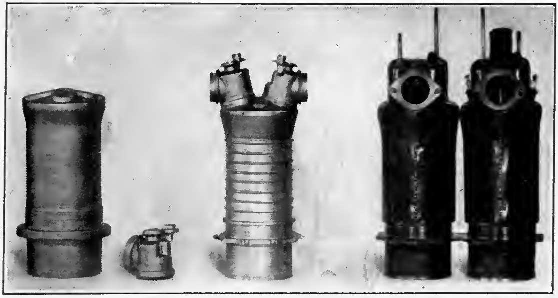


AN END VIEW OF THE LIBERTY MODEL A, THE ARMY TYPE OF MOTOR of every detail to American manufacturing methods and facilities. It was, obviously, the quickest way to produce results, since such an engine would not require radical changes in prevailing American shop practice, tool design, or the training of American mechanics.

There was not among the Allies any well-proved engine of a horse-power sufficiently large to insure its continuing suitability for two years to come. Several were in process of development over there, but up to May, 1917, none of these had been demonstrated to be an assured success, with the possible exception of the British Rolls-Royce. The highest power aviation engine then in use by the Allies, except the twelve-cylinder Rolls-Royce, which developed 250 horse-power, was the Lorraine-Dietrich, a French engine of about the same power. England at that time was manufacturing or experimenting with about thirty-seven different kinds of engines, and France had no less than forty-six different types, necessitating almost innumerable quantities of repair parts.

As soon as this situation became known to our army authorities, in May, 1917, it was decided to proceed at once to design and develop a single type of engine with unit cylinders capable of various combinations and which in either four-, six-, eight-, or twelve-cylinder engines would perform nearly, if not all, the duties which war requirements would exact, and which could be kept in repair cheaply and easily.

The designing of the American aviation engine, the Liberty motor, was a story so romantic that when it was first told to the American people, in the summer of 1917, it was received with incredulity. It was a characteristic American conception, carried out in a thoroughly American way; it stands as the most perfect example in recent technical history of that Yankee ingenuity which has for so many years excited the admiration and aroused the amazement of our European cousins, and which has furnished the theme for many romantic tales by writers like Jules Verne. It was a fresh proof to the doubters



STEEL CYLINDERS FOR LIBERTY MOTORS

Showing how the thin-steel water-jacket is attached by electric welding. This is a "Yankee trick" that puzzled the Germans.

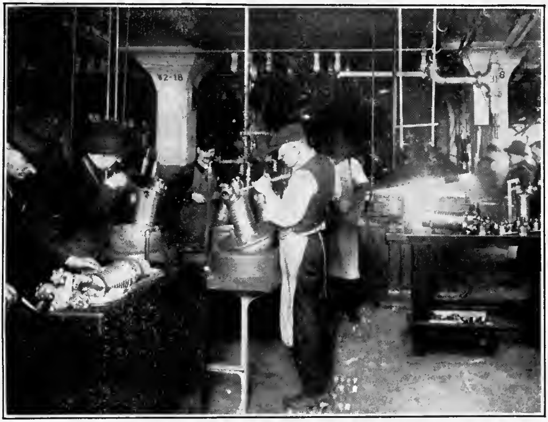
on this side and the scoffers on the other side of the Atlantic that America had lost none of its time-honored resourcefulness, that the Yankee of to-day is as ingenious as the traditional Yankee of half a century ago; it was also a demonstration and a warning to Germany that the subjects of the Kaiser had no monopoly of technical and scientific ability.

The two best qualified mechanical engineers in America for this task were called to Washington early in May, 1917. They were J. G. Vincent, vice-president and chief engineer of the Packard Motor Car Company, of Detroit, and E. J. Hall, president of the Hall-Scott Motor Company, of Berkeley, California. Mr. Vincent had for two years been working on the development of aviation engines and had built two, of approximately 100 horse-power and 200 horse-power. These engines had been designed primarily for durability and weighed about three and a half to four pounds per horse-power. They had been developed and tested in racing automobiles, but had not yet been tested in the air. Mr. Vincent had, however, made many airplane flights and had been personally for a number of years a close student of aviation and the requirements of aviation engines.

Mr. Hall had for eight years been building various types of aviation engines for foreign governments, chiefly in the Orient, and had patiently and painstakingly developed an engine which he had made in four-cylinder, six-cylinder, and twelve-cylinder sizes, having a cylinder bore of five inches with a seven-inch piston stroke.

The first requirement of the aviation engine which these two men were told to design as speedily as possible was a maximum of power and efficiency combined with the minimum of weight; the average automobile motor weighs from six to ten pounds per horse-power, while the new aviation engine must weigh two pounds or less per horse-power. Second, the new engine must be able to run as required at practically its maximum power or speed during a large percentage of its operating time; automobile motors, except in racing, rarely, if ever, run at maximum power or speed for more than a few minutes at any one period. Third, the consumption of fuel and of lubricating oil must be as limited as reasonably possible, in order to conserve space occupied in the 'plane and weight to be carried in the air.

On May 29, 1917, Mr. Vincent and Mr. Hall locked themselves in Room 201 in the New Willard Hotel in Washington, and began to design an engine calculated to produce 200 horse-power in the eight-



ASSEMBLING THE CYLINDERS OF LIBERTY MOTORS
In the background, the electric-welding apparatus for attaching the water-jackets.

cylinder size, and 300 horse-power when made with twelve cylinders. The task imposed upon the two engineers was a gigantic one. To agree upon the essential features of an engine that would work was not difficult for men of their experience; to reduce the agreed-on elements to detailed working drawings, involving the most precise and accurate calculations of dimensions and clearances, was a piece of work which in ordinary engineering practice would have occupied a staff of designers and draftsmen for many months, on a machine as detailed and complicated as an aviation motor. Vincent and Hall did it in five days and nights!

It does not detract in the least from the stupendous character of this achievement to point out that the Liberty motor, which was the result of this intensive feat of engineering, is a composite of well-tried and tested elements, principles, and methods. Vincent and Hall did not go into the hotel room with nothing but a blank sheet of paper, a set of drawing instruments, and their imaginations; they had with them working plans of internal-combustion engines of many types, and an enormous experience and intimate personal knowledge of every type of engine that had ever propelled an airplane, as well as a staff of draftsmen accustomed to making exact calculations and reducing rough sketches to precise measurements. And in designing the Liberty motor they drew heavily upon the experience and practice of others. Some of the parts were copied bodily and without essential change from the second Packard aviation motor; I have personally taken the actual parts from this Packard motor and placed them in a Liberty motor, and *vice versa*. The cylinder size which Mr. Hall had developed in the latest Hall-Scott aviation motor, five-inch bore and seven-inch stroke, was adopted; this is the largest cylinder ever used in a mobile internal-combustion engine, except the Diesel marine engine. From the Cadillac was adopted the forked-end connecting-rod. From the German Mercedes was taken the lubrication system. The crank-case of aluminum alloy resembled that of the Rolls-Royce. All previous engines of the so-called V-type—that is, having two rows of cylinders set at an angle to each other, had an angle of sixty degrees between opposite cylinders; to economize space and to lessen head resistance the Liberty motor was designed with the cylinders set at an angle of but forty-five degrees. This was a very radical departure from accepted principles of engine construction; the theory of opposed cylinders had always been that the greater the angle the more efficient the engine and the less vibration to be absorbed by the machine. Vincent and Hall believed that this theory was based upon the results of poor design rather than upon any fundamental principle, and the success of the Liberty motor has proved them right.

As fast as drawings of the different parts were completed they were passed upon by the Joint Army and Navy Technical Board, and hurried to the Packard Motor Car Company plant in Detroit, where a staff of expert toolmakers fabricated each separate part by hand. So rapidly did they work that on the 4th of July, 1917, less than six weeks after the designing of the engine was begun, an eight-cylinder Liberty motor, completely set up and running, was delivered in Washington. Tested at the Bureau of Standards, the new engine proved so much more efficient in all essential respects than any other aviation engine then known that it was immediately approved and adopted as the standard motor for American aircraft.

Meantime word had been cabled by the Signal Corps representatives overseas that the pressing need was for more power in aviation engines. This first eight-cylinder engine was immediately expanded to the twelve-cylinder size. The first twelve-cylinder Liberty motor passed its successful fifty-hour test on August 25, 1917, delivering from 301 to 320 horsepower during the test. In September, 1917, it was given its first trial in the air at Mineola, Long Island, the first time that an airplane had ever ascended from American soil with more than 150 horse-power in a single engine.

The Liberty motor was a huge success!

The hardest task, however, was yet to come. As every engineer knows, the designing of a machine and the painstaking fabrication by hand of the first experimental model is one thing; to equip factories, install machinery, make the tools and manufacture the finished product in quantities means a long, patient, tireless, heart-breaking strain. The Allies were calling for our airplanes, our men were going overseas to fight, and we had not the means wherewith to equip them with this essential arm of modern warfare. The situation called for organizing talent of the highest order, for speed unequaled in the history of industry. In ordinary commercial practice it would have been at least a year, and more likely two years, before any manufacturer would undertake to turn out the finished machines in quantities.

On the day the United States became a belligerent there had reported at Washington for service a young lawyer of Detroit who had for twelve years been a member of the United States Naval Reserve. His name was Harold H. Emmons. He had given up his law practice a few years before to become manager of a manufacturing concern operating nine different plants, which he had directed successfully. At the request of the Aircraft Production Board Lieutenant Emmons was detailed by the Navy Department to service with the army and placed in charge of engine production. The army and navy had agreed to combine their aviation programs so far as engines, among other phases of their joint needs, were concerned.

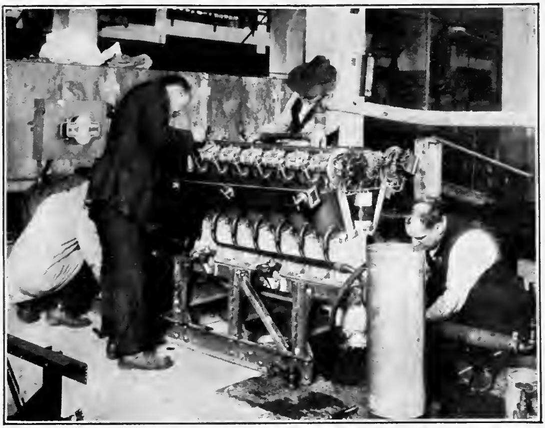
The task which Lieutenant Emmons faced was

MACHINING LIBERTY-MOTOR CYLINDERS

They are first formed from steel tubing, the closed end being welded on. Then the shape is formed by hot-forging, the ring for attaching the water-jacket shrunk on and welded, and the cylinder is then machined to its final dimensions.

even more difficult than that which Vincent and Hall had accomplished; it involved more elements of a pioneering nature. Nobody in America had ever built gasolene engines with steel cylinders except as a laboratory experiment; no machine bigger than a watch had ever been designed for such minute clearances and close tolerances; there was not a manufacturing plant in the world equipped with either machines, tools, or skilled workmen competent to produce these engines. Their manufacture involved the invention of processes which had never been used in industry, tests and measurements accurate and minute beyond anything ever done on so large a machine. Beside the Liberty motor the finest automobile engine ever manufactured is a crude, clumsy makeshift. Automobile engines, even the best of them, are made principally of cast iron; weight is no objection and strength a comparatively minor factor. The Liberty motor is made of aluminum alloys and steel; to pack 440 horse-power into 880 pounds calls for the elimination of every superfluous ounce; the resources of metallurgical skill were taxed to give every part the maximum of strength with the least amount of metal.

An engine of 60 horse-power is a giant among automobile motors; to build the 440 horse-power Liberty there wasn't an engine-shop in the country that had machines large enough to hold the parts while they were being shaped. New machines had to be designed and built; then they had to be equipped with jigs, tools, and fixtures—more than 2,500 separate and distinct kinds of these appliances. Every toolmaking shop from the Mississippi to the Atlantic coast was commandeered that was not already engaged in war work; every toolmaker who could be spared from Naval or Shipping Board work was called in. Because of the rush and the need for utilizing comparatively unskilled mechanics, and due, too, to a certain amount of pro-German interference, it was found, when the first tools were delivered at the engine plants, more than 80 per cent. of them were unfit



THE FIRST LIBERTY MOTOR TURNED OUT AT THE FORD PLANT BEING ASSEMBLED FOR ITS FINAL TEST

for use and had to be made over. In spite of this, deliveries of the Liberty motor were begun in November on the original design of a 330-horse-power engine. General Pershing cabled that more power was needed, though none of the Allies had engines even as powerful as that. The engineers "stepped up" the motor to 375 horse-power. This involved mechanical changes and new tools.

Under the increased power the crank-shafts broke.

The ablest metallurgist in the automobile industry, C. Harold Wills, of the Ford Motor Company, after weeks of study, discovered that the process which had always been used for crank-shaft manufacture caused internal strains in the forging, and devised a new process, which is already being applied to automobile manufacture—one definite contribution to peace industry arising from the war. No sooner had the crank-shaft weakness been remedied, by redesigning not only this part, but all the parts working with it, than the officers of the A. E. F. demanded still more power, and the Liberty motor was again "stepped up": this time to 440 horse-power. Many parts had again to be enlarged and the metallurgical constituents changed—but some of the new engines have delivered above 500 horse-power!

In the beginning nobody knew any better way of making steel cylinders than by boring them, slowly and expensively, out of blocks of steel; the Ford works devised a method of shaping them from cold-drawn steel tubing, slicing a piece of tube across diagonally and welding the turned-over end to form a cap. How to fasten the thin-steel outer casing of the water-jacket to the cylinder was a puzzle; the Packard Company solved it by an electric-welding process, simple in its application, yet so puzzling to the uninitiated that it is reported the Germans were unable to unravel it when they studied the first Liberty motors brought down in their lines.

Detroit contains probably more mechanics accustomed to working with micrometer calipers and gages than any other city in the world, yet so delicate are the final grindings and adjustments of the Liberty motor that those made in one plant are not interchangeable with those made in another plant, nor even with each other, without painstaking attention by a skilled machinist. It is not deemed sufficient, for instance, to finish the contiguous surfaces of the two halves of the aluminum crank-case as well as this can be done by machinery; before they are permanently mated they are "lapped" or ground to an oil-tight, gas-tight joint by rubbing them against each other with minutely pulverized ground glass as an abrasive. Those two halves *fit*, and no other part can thereafter be substituted for either of them without going through the same process. And since the crank-case is the foundation upon which the whole engine is built, a variation of a ten-thousandth of an inch resulting from this lapping must be compensated for in the fitting of every part subsequently added. It is no unfounded assertion that better automobile engines than were ever produced in America will be built in Detroit in the years to come because of the Liberty motor. Detroit knew more about engines than any other city; now it knows about working to a thousandth of an inch where it used to work in sixteenths!

How well Lieutenant Emmons succeeded in organizing and speeding up engine production is demonstrated by the fact that on May 29, 1918, just one year after the beginning of the first design of the engine, 1,100 Liberty motors had been produced and delivered into service. In January, 1918, the first three Liberty motors to go overseas were shipped to the A. E. F. In March, 1918, ten were shipped to the British, six to the French, and five to the Italians. By June 7th tests abroad had proceeded so far that the British Air Ministry cabled to Lord Reading, the British ambassador at Washington, that the excellent results obtained from the Liberty engine placed it at once in the first line of high-powered engines and convinced them that it would be a most valuable contribution to the Allied aviation program. On September 26th the British Air Ministry reported that in identical machines it performed at least as well as the Rolls-Royce, a concession the importance of which can only be appreciated by those who understand the devotion of the British to the motto, "Made in Great Britain." To any one who understands this phase of British character the admission of the equality of the Liberty motor amounts to conclusive proof that it is the better engine of the two, which means unqualifiedly the best aviation engine yet built. The Rolls-Royce is nearest to the Liberty motor in power and efficiency, but it weighs 100 pounds more and delivers 100 horse-power less than the Liberty motor, while its maximum production in England has never exceeded seventy engines per week.

Engineers of other nations were even more generous in their praise of the Liberty motor. Birkhight, the designer of the Hispano-Suiza engine in France, advised Count Poniatowski, the head of the French Technical Advisory Board on Aviation, that the Liberty engine was superior to any high-power engine developed on the Continent. Nor were these merely idle compliments. The British government at once placed an order with the American government for 1,000 Liberty motors and later asked for another 4,500 to be delivered by the end of 1918. The French made inquiry as to the possibility of securing 20 per cent. of America's total output of Liberty motors. The Italian government also indicated a desire to purchase a large number for immediate delivery. It had been planned to build 22,500 Liberty twelves to take care only of the requirements of the American army and navy. With this recognition of the superiority of the Liberty motor, increased orders for Liberty twelves up to 48,000 were placed, and 8,000 Liberty eights were ordered, while the English, French, and Italians redesigned their 'planes to adapt them for the installation of the Liberty engine.

At the time the armistice was signed there had been actually manufactured and delivered 15,572 twelve-cylinder Liberty motors, less than fifteen months after the first twelve-cylinder Liberty had been made and tested. Of these, 3,742 had been turned over to the American navy, 1,089 shipped to the Allies, 5,323 delivered at airplane-manufacturing plants, 907 sent to aviation-fields for training purposes, and 4,511 separate engines in addition to those installed in 'planes shipped to the A. E. F. in France.

There is no manner of doubt that the successful development of the Liberty motor and its production in these enormous quantities was one of the most important of the deciding factors that brought about the surrender of Germany. So long as Germany retained the control of the air she saw victory ahead. Up to the time of America's entry into the war the balance between the air forces of Germany and of the Allies was at all times very close; the loss of a few hundred airplanes by either side could at any time have meant the difference between victory and defeat. Germany scoffed when news first reached that country of America's intention to put into the air within two years several times as many 'planes as the entire forces of all the armies on the western front had ever been able to muster. Germany knew it could not be done. By November, 1918, Germany had discovered that the impossible was being done, and surrendered to Yankee ingenuity.

The troubles of Lieutenant Emmons and the builders of aviation engines did not begin and end with the Liberty motor alone. The Le Rhone, the Hispano-Suiza, and the Bugatti, three new European types of engines, production of which was under way in America when the war ended, involved complicated and difficult mechanical and technical problems. These three other types of low-power engines are used by the American air forces for various purposes. The Gnome engine, the first successful rotary motor and for years before the Great War regarded as the best of all aviation engines, was just being got into factory production in America when the war ended; it was designed principally for use in advanced training-'planes. The Bugatti was a new Italian engine, having sixteen cylinders arranged in blocks of four. It had given good service on the Italian front, where some of the officers of the American Air Service saw it and had one sent over to this country. An American motor company undertook to make it and had delivered eleven on an order of 2,000 when the armistice was signed.

The OX-5 engine and the A-7-A are low-powered motors, of types which were in general use in America for aviation before the war began. They involve no new methods or principles in their manufacture, being built of cast iron, like automobile motors, but of lighter design. Of the OX-5 the government had more than eight thousand on hand when the war ended. There were 2,250 of the A-7-A. The training of aviators, both in the army and the navy, is not to be discontinued; it will continue as a permanent measure of national defense. For this purpose, regardless of changes that may be made in types and designs of 'planes—and they will be many—there is a sufficient supply of engines in the stock on hand of these two kinds for ten years and more to come.

In point of all-around usefulness for commercial aviation, as well as for such a variety of governmental uses as mail-carrying, exploration, surveying, forest patrol, etc., extremely valuable service will be rendered by the 4,101 Hispano-Suiza and the 1,178 Le Rhone engines which were on hand when hostilities ceased. The Le Rhone is a new type of rotary engine, "the finest ever built," army officers say. It develops 80 horse-power with nine cylinders. This engine was developed in France in the third year of the war. Our officers saw it in use and advised its production in America.

Drawings and specifications were obtained from the French makers, not without a good deal of difficulty. Finally they reached America. The drawings proved almost unintelligible, the specifications impossible. A cabled request for better specifications brought the reply that the ones sent were all that were obtainable—and these contained such assertions as that the crank-shaft, the point where the greatest strain comes, was made of mild steel! Nothing could be done until a Le Rhone engine was obtained and shipped over. Every part of it was first measured and copied in exact model, then turned over to metallurgical chemists, who subjected it to analysis, while American engineers undertook to improve the design of the engine construction. As a result the Le Rhone engines turned out in America are of better material than the French makers used, and a loss of power that, in the French engine, ran as high as 33⅓ per cent. has been reduced to 3 per cent. Many French engineers who were inclined to scoff at American manufacturing methods were converted when they had an opportunity to witness the performance of some of the 250 Le Rhone engines made in this country and shipped to the A. E. F., and to compare them with the motors of the same type made in their own plants.

The Hispano-Suiza engine is a Spanish motor which was being manufactured under contract for the French government by an American company when the United States entered the war, although actual production had not begun. This is an eight-cylinder engine and is the only motor with steel cylinders manufactured in the United States before the Liberty motor was produced. It is made in three sizes, of 150, 180, and 300 horse-power. It is an engine of the highest grade, but weighs more per horse-power than the Liberty. Like all other aviation engines, production of this machine was placed under the control of the Aircraft Production Board. The best proof of the wisdom of the Aircraft Production Board in undertaking to design and build a completely new American motor is found in the fact that, with completed engines before them to work from, a corps of French engineers and machinists who had worked in the manufacture of them and adequate capital and equipment, it had taken the Wright-Martin Aircraft Corporation thirteen months from the time of beginning to make the tools before they were able to produce their first Hispano-Suiza motor.

III

THE CREATION OF THE AIRPLANE INDUSTRY

IF the path of the designers and builders of airplane engines was beset with obstacles, that of the men who undertook to establish an airplane industry in America was even more perilous. How they overcame it will some day be recognized as one of the most romantic chapters of America's industrial and technical history. Misrepresentations and undue boastfulness so magnified the proposed program in the public mind that the prevailing impression is undoubtedly one of woeful failure. On the contrary, when our country's almost total unpreparedness in aircraft plants and knowledge of the methods of manufacture is considered, the achievement of producing in eighteen months more airplanes than all the Allies had built since the beginning of the war is something to be proud of.

There has been much emphasis laid on the delays and difficulties incident to the selection and determination upon particular types of planes; the truly romantic story of the airplane as developed and produced under war's stress is one of almost superhuman struggle against unknown and overwhelming odds. There was no chart or compass for the unknown seas that had to be navigated by those who undertook to build our aerial fleet. There was at least a body of experience in engine construction and tool design to guide the builders of engines, but no manufacturer had ever engaged in any business comparable to the airplane industry. The principles of construction had to be mastered, the material to be used not only to be determined upon, but invented, discovered, or improvised. To decide that spruce was needed was one thing; to get the spruce meant, first, exploration of unmapped forests, then the development and application of new methods of lumbering, of seasoning, and of shipping the wood. When all the Irish linen in the world was used up and millions of yards of fabric were still needed for airplane wing-coverings, a new fabric had to be invented and spindles and looms converted to its manufacture. The whole earth did not produce the oil needed to lubricate the high-speed airplane engines at the temperatures involved in active service; plantations of castor-beans had to be set out and mills erected for expressing the oil. Did airplane propellers fly apart? We invented a glue that makes a joint stronger than the solid wood itself! And these are but a few of the problems that had to be solved before we could even begin to build airplanes in quantity.

When hostilities began in 1914 the airplane was a toy. Its manufacture was in the hands of inventors and experimenters, whose aim was to make each succeeding machine an improvement on its predecessor, with the result that it is extremely doubtful whether, outside of Germany, there had ever been built two airplanes exactly alike. The scientific principles of aerodynamics were barely beginning to be understood. A thousand engineers with a thousand conflicting theories were struggling with the problems of stresses and strains, engine power and wing design, but the airplane was still chiefly a toy, and an extremely dangerous toy at that. Poets and men of vision had dreamed of

> . . . Heavens filled with commerce, argosies of magic sails,
> Pilots of the purple twilight, dropping down with costly bales.

But hard-headed men of affairs looked askance at the fantastic dreams of passenger-carrying, freight-carrying airplanes. Under the slow and orderly

MAKING THE TIDE HELP

One of the rafts of airplane spruce floated to the desired point on shore by scientific utilization of tides and ocean currents.

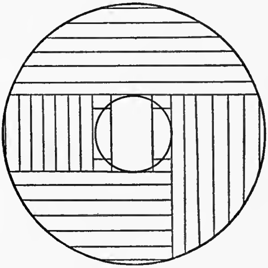
processes of peace-time development there might have come a time, perhaps fifty years hence, perhaps a hundred, when these dreams would be realized. Four years of war have brought them to what amounts to a complete realization.

For nearly three years before the United States entered the war American companies were building 'planes and parts of 'planes for the Allies. Their experience was the only foundation we had on which to erect the huge program we undertook in 1917. To-day the manufacture of heavier-than-air flying-machines and their equipment is a well-defined, thoroughly understood, and fairly commercialized industry. The men in control, who have developed this industry, are among the solid, substantial business men of America and Europe. The dangerous toy of five years ago became, first, the most spectacular of all the tools of war, and in its development to that end became as safe and stable a vehicle as the automobile itself, in that risk to life and limb in a properly constructed modern airplane is hardly greater than the risk to life and limb in an automobile; the most serious danger in the operation of either lies in lack of skill or want of care on the part of the driver.

Aerodynamics, from a mystery, has become a well-understood branch of science; theories have been scrapped; demonstrated, accepted facts have taken their place. That is not to say that the airplane for any particular purpose has been either perfected or standardized; neither has the automobile or, for that matter, the steam-engine. But we know to-day how to build airplanes, in quantities, cheaply by comparison with methods that formerly obtained, what materials to use and where and how to obtain them, and we have actually built thousands and tens of thousands of many types, adaptable to a wide variety of commercial peace-time uses.

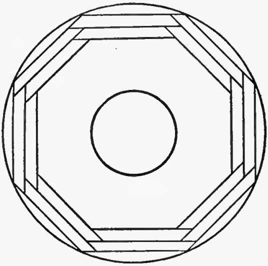
Moreover, in the development in America of the airplane and airplane-engine industry from almost absolute zero to a state of productivity almost unbelievable, in a period of eighteen months, we have not only furnished one of the demonstrations of our technical and industrial superiority over Germany, but have actually added to the world's wealth in many collateral and unrelated lines of activity by the enforced necessity of devising, inventing, and applying materials and methods that were unknown or non-existent before America undertook the gigantic task of building an aerial fleet that would, by sheer weight of numbers, beat down the last of Germany's defenses.

When the United States entered the war our army possessed few airplanes and still fewer engines suit-



HOW TO CUT A LOG WITHOUT WASTE

This diagram shows the sawyer how to get the largest number of feet of straight-grained airplane stock from spruce logs. The cuts are made parallel to the bark; the coarse heart-wood, indicated by the inner circle, is worthless for airplanes.



HOW TO GET ALL STRAIGHT-GRAIN STOCK

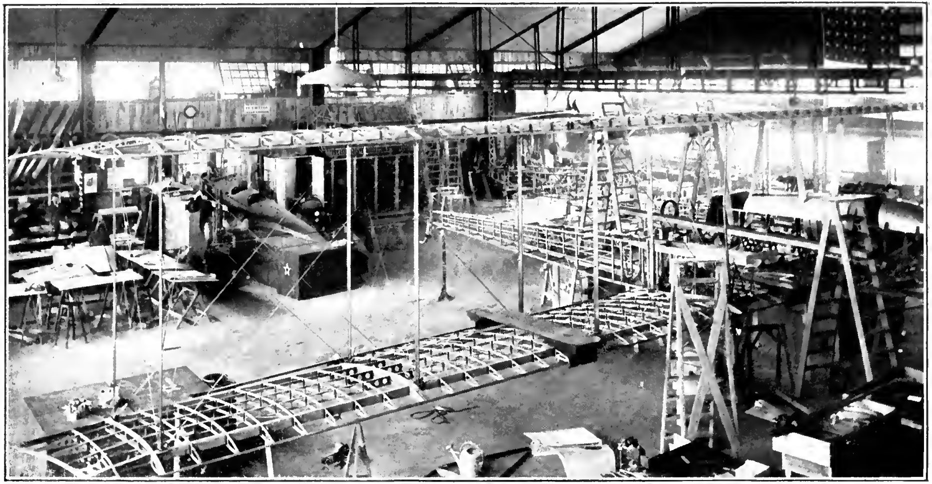
A peculiarity of spruce is the "twisted grain" that is frequently found. By sawing the logs as indicated in this diagram it has been found possible to obtain practically straight-grained airplane stock from such trees.

able for the propulsion of aircraft. An official survey of our military airplane situation made on May 12, 1917, showed that in the eight preceding years the United States army had ordered 334 airplanes from sixteen manufacturers; these were of ten types and thirty-two different designs, and, as I have already pointed out, only a portion of them had ever been delivered to the army.

When the armistice was signed, eighteen months later, the United States military forces had on hand 12,285 airplanes. 'Plane production was increasing at a rate that would have given us 10,000 service-'planes by the summer of 1919, although it had been agreed between the United States and the Allies that this country should contribute proportionately more engines than 'planes, partly because, while we could make engines faster than Europe could, they had developed their 'plane-making capacity to a higher degree, and partly because the shipment abroad of engines was a simple matter in comparison with the shipment of finished 'planes.

In learning how to build airplanes we literally did so "from the ground up." There is no phase of our war story that carries a stronger flavor of romance or paints a truer picture of a winning fight against overwhelming odds than that of the "Spruce Regiments." It is more than merely an interesting story, for in learning how most efficiently and economically to obtain the spruce lumber needed for airplane construction, or, rather, in applying the knowledge which the United States Forest Service had acquired through years of scientific research, but which had been scoffed at by "practical" lumbermen, we have learned how to achieve the apparent paradox of obtaining high-grade lumber more cheaply and at the same time conserving our forest resources.

This has come about through the intensive application of scientific methods to every detail of the process of converting spruce-trees into the wings of the army and navy, from the exploration of the forest to the shipment of the finished lumber. Moreover, in the treatment and technical manipulation of the wood in the airplane plants and factories, there were developed, under the pressure of war needs, new methods



INSIDE AN AIRPLANE FACTORY

In the foreground is the skeleton frame of one of the giant Handley-Page night-bombing 'planes built for our army; the smaller 'planes in the background are De Havilland 4's.

and processes, the application of which to a thousand of the arts and industries of peace is of the greatest value and importance.

Spruce was essential for airplanes and airplanes were essential for winning the war. Other factors contributed, of course, from doughboys to dreadnoughts, but without the numerical superiority of aircraft on the side of the Allies Germany would not have been forced to quit when she did. And nothing takes the place of spruce for airplanes. Other woods are as tough, but heavier; the difference in speed between a 'plane made of spruce and one of fir, for instance, on the same model, is measured by miles per hour. Spruce is elastic, absorbing shocks instead of breaking under them. Clear, straight-grained spruce does not splinter when hit by a bullet; the missile passes through, leaving a clean, round hole that does not materially weaken the structure.

Even before the United States entered the war the forests of the East and parts of the Far West were being cruised for spruce for the Allies' airplane needs. When we came in and our airplane program was fixed at 22,500 training- and service-'planes by the spring of 1919, the first and vital question to be answered was, "Where can we get the spruce?"

Clear, straight-grained spruce had been almost an unknown commercial commodity for many years; many lumbermen were shipping spruce to the Allies, but the waste was terrific. Out of a million feet of lumber perhaps a hundred thousand might be usable; this, with the waste involved in shaping the parts from the rough timbers or "cants," might build a hundred airplanes. And the agents of the Allies were paying up to $300 a thousand feet for this stuff and taking whatever they could get at that price. Clearly, new sources of spruce and new methods of getting it out must be found if our needs and the growing needs of the Allies were to be supplied. So the government at Washington decided to go into the lumber business and provide spruce for everybody.

There was spruce in plenty, the giant Sitka spruce especially, with its huge trunks measuring from six

A SITKA SPRUCE LOG
Many of these trees cut up for airplane stock measured twelve feet in diameter.

to ten or twelve feet through at the butt, on the west slope of the Coast Range in northern Oregon and Washington. But that country had never been lumbered; there were no railroads, hardly any other roads.

Mills were a long way off; besides, there were labor troubles, fomented by the I. W. W. and German influences. Lumbermen looked at the government program and said, "It can't be done." One man said it could be done. He had been thinking about this spruce problem and the Sitka spruce of the Pacific coast, and he thought he knew how to get the lumber out. So they told him at Washington to go ahead and see what he could do.

This is what he did in a little more than one year:

Located more than eleven billion feet of spruce in a fifty-mile strip of forest.

Built thirteen lines of railroad, with 167 miles of main line and 149 miles of branches, to tap the territory containing 2,345,000,000 feet of this lumber.

Built the largest sawmill in the world, and three smaller ones.

Organized the "Loyal Legion of Loggers and Lumbermen," with 90,000 members, and put an end to labor troubles in the logging camps and mills.

Sent an army of 30,000 soldiers into the woods to fight the Hun with axes and saws.

Produced 104,351,000 feet of airplane spruce and 72,385,000 feet of fir, of which 69,879,000 feet of spruce and 52,932,000 feet of fir were shipped to the Allies.

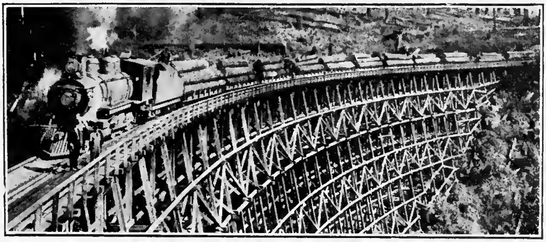
Cut the cost of spruce, including total cost of railroads, sawmills, and all permanent improvements, to $180 a thousand feet.

These are merely the gross results of the work of Brig.-Gen. Price P. Disque, the man whose combination of vision and force gave the United States and all the Allies spruce when they needed it worst.

When the United States entered the war General Disque had tried to get back into the service with his old rank of cavalry captain. He had enlisted in the regular army as a private in 1899, been promoted to a commission while serving in the Philippines, and had resigned to become warden of the Michigan

State Penitentiary. Here he had made the unique record of placing a penal institution on a self-supporting basis, by developing the industrial abilities of its inmates and marketing their product at prices that paid the entire cost of maintaining the institution.

Instead of getting back into the cavalry he was commissioned a lieutenant-colonel in the Signal Corps



HAULING SPRUCE LOGS TO THE GOVERNMENT AIRPLANE SAWMILL

Hundreds of miles of railroad like this were built to get the lumber needed for airplanes.

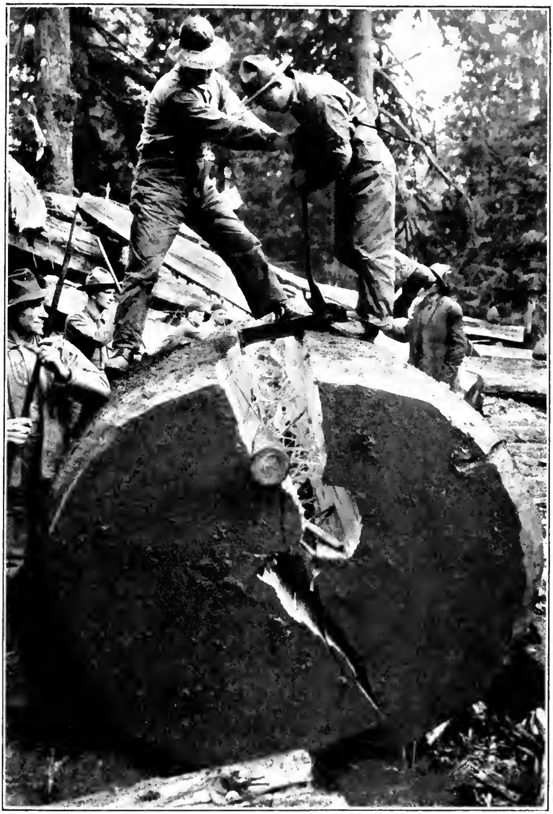
and assigned to the job of getting out spruce, because he had once expressed himself as believing that all the spruce needed could be got out of the west slope of the Coast Range. He was not an engineer and had no experience in lumbering, but, as events proved, he was an organizer with a profound knowledge of human nature and a rare belief in the efficacy of scientific methods properly applied.

Old-fashioned methods of lumbering were to cut every tree in the area logged. Colonel Disque called on the Forest Service for expert advice, and the first program of scientific forestry on an important scale was begun.

"Cruisers" were sent into the woods, with carefully prepared maps on a large scale, and told to indicate on these maps the spruce and fir trees conforming to certain specified requirements. Commercial lumbermen sat back and laughed; such piecemeal methods would never succeed, they were sure. But the "cruisers" came back with their maps thickly dotted in certain sections, less thickly dotted in others, hardly dotted at all in places where the lumbermen had advised running roads. There was spruce in these places, true, but not big enough or straight enough for what was needed.

No time was wasted on those areas, but railroad lines were surveyed and run right into the heart of the thickest stands of the biggest timber. There was no guesswork about it. Where the survey showed a railroad cost of less than three dollars a thousand feet of spruce tapped by the line, it paid to build the railroad. The croakers predicted the roads couldn't be built; steel couldn't be got for the bridges and trestles. The bridges and trestles, built of logs, but built with all the scientific accuracy of the most modern steel structure, that carry these thirteen railroads into the woods, are marvels of engineering. And into the tracts where there wasn't enough airplane spruce to pay for running railroads there were built motor roads, "corduroy" paved, so that motor-trucks could bring the logs out.

With the old method of sawing logs into lumber the log is first "squared," then sawed into beams and boards. That answers for ordinary purposes, but for airplanes it caused great waste, for the grain of the tree runs parallel with the bark, and the timbers got out in the old way were sawed parallel to the heart, so the grain ran diagonally. This meant that two-thirds of almost every timber had to be cut away



RIVING A SPRUCE LOG FOR AIRPLANE STOCK

Every piece of wood that goes into an airplane must be perfectly straight-grained. As the spruce grows often with a spiral grain, the timbers or "cants" must be split or rived from the log instead of being sawed.

before a straight-grained piece was available. There is not much more than a hundred board-feet of lumber in an airplane, but it used to take a thousand feet of stuff as it came from the sawmill to get this amount of straight-grained stock; now the loss is less than one-third of what it used to be.

First the difficulty was overcome by splitting the logs—"riving," they call it in the lumber-camps. A split log naturally follows the run of the grain. Only rived beams, or cants, were accepted, until Colonel Disque got his big sawmill running at Vancouver, Washington. Then he brought in expert sawyers from the Eastern hardwood mills, who introduced a method of sawing that follows the grain wherever it runs. Even the spiral grain peculiar to spruce-trees, but never considered of importance before, does not baffle the scientific sawmill man who uses the new methods.

For some unexplained reason spruce-trees have a tendency to twist while growing; one recently felled in Alaska had made five complete revolutions in its eighty-three years of life, as the corkscrew-twisted grain disclosed. Clear, straight-grained planks, fit to go into airplanes, are sawed from even these twisted trunks in the Vancouver mill.

The commercial mills were not getting out enough good airplane stock—only 25 per cent. of their output was fit for that use. Colonel Disque decided to build the biggest sawmill in the world. Lumbermen said it would take a year. It was finished in forty-five working days! In this mill 65 per cent. of the spruce brought in was converted into perfect airplane lumber—and a big commercial market was made for the planks, beams, and boards that did not come up to airplane specifications, in sections where Western spruce was never used before.

The Vancouver mill covers about five acres. It is operated for quality rather than quantity. A model of a finished airplane wing beam serves as a guide to the sawyers who make the final cuts that reduce the logs to shipping dimensions.

Riving great logs where they fall, so they can be brought out by motor-truck; utilizing tides and ocean currents, scientifically studied, to bring log rafts to shore at determined points without the dangerous towing through the surf—these and a hundred technical details and refinements have revolutionized lumbering methods in the Northwest, because the hard-headed, "practical" lumbermen, having seen the results demonstrated, have been quick to adopt the new methods.

Felling trees and sawing them into lumber isn't all that has to be done before you build airplanes out of the product, however. Green lumber won't do, and the processes of seasoning that have been mainly used either take too long—a couple of years or less—or make the wood crack and check and warp, or both. Here, again, science scored a victory, in the application to war's necessities of a method of seasoning developed through patient laboratory research.

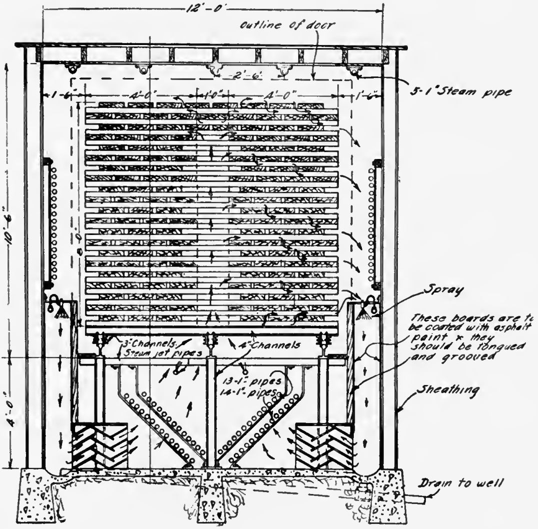
Under the quickest method of kiln-drying lumber in ordinary commercial use, from six to eight weeks were required, and lumber so seasoned was seldom satisfactory, shrinking in dry weather and swelling in damp climates. Open-air seasoning took a year or more; either process took no account of internal strains that cause splitting and "checking."

For years the Forest Service Laboratory at Madison, Wisconsin, had been giving the most intensive scientific study to the subject of wood-seasoning. Almost at the beginning of the war an experiment was perfected on a commercial scale. The patents had already been dedicated to public use by H. D. Tiemann, the inventor of the process, and it was immediately put into effect for the seasoning of airplane lumber.

It has been a wonderful success. Huge kilns using the Tiemann process have been erected at Vancouver and other sawmill points on the coast, and the seasoning process, which formerly took many weeks, now takes from eight to fourteen days! Moreover, the method being based upon scientific study of the internal composition of wood and the multiplicity of elements that enter into its behavior under given conditions, wood seasoned by the new process is not only free from all defects of the old methods, but actually stronger, more elastic, and tougher than when air-dried.

The Tiemann dry kiln is merely a closed chamber in which the lumber is piled in a certain specified way and the temperature and humidity are definitely and automatically regulated in proportion to the progress of the seasoning process. The lumber is dried from the inside toward the surface, at a speed carefully calculated for each kind and size of wood. Water-sprays keep the confined atmosphere of the kiln at a predetermined degree of humidity; there is no guesswork about the procedure at any stage, and the result is perfect lumber.

I hardly need to point out the permanent industrial value of a process of wood-seasoning that not only saves time and money, but gives a better product than was obtainable before at any cost. To the furniture-maker who would like to build bureau-drawers that won't stick in summer and rattle in winter, to the user of wood for every purpose from house-building to the manufacture of ukuleles, the war demonstration of this scientific method and its commercial practicability has proved a heritage of great and continuing value.



THE KILN THAT MADE OUR AIRPLANE PROGRAM POSSIBLE

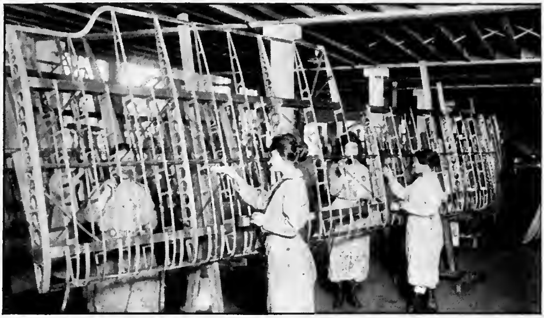
Diagram showing the operation of the Tiemann dry kiln for seasoning lumber in two weeks or less, where it formerly took a year or more. Through the use of this kiln, which was developed by the Forest Service and dedicated to public use, we were able to turn out enough seasoned spruce for our own and the Allies' airplane needs.

What has been learned about the manipulation of lumber by the makers of aircraft is not without its permanent and valuable import in the arts of peace. Not only have the builders of airplanes had to master the fundamentals of the new science of aerodynamics, with which business men were totally unfamiliar, but they had to apply to the fabrication of devices of wood and canvas manufacturing and production methods that had not before been applied except to metal products. They learned as they built, until now we know vastly more about wooden construction than ever was known before by any considerable body of business men.

The whole fabric of an airplane is composed, as one engineer puts it, of "struts, stretchers, stresses, and strains." Incredibly light and thin veneers, glued together, give almost the strength of steel. Braces and beams that look like solid wood, but that are in reality only shells, with the internal substance cut away by carefully determined rules and measurements, until they weigh half what they did before, prove as strong as solid sticks. As delicate as a grasshopper's wing, the transverse webs that shape the airplane's wings are carved from the thinnest of boards, yet under the strain of the piano-wire braces they hold like rigid iron. The secret is, first, straight-grained, clear, properly seasoned spruce, and, second, glue.

Perhaps nothing more revolutionary has resulted from the scientific research set on foot by the war than the casein glue, invented in the United States Bureau of Standards and now universally used in airplane construction. Ordinary glue is made from hoofs, horns, cartilage from the slaughter-houses, from the trimming of hides and other animal scrap; the better grades are made from the sounds, or air-bladders, of codfish. But the best glue ordinarily in use had proved not good enough for airplane manufacture. When we sent airplanes to the Mexican border in 1916 they literally fell to pieces in the hot, humid climate; propellers, which are built up of laminations of wood, laid end for end to get an exact balance, flew apart at high speeds; the glue would not hold.

Seeking new sources from which to obtain a supply of a suitable adhesive, the government scientists hit



WORKERS IN A NEW ART

Before we could build a single effective military airplane we had to train the thousands of workers in an industry that had no traditions, no history, and no foundation on which to build.

upon casein, the remarkable substance obtained from skimmed milk, from which almost anything, apparently, can be made. Casein has been used to make billiard-balls, for a thousand other things to imitate ivory and to replace celluloid with a non-inflammable substitute, but that it would yield a glue was undreamed of. The process was quickly developed and half a dozen large factories were soon producing this and another new glue made from blood, in great quantities.

The new casein glue is applied cold. It sets in six hours, and there is no chance for the user to change his mind thereafter. I saw a propeller, the laminations of which had been fastened together with this glue, that had been *boiled for five days*, yet under a laboratory test the wood itself—tough oak and walnut—pulled apart and the glue did not yield!

I do not need to point out the commercial and industrial importance and permanent value of this war-developed invention; any one's imagination will readily picture furniture that can safely be left out on the summer porch, violins that will not suffer from sea-travel, tables and chairs that can be placed close to the radiator without falling to pieces—these are only the perfectly obvious applications of the new glue. But its range of usefulness may be far wider. Packing-boxes put together without nails may be only a forerunner of houses built so solidly of glued-on veneer weather-boarding that they will outlast the centuries. With the new adhesive wood is welded together as solidly as the blacksmith welds two iron bars into one.

After the wood has been fashioned and glued and wired into place comes the wing-cover fabric, without which the airplane would still be but a skeleton. Up to America's entry into the war but one material was available for this purpose—Irish linen. Linen had certain definite advantages over all other fabrics: the fineness, strength, and length of the fiber made it at once the most durable and the least likely to tear when punctured.

A bullet-hole through stretched cotton cloth speedily becomes a huge, jagged rent and a crash follows; through Irish linen it remains a round bullet-hole, and the 'plane can fly with a couple of dozen or more of such punctures. One French 'plane, early in the war, returned safely from a trip over the enemy's lines with 142 bullet-holes in its wings.

But all the linen Ireland could weave was not enough for the stimulated production of 'planes when

COVERING AN AIRPLANE'S WINGS

Girls sewing the Yankee substitute for Irish linen on the wing-frame of a De Havilland 4.

we got into the war. Little flax is grown in Ireland; it comes mainly from Russia and Belgium. These supplies were curtailed, and even though flax could have been grown elsewhere it would have to be sent to Ireland to be spun and woven, for in no other accessible part of the globe is there the combination of temperature, humidity, and mineral constituents in the water necessary to "rot" the flax and make it yield up fiber of precisely the quality required.

American scientists experimented with a hundred substitutes. Silk would not answer, and could not be got in the quantities needed; no metal, even as light as aluminium, would stand up under the vibration. There was one American fiber that might do, sea-island cotton. It was used only for sewing-thread and for the finest, sheerest fabrics, however. There were neither spindles nor looms adapted to convert it into the heavy fabric needed for airplanes. Laboratory experiments proved that it could be woven into a wonderful cloth. Tests of this cloth, stretched diagonally on the airplane wings, indicated that the perfect substitute for Irish linen had been found.

The government practically commandeered the big cotton-mills at Fall River and set them to work on the new cloth. We had almost used up all the Irish linen we could get—3,187,000 yards—when the new fabric became available. At the time the armistice was signed we had produced 7,790,000 yards of airplane cloth, thousands of 'planes had been built of it, and in every way it had done all that was required of it. And our cotton manufacturers had learned something new—how to make a cloth that will supply hundreds of the purposes for which Irish linen has been used, that will wear like iron, is almost waterproof and looks as well as it wears, its mercerized threads giving it a smoothness of finish comparable to linen itself.

After the cloth has been stretched on the wings it is treated with a varnish known in the aircraft industry simply as "dope." Dope has the peculiar quality of shrinking the fabric permanently, so that it is as taut as a drum-head, and of rendering it waterproof, while at the same time penetrating the fibers and practically gluing them together, reducing the danger of tearing. The principal constituent of dope is glacial acetic acid. This is derived from the dis-

PUTTING ON THE "DOPE"

"Dope" is the term used in the aircraft industry for the acetone varnish that renders the fabric waterproof and at the same time shrinks it tight to the frame and sticks the fibers together so the cloth does not tear when pierced by a bullet.

tillation of wood, in the manufacture of wood alcohol. To produce dope in sufficient quantities new alcohol stills were set up and new processes devised that are of considerable commercial importance in many branches of industry.

Castor-oil is the only lubricant available in quantities that can be used in airplanes when high altitudes are to be negotiated. In the extreme low temperatures of the upper air the best mineral lubricants chill and even freeze; castor-oil remains fluid at many degrees below zero. Belligerent Europe was using the world's supply of castor-oil, so, while our airplane-production program was getting under way, the government arranged for great castor-bean plantations in Florida and Texas and for mills to express the oil from the beans. By the time we had the 'planes and engines ready there was oil aplenty for their lubrication.

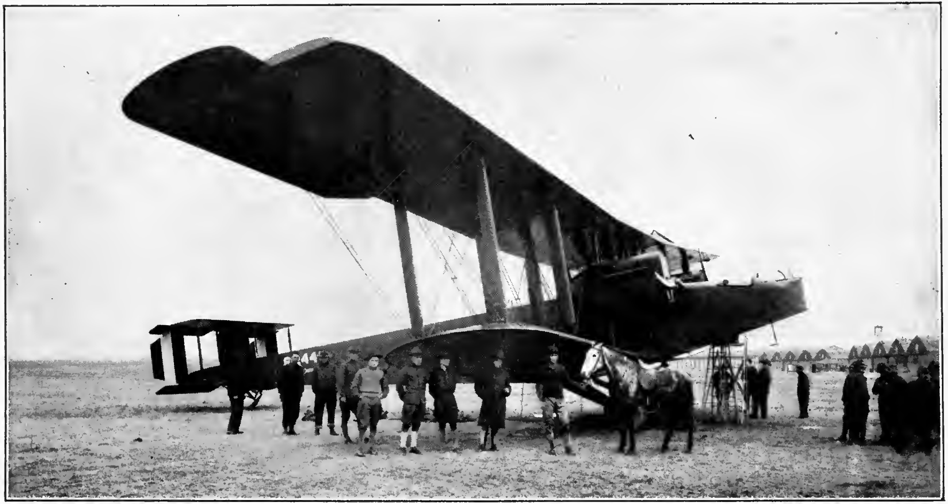
IV

AMERICAN MILITARY AIRPLANES

AS I have already indicated, there was in the United States at the time of this country's entrance into the war almost no experience or practical knowledge of modern methods of airplane designing and construction. While European governments, for six years before the outbreak of the Great War in 1914, had made huge annual appropriations for aircraft experimentation, the government of the United States had given so little encouragement to the development of this distinctive American invention that, even as late as the summer of 1917, after this country had become a belligerent, we had no authoritative information, in the possession either of the government or of private individuals, upon which to base a determination as to types and designs of 'planes that would be useful in war, nor plants equipped to build fighting airplanes and their essential accessories. Still less did we have either facilities for training aviators or competent instructors.

Europe was still experimenting, it is true; with 'planes as with a thousand other elements of military equipment, the effort to overcome Germany's tremendous initial advantage kept the resourcefulness of the Allies at all times strained to its utmost limit. But, although none of the Allied nations ever succeeded in putting into service on the western front a 'plane as well designed for its purpose as the best of the German 'planes, the French and English had, by midsummer of 1916, succeeded in taking control of the air away from the enemy by sheer force of numerical superiority in 'planes, and of better engines than the Germans had. And in the struggle to gain and hold air control there had been developed 'planes which, in design and construction, were superior in every detail to even the most advanced experimental machines that had ever been built in America.

One American concern, the Curtiss Company at Buffalo, had been building training-'planes for the British and Canadian governments and a few flying-boats for the British navy before America's entrance into the war. There were not more than four or five other airplane manufacturers who had ever built as many as ten machines, and there were a dozen or more companies and individuals each of which had built from one to a half-dozen airplanes of different types, mostly for exhibition purposes. There our aircraft-manufacturing experience began and ended. There were probably a dozen men in America who had more or less experience in the designing of flying-machines, but none who even remotely comprehended the progress that had been made in Europe and was competent to design a complete fighting-machine. Not a single airplane had ever been built in the United States equipped to carry a machine-gun, nor was there an aircraft machine-gun being manufactured in America. These facts, which I have here briefly summarized, must be thoroughly understood if one is to realize even incompletely what a triumph of Yankee resourcefulness and ingenuity our actual achievement in airplane design, construction, and equipment really was.



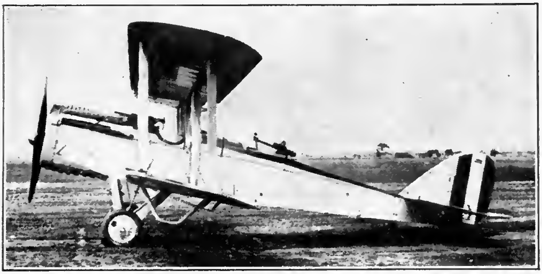
AMERICA'S LARGEST OVERLAND FLIER

The Handley-Page night-bomber, built in the United States from an English design.

It was not until after General Pershing had arrived in France with the first detachments of the American Expeditionary Forces that a decision was arrived at even as to the main outlines of America's aviation program for the war. Seventeen months later, when the armistice was signed, there had been completed, equipped, and put into service by the United States 11,804 military airplanes of all kinds, including 3,765 combat-'planes, of which 2,899 had been shipped overseas to the A. E. F. This does not take into account more than 4,000 'planes which we had bought from the French, in pursuance of the policy agreed upon between General Pershing and the Allied governments immediately upon his arrival in France, that the United States should leave the production of single-seat fighters and pursuit-'planes to the French and British, who were by this time adequately equipped to produce these in quantities, and that we should concentrate our efforts, beyond the production of necessary training-'planes for our own fighters, upon two-seated observation-'planes and the larger and heavier type of bombing-machine.

Between our state of total unpreparedness in aviation existing on June 1, 1917, and the record of airplane production up to November 11, 1918, there lies the story of a stupendous battle against time and the limitations of men and materials. The mechanical miracles that had to be performed, the superhuman achievements for which men were daily called upon in the execution of our airplane program, were so terrific that, had they been foreseen, it is doubtful whether men could have been by any means persuaded to undertake them. It was only our blissful ignorance of the magnitude of the obstacles to be overcome that made possible the adoption and acceptance of the 'plans which ultimately were successfully worked out.

I do not propose to tell here the details of the execution of the entire airplane program, romantic as



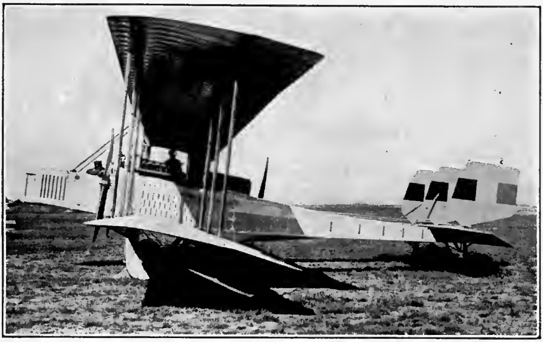
AMERICA'S STANDARD FIGHTING AIRPLANE

Two views of the De Havilland-4, the two-seated observation- and combat-'plane manufactured in this country for use overseas.

are many of the episodes of the conversion of factories of every sort into aircraft plants, the creation almost overnight of a huge industry, the training of tens of thousands of workers in new arts and handicrafts, and the reduction to standard shop practice of construction methods that had previously been individual and experimental. I can touch only upon the distinctively American contributions to the science and art of military aviation that helped us to win the war.

In the manufacture of the 'planes themselves we undertook no such radical and revolutionary departure from European practice as we did in the matter of motors; the Liberty motor stands as the one completely American achievement of this sort. Our 'plane program called merely for the duplication of types and designs already proved out in practice by the European Allies, with some adaptations to permit the use of the Liberty motor in place of the engines for which they had originally been designed. For the elementary training of our airmen we adopted the standard type of training-'plane already being manufactured by the Curtiss Company for the British. It was the original intention to use an English machine—the Bristol biplane—for use as an advanced training-'plane for our own aviators. The Bristol 'plane was redesigned to take the twelve-cylinder Liberty motor. This turned out to be our most serious and important failure, and after a number of men had been killed by the collapse of Bristol machines on their first trials, due to faulty engineering in the redesigning, this type of 'plane was abandoned and an improved type of Curtiss machine substituted for advanced training purposes. And for our standard combat-'plane, for observation and bombing, we copied as closely as possible the English De Havilland-4.

In redesigning the De Havilland-4 to take the Liberty motor, our engineers were more successful than with the Bristol. American-built De Havilland-4's in service on the western front, and in use for advanced training of airmen in America, did all and more than was expected of them. The American De Havilland-4 is a two-seater observation biplane. It measures 42 feet 5 3/8 inches from tip to tip of the upper wings, and has an over-all length, fore and aft, of 29 feet 7 inches. Resting on the ground it measures



THE AMERICAN CAPRONI NIGHT-BOMBING 'PLANE
When the war ended we were beginning to build these huge machines of Italian design.

10 feet 1 inch to the highest point of the upper wing. It has a total wing surface of 439 square feet, and its total weight, fully equipped and ready for flight, is 3,868 pounds, or 8.8 pounds per square foot of wing surface. Equipped with the 400-horse-power Liberty motor, it has an officially recorded speed of 120 miles an hour at a height of 6,500 feet. In spite of the fact that it carries a heavier load per square foot of wing surface than any of the observation-'planes used by the Allies, the greater horse-power of the Liberty motor makes it the fastest of all the observation-'planes that were in service prior to the signing of the

armistice. And to complete the statistical record of the American De Havilland-4, I note here that it can climb in eight minutes to a height of 6,500 feet, in fourteen minutes to the height of 10,000 feet, and in twenty-four minutes to the height of 15,000 feet; that its "ceiling," or limit of height to which it can fly, is approximately 20,000 feet or slightly under four miles.

While classed as a combat-'plane, in that it is a machine used for active service at the front and not primarily and exclusively for training, the De Havilland-4 is not one of the types of airplanes used by fighting fliers for the daredevil exploits that make the stories of aerial warfare read like pages from the romances of chivalry. All of the airplanes of that class, the so-called scout and pursuit 'planes, used by American airmen in the war, were the product of French manufacturers. But, spectacular as are such aerial combats, they are only incidental to the real purposes of military aviation which are, first, observation of the enemy's movements and positions, and, second, the dropping of bombs. The fast-flying, high-climbing single-seat fighting-'planes have as their reason for existence merely the protection of the necessarily heavier observation and bombing 'planes. These heavier 'planes carry even more fighting equipment than do the single-seaters, but they are armed chiefly for defense. In another chapter I describe some of the "Yankee tricks" in the fighting and observation equipment of airplanes that in the last months of the war played a decisive part in bringing about the Allied victory.

Early in the war airplanes were used by the Allies solely for observation purposes. As the war progressed, and German raids upon hospitals and unfortified towns brought home to the Allies the full realization of the fact that they had to deal with a foe that had deliberately discarded every rule of civilized warfare, the use of aerial bombs against the Germans was sanctioned and, by the time the United States entered the war, bombing of the enemy's positions both by day and night had become standard military practice. For bombing-'planes, also, we adopted European models, the De Havilland-9 for day bombing, a machine differing only in minor details from the De Havilland-4; for night bombing we began the construction in this country of the Handley-Page, the largest of all military airplanes, and the Caproni, an Italian 'plane almost as large. At the signing of the armistice we had built and delivered to the A. E. F. one hundred of the great Handley-Page 'planes, measuring 100 feet across the wings, with an over-all length of 62 feet 10 inches and a height of 22 feet. These great 'planes, weighing more than 14,000 pounds, and with a wing surface of 1,642 square feet, can carry nearly a ton of bombs in addition to the crew of four men, and fly at a speed of eighty-two miles an hour. The Caproni is almost as powerful a machine, although of less wing spread. It flies at a higher speed than the Handley-Page, and carries approximately the same useful load of bombs. American-built Handley-Pages and Capronies, the former equipped with two Liberty motors each, and the latter with three, rank among the noteworthy technical achievements of the American airplane industry, so suddenly developed under war pressure from practically nothing at all. Airplanes of both these types, although built from European designs, made better records in the air in every respect than their exact prototypes produced on the other side, so cleverly did their American builders apply the methods of construction that had been worked out in this country in the course of learning how to build flying craft.

One of the most important details in which the later American airplanes excelled those of Europe was the adoption of the so-called "stream-line" wire for stays and guys instead of the round wires and cables that had always been used. The problem of air resistance has, from the beginning, been one of the most difficult for aircraft designers to solve. Before the war began it had been discovered that the blunt-nosed, long, tapering body enabled a 'plane to make higher speed than the old-fashioned machines had been capable of. The principle is exactly that used in ship construction. Naval architects long ago learned that the more closely they could model their craft on the lines of a fast-swimming fish, like the mackerel, the less resistance there would be to their passage through the water. So every part of a modern airplane is designed to present, as far as possible, only smooth surfaces to the air through which the machine passes, and to taper off in carefully calculated curves from front to rear; for what slows down the flying craft is not so much the head resistance of the air as it is the friction of the air against the surfaces of the wings and body and the suction or "drag" caused by the partial vacuum created when the stern is tapered too abruptly. And just as one can tow a large boat through the water with much more ease than a comparatively small tub, so it was found that changing the shape of the exposed wires that hold the airplane wing structure together from a circular cross-section to the shape of a flattened ellipse made a material difference in the speed of the 'plane. Tested on the De Havilland-4, the change from round wires to "stream-line" wires made a difference of more than six miles an hour, and with the huge Handley-Page and Caproni bombing-'planes the difference was even more marked. And when the war ended an American manufacturing concern had perfected a method of producing these "stream-line" wires so flat as to be almost ribbon-like, and yet as strong as the piano-wires and cables previously used, and costing little, if any, more.

In the last few months of the war another type of observation-'plane, the Le Père, was beginning to be made in America. This is of a French design, similar in its general appearance to the De Havilland-4 but with many finer details of line and in its construction. None of the Le Pére 'planes were in service when the war ended, although one had undergone official tests and proved to be faster than the De Havilland at all elevations, and able to climb more rapidly and higher, although weighing slightly more per square foot of wing surface.

So far we have considered only the American production of European designs of airplanes, and only those made for the army. But while this plan of copying European designs seemed to be, and probably was, the only way that offered any hope of getting any adequate supply of American 'planes into the air on the western front in time to save the Allies from defeat, American inventive genius did not stop functioning with the adoption of this program, nor were the designers and builders of American types either asleep or entirely neglected.

Just as the war was coming to a close a new type of fighting airplane, original and unique in design, and possessing many points of superiority over any machine then in use, was perfected by a young American engineer, Grover Cleveland Loening. The Loening machine, an observation-'plane carrying two passengers, is at once the smallest and lightest, as well as the fastest, of all military airplanes so far produced. The Loening machine is a monoplane, a return in this respect to the class of airplanes most highly favored by both the Germans and the Allies at the beginning of the war. Prior to 1914 the French had developed the monoplane, a type of machine almost unknown in America. The famous German Taube 'planes, of which so much was heard early in the war, were monoplanes, and so were some of the first British scout-'planes. At the end of the war, however, there was not a single monoplane type in use by any of the Allies or the Germans. The abandonment of the monoplane was due, not to any prejudice in favor of the biplane, but because the latter could be more readily produced in large quantities by comparatively inexpert workmen, with less risk of imperfections that might prove fatal to the flier. Previous types of monoplanes, however, had been exclusively single-seat machines, with the pilot so located that his range of vision was greatly curtailed, making it very difficult for him to protect himself successfully from attack. In the Loening monoplane both of these difficulties are overcome. On its official test, under the observation of army authorities, the Loening 'plane achieved a ground speed of 143½ miles an hour, and at 6,500 feet elevation it made 138.2 miles per hour with full military load. This compares with 135 miles an hour for the swiftest type of French "Spad" and 131 miles an hour for the fastest of the British "Sopwith" biplanes. The only military 'plane having an official record of a higher speed than this is the Italian "S.V.," with 142 miles an hour.

The Loening monoplane has the wings attached to the top of the body, and they are cut away so that the pilot, who sits between them, has not only a clear view in every direction from the zenith to the horizon, but also downward and sideways over a very large

THE FASTEST YANKEE MILITARY 'PLANE

The Loening monoplane, America's answer to German superiority in 'plane design.

arc on each side, while the observer's vision is almost entirely unobstructed in any direction. The Loening 'plane has a wing-spread of 32 feet and weighs but 1,300 pounds without its military equipment and passengers. Fully equipped and ready to take the air with two passengers, it weighs 2,608 pounds. In other words, this remarkable little machine can carry a load equal to its own weight, whereas the average load-carrying capacity of all other airplanes is about half of the weight of the bare machine. The Loening monoplane, equipped with a 300-horsepower Hispano-Suiza engine, has an official record of 5 minutes 12 seconds for climbing to 6,500 feet; 9 minutes 12 seconds to 10,000 feet, and 18 minutes

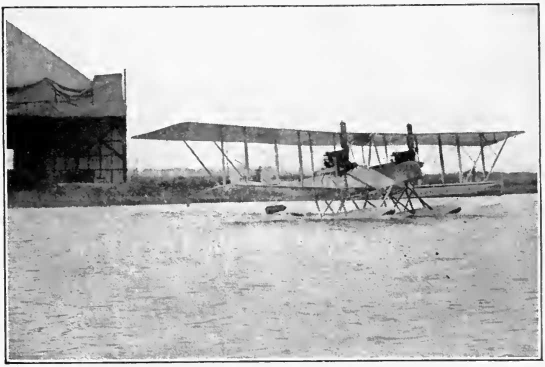
24 seconds to 15,000 feet. In every sort of maneuvering this machine, with two passengers, has equaled the best performance of the single-seat scout-'planes of the British and French.

Its designer, Mr. Grover Cleveland Loening, was only thirty years old when this revolutionary airplane was accepted by the army. He had, nevertheless, had almost as long an experience in airplane design and construction as any one in the world, so new is the whole art of heavier-than-air flying. He had taken up aviation while a student at Columbia University, from which he was graduated in 1911. The following year he built the first monoplane flying-boat. Then he became assistant to Orville Wright in the designing and manufacturing of airplanes, and in July, 1914, was appointed chief aeronautical engineer of the United States army and stationed at the Signal Corps Field at San Diego, California, where he wrote his book, *Military Airplanes*, which has since become an official text-book at the aviation-schools of the American, British, and Canadian governments. He resigned from the government service to go into commercial-airplane manufacture, and in 1917, after the United States had entered the war, he went to Europe and made a first-hand personal study of types of military airplanes then in use, as a result of which he brought out the machine which is quite generally regarded as being America's most important contribution, next to the invention of the airplane itself, to military aviation, and, with the possible exception of the German Fokker-7, the most formidable aerial fighting-machine ever devised.

Tests of captured Fokker-7's made in France and Belgium in the autumn of 1918, under the direction of Lieut.-Col. E. J. Hall, U.S.A. one of the designers

THE AIRPLANE OF THE "ACES"

The famous "Spad" single-seater pursuit-'plane, a French machine made for the American army under the arrangement for specializing aircraft production.

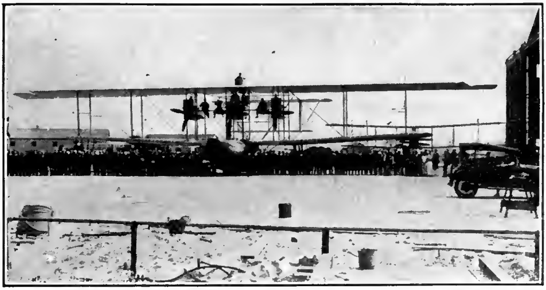


THE "D" TYPE SEAPLANE

This is the sort of flying craft carried on the deck of a war-ship for scouting purposes.

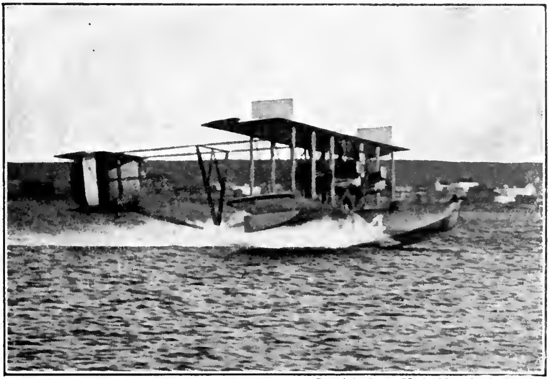
of the Liberty motor, demonstrated that that machine, if adequately engined, was superior to the best of the Allied fighting aircraft in the essential elements of horizontal and climbing speed, ease and safety in maneuvering in the air, visibility from the pilot's seat, and comfortable riding qualities.

While the program of airplane production which has just been reviewed was to some extent for the joint benefit of both the army and navy, and entirely so in so far as the Liberty motor is concerned, the Navy Department, and aircraft manufacturers working under its direction, were developing seaplanes and flying-boats to a degree of perfection not before attained. Unlike the army, which depended entirely upon private contractors, the navy built its own aircraft-manufacturing plant at the League Island Navy Yard, Philadelphia. Authorized on July 7, 1917, the plant, a permanent steel structure covering a ground area of 160,000 square feet, was built in three months at a cost of a million dollars. Three months later it had expanded itself to five times its original size, and, besides building seaplanes complete, the navy was having parts made to its own designs in hundreds of commercial plants throughout the country and assembling them at the League Island factory. The seaplane proper differs in no essential respect from the ordinary airplane, except that instead of rubber-tired wheels to enable it to run along the ground it is equipped with pontoons under the body and attached to the tips of the lower wings, so that it may light upon and arise from the water. High speed is not so important a factor in the seaplane as is endurance; the Liberty motors used by the navy are geared down from their normal 1,800 revolutions a minute to about 1,400, reducing their power some-



AMERICA'S FIRST GIANT SEAPLANE

The NC-1, which carried 51 persons in flight, and which was sunk off the Azores while flying across the Atlantic.



Official photo U. S. Naval Air Service

THE FIRST AIRPLANE TO CROSS THE ATLANTIC

The NC-4 ("NC" means "Navy-Curtiss") as she started from Trepassey Bay, Newfoundland, for the Azores.

what, but greatly increasing the length of time they can remain in the air on the same supply of gasolene.

By far the most spectacular and important phase of the navy's aviation program, however, was the development and perfection of the flying-boat. The flying-boat is as distinctly American as is the airplane itself. Instead of being merely an airplane equipped with pontoons, it is actually a boat fitted with wings. Glenn H. Curtiss, who made public flights in an airplane even before the Wright Brothers, invented the flying-boat. Under the direction of the navy, the design of the flying-boat was perfected in 1918, and just before the end of the war the first flights were made in the gigantic NC-1. This huge biplane measures 126 feet across the wings, while the hull of the boat is more than 50 feet long. It is propelled by three Liberty motors, and on one of its first public flights carried fifty-one passengers, afterward making a successful flight to Rockaway Beach, Long Island, from Langley Field on Hampton Roads, an airline distance of approximately 300 miles, in 4 hours and 20 minutes. So successful were the experiments with this first great flying-boat that several others of the same type were immediately constructed, a fourth Liberty motor being added to the later models, in one of which, the NC-4, Lieutenant-Commander Read made the first flight across the Atlantic.

V

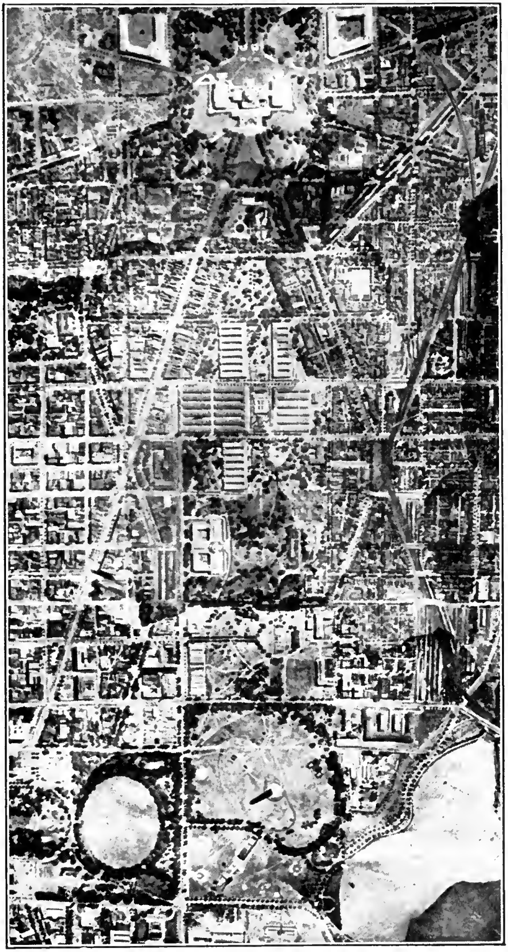
AERIAL PHOTOGRAPHY AND AIRPLANE EQUIPMENT

I HAVE indicated some of the difficulties that had to be overcome and the strain imposed upon the ingenuity and resourcefulness of American scientists, engineers, and manufacturers before we were able to produce the necessary airplanes and their engines, and establish their manufacture on a basis that would insure a sufficient and continuous supply. But all the airplanes and all the Liberty motors that we were finally able to turn out would have been useless for military purposes without a tremendous variety of equipment, with the design and manufacture of which we were even less familiar than we were with the designing and manufacture of 'planes and engines themselves.

There had never been built in America an airplane carrying a machine-gun; the instruments with which our 'planes were equipped were of the simplest possible nature, for determining altitude and direction. We had first to learn what devices had been found useful by the European Allies for the military equipment of airplanes, then to devise ways and means of making these or improving upon them, and then undertake their manufacture. When we finally sent completely equipped De Havilland-4's to France, they carried instruments and equipment which in almost every item and detail represented scientific and technical advances over anything that had been produced in Europe. In the eighteen months in which the United States was actually a belligerent we had invented in this country and begun to manufacture many totally new devices, without which no airplane is now regarded as completely equipped, and had introduced striking improvements on apparatus previously in use.

The equipment of a military airplane, apart from the propelling mechanism, falls into five classes. There are, first, the instruments and apparatus necessary for the most successful operation and guidance of the aircraft itself; then there are the devices requisite for the comfort and safety of the pilot and observer in flight; apparatus for signaling and communication must be provided; there is then the special equipment for observation. And all of these would be of little avail were the machine not also equipped with weapons of offense and of defense against the efforts of the enemy to bring it down. In addition to all of these five classes of equipment, the heavy bombing-'planes carry a sixth, the mechanism for dropping bombs, which was the latest of all developments in aerial warfare.

The primary purpose of aircraft in war is as a means of observation of the enemy's positions. For every phase of aerial warfare, except that of bomb-dropping, is secondary to the function of aircraft as a means of ascertaining the enemy's whereabouts and movements. Spectacular and thrilling as are the stories of the exploits of the famous "aces," the modern knights-errant, whose single-handed combats are reminiscent of the days of chivalry, these aerial duels have no military value or purpose except that of protecting the observation-'planes and balloons from attack by



AIRPLANE MAP OF WASHINGTON, D. C.

Composed of hundreds of aerial photographs matched and pieced together the enemy and preventing the enemy's observers from obtaining the information they are seeking. The amount of damage that can be inflicted upon the enemy by means of airplanes, other than by dropping bombs, is so trifling that the risk and cost would not justify their use for fighting purposes alone.

Very early in the war the Allies found that the best results from the use of the airplane for observation could be obtained by means of photography. Here, as in almost every other field of applied science, Germany had a distinct advantage at the beginning of the war. Germany had developed photographic apparatus especially for airplane use; the aerial observers of the Allies had to compete, in the beginning, with short-range, portable hand cameras. Germany had trained hundreds of men in the new art of reading aerial photographs; the Allies had to learn it all after they got into the war. But here, as in other fields, Germany made the mistake of supposing that because her enemies had not prepared themselves in these directions they were unable to do these things. When the Allies, and especially when the United States took up seriously the development of aerial photography, it was carried so much farther and developed to such a higher pitch of perfection than anything Germany had dreamed of that no Prussian camouflage could hide the Huns' movements from us in the latter days of the war; hardly could clouds, even, prevent the photographing of every detail of the enemy's positions, while our observers remained themselves unseen from the ground!

Beyond a doubt, Germany relied upon her practical monopoly of the optical-glass industry to keep the nations opposing her in the field from being equipped with high-grade lenses for photography, for range-finders, and for field-glasses, necessary to war, on any large scale. For nearly a quarter of a century the manufacture of the best grades of glass for these purposes had centered at Jena, in Prussia; many grades essential to the manufacture of modern high-speed lenses were not made anywhere else in the world. The University of Jena had established great laboratories for research in glass-making and lens development, and the German government had subsidized extensive manufacturing plants which made the photographic and other lenses for the whole world.

By the end of 1914 the importation of optical glass had become difficult and uncertain. One American firm had begun some experiments, others established laboratories, and the Bureau of Standards of the United States Department of Commerce set some of its scientists to work on the problem. Glass that answered one important purpose of Jena glass, that of material for test-tubes and other laboratory apparatus, was soon developed and has proved so much better than anything Germany ever made that there is no possible chance of any future German competition. Great Britain succeeded in getting good production of some grades of glass that gave acceptable results when ground into camera lenses, but by 1917, when the United States entered the war, the optical-glass situation had become critical. Such as France and Great Britain were able to produce was inadequate for even their needs; if we were to take an effective part in the war it was imperative that we make our own glass.

Of all American institutions there is none that is so distinctly and exclusively devoted to the pursuit of pure science as the Carnegie Institution of Washington. When its scientists were called upon for aid they responded with enthusiasm. A party of scientists from the Geophysical Laboratory of the Carnegie Institution was sent to Rochester, the center of photographic lens grinding in America, and for seven months from April, 1917, all of the energies of the laboratory were centered at this point, while the Bureau of Standards pursued its researches. By the end of 1917 the last German secret had been disclosed and the manufacture of glass comparing with that of Jena for every purpose was under way on a commercial basis in America. Glass manufacturers in other cities were enlisted, and to-day it may fairly be said that there is nothing the Germans have ever done in the manufacture of photographic lenses that we are not doing in America, and there are some distinct advances over German practice which are now standardized commercial practice here.

Wonderful as are the German lenses, composed of glass of three or four different qualities and consistencies, to give the greatest possible light-gathering power, they have seldom been produced in the larger sizes without flaws in the glass, which, the German herr professors solemnly assured us, did not really impair the excellence of the lenses. We are making the largest lenses without flaws, and find they work faster than those with flaws in them, strange as that may seem—to the Germans. And never again will America and the rest of the world be dependent upon Germany for lenses; that chain has been snapped forever!

America's need for lenses in the war was not confined to photographic requirements; for range-finders for our artillery and for the navy, for field-glasses and optical instruments of every sort, the discoveries and inventions developed by our scientists made it possible to provide equipment in these lines without which we would have been seriously handicapped.

Learning how to make lenses was only one step in the application of scientific knowledge and methods of photography that was such an important development of the war. In the beginning of the war photographic observers could fly at low altitudes; before hostilities ceased it was a foolhardy photographer who tried to take pictures from less than a mile high, while two or three miles was a much safer altitude. This made a hand camera useless, and huge devices permanently attached to the airplane, equipped with lenses larger than had ever been used for such purposes, had to be devised. The ordinary view-camera has a "focal length," or distance between the focal center of the lens and the plate, of from seven to ten or twelve inches; lenses ordinarily in use having a longer focal length are small, having a working diameter of from one-eighth to one-fifteenth of the focal length, requiring long

BIGGEST OF AERIAL CAMERAS

This huge apparatus, with a ten-inch lens of fifty inches focus, makes clear photographs of people on the ground from a height of three miles or more.

exposures. But before the armistice was signed we had made in this country perfect lenses having a focal length of fifty inches and having a diameter of ten inches—what photographers term "an aperture of F. 5."

Equipped with a camera of this enormous size, the lens protruding through the bottom of the fuselage of his airplane, the aerial observer can fly at a height of three miles or more and with an exposure of a five-hundredth of a second, or even less, make a picture of the ground beneath so full of detail that the trained experts at the laboratory behind his own lines can detect even the footprints that show where men had marched over the damp earth the night before. From this mechanical eye nothing is hidden; even objects that the airman himself cannot see are brought out in full detail by these huge lenses, while the color values that make it possible to differentiate even between two varieties of evergreen-trees by a study of photographs taken from the sky are accentuated by two other remarkable photographic developments of the war, the pan-chromatic plate and the new ray-filter. Heretofore the combination of high-speed photography with accurate color values has been regarded as impossible; it is literally true that with the new "emulsion," as the chemical coating of the negative plate is called, photographs can be made under light conditions heretofore impossible, at speeds almost as high as were formerly possible in full sunlight. And instead of being merely solid blacks and whites, as is usually the case with under-exposed pictures, these photographs contain a wide range of gradations that make the distinction between objects of the same shape but of different materials so easy as to be almost miraculous.

Proper rendition of color value is aided by ray-filters devised by American university professors working as army officers. One of these devices, in addition, enables the aviator to perform the marvelous trick of photographing through a cloud or haze that

THE AUTOMATIC AERIAL CAMERA

The photographer is telling the pilot, over the wireless interphone, just where to fly to get the picture he wants.

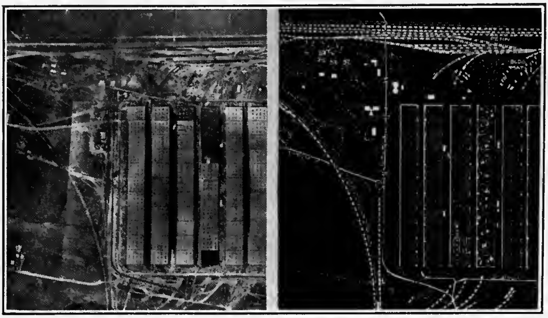
completely obscures his vision of the earth and getting a picture that shows the details of the surface. Through a haze that is hardly thick enough to be called cloud, but which makes ordinary long-distance vision impossible, such photographs are as easy as though the atmosphere were perfectly clear; through thin clouds, almost, if not quite, thick enough to hide the airmen from observers on the ground, photographs have also been made.

Developing negatives and making prints from them was formerly a comparatively slow process; few photographers, even the fast-working professionals of the newspaper staffs, knew any tricks that would speed up the process to an elapsed time of much less than twenty minutes. Through purely scientific methods, devised by experts who had never had practical experience in high-speed photographic work, but who were completely equipped chemists, ways have been found to develop the negative and produce not only one, but a number of finished prints in less than ten minutes; a quarter of an hour after the aerial observer has landed, expert photograph-readers are transferring to maps the new data which his photographs reveal, five minutes later the commanding officers of the entire sector know the enemy's latest movements miles behind the lines.

More than one hundred thousand prints of aerial photographs had to be turned out in four days by the aerial photographic force of the Air Service during the September, 1918, offensive west of Verdun and in the Argonne region. The aerial negatives had originally been made by French squadrons operating over the sector, but the production of prints on the large scale necessary had been left to the American service. As the offensive was in the nature of a surprise, all the preparatory work, especially the bringing up of American air squadrons, had to be concealed up to the last minute.

The American photographic force was brought together and traveled all night to headquarters, arriving at 9 A.M. By ten o'clock a laboratory had been improvised in the shed of a brewery, and the printing was actually in progress. During the first night, with most limited facilities, 3,000 prints were made, and later a record of 9,000 prints in sixteen hours for a single photographic section was established.

During the offensive the advance of the troops was so rapid that nearly all the 'planes and observers were occupied in making visual observations and regulating artillery fire. Aerial photographs, however, were



HOW AERIAL PHOTOGRAPHY AIDS THE MAP-MAKER

On the left is the picture of a quartermaster's depot made up of a number of airplane photos; on the right, the topographical drawing made from these data.

made by the American forces of the results of heavy artillery fire, and proved very valuable. A photographic mission also was sent out along the Meuse to ascertain if reports were correct that all the bridges were down. The results were so good that the exact number of troops, trucks, and even machine-gun companies in movement at that hour was ascertained.

The development of the aerial camera into a magazine carrying fifty plates was followed by an automatic plate-changing device that made the observer's task the mere pressing of a button. On America's entry into the war the adaptation of the flexible photographic film to the aerial camera began. The film is America's most important and distinctive contribution to the art of photography. It had been rejected by the professional photographer because of the difficulty in making it lie flat and the way it has of "fogging" because of frictional electrical discharges as it is rolled from one spool to another in very cold weather—and it is always very cold weather at three miles up in the air!

Again science overcame obstacles. Films in rolls twenty inches wide and containing enough for one hundred exposures of 15x20 inches are made to lie flat in the latest American aerial camera by passing the part of the film to be exposed under a plate pierced with hundreds of tiny holes through which air is exhausted, thus holding the film flat against the plate; the suction is accomplished by means of a Venturi tube attached to the frame of the machine, the wind caused by the machine's motion providing sufficient pressure. This simple and efficacious scheme was the invention of one college professor; another worked out the scheme for preventing electrical fogging by covering every metal part over which the film passes with cloth, the threads and meshes of which are filled with graphite, reducing friction to practically nothing. This same camera is entirely automatic in its action. The observer needs only to pull a trigger, and so long as he holds it down the camera will take one photograph after another at a rate dependent upon the speed at which he is flying. These photographs, placed edge to edge, or with a slight overlap, give a perfect map of the terrain traversed.

With the combination of powerful lenses that take in every detail at high speed, ray-filters and pan-chromatic plates that distinguish and record color values, and the automatic device that shifts the film at regular intervals, it is now possible to make in a few minutes a map that would have taken surveyors years to make. There are sections of the United States, many of them huge areas like the desert and mountain country of the Southwest, that have never been explored nor surveyed. It is now possible to map them easily and with mathematical accuracy, only a moderate amount of triangulation to determine relative elevations being necessary. Where the country is level or with a few elevations there is practically nothing left for old-fashioned surveying methods to accomplish.

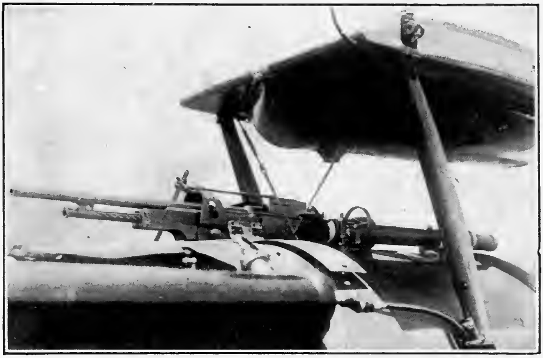
The photographic section of the Air Service in the autumn of 1918 made a photographic map in and around Fort Sill, Oklahoma. This map shows not only highways, lanes, trees, buildings, railroads, fences, and every landmark, but indicates every elevation and depression in the terrain. With over four thousand separate prints pasted into one huge mosaic, the finished product covers a space 16 feet long and 6 feet wide, representing a ground area of 310 square miles. The map takes as its center point the town of Lawton, which lies three miles south of Post Field, extending from this point east and west three and five miles, respectively, and from the northern boundary of Fort Sill reservation, thirty-one miles south to a point below the town of Walters.

When work was started on this map, the territory was plotted out on a ground map, and by figuring the exact area possible to cover with three magazines of plates, allowing for the proper overlaps, zones or strips of country were established to be covered on every aerial flight. Observers were sent up with assignments to cover specified zones or strips, and as fast as the finished negatives showed that these strips had been covered satisfactorily the work proceeded to unfinished zones. Three 'planes went up daily at the start and negatives were produced with great rapidity. More than 4,200 separate exposures were made. Approximately sixty trips, averaging an hour and a half per trip, were necessary to produce the map, or a total flying-time of ninety hours.

The most remarkable photographic map, however, is that of the city of Washington, D. C. This map, composed of 300 photographs placed together, was made in two hours and a half; it has been calculated that a corps of one hundred surveyors would take five years to do the same piece of work, and the results would not be so accurate! Every bush in the parks is shown, the shape of every building, every alley and thoroughfare, while the black shadow of the Washington Monument, with its known 555 feet of height, gives a key from which every other elevation can be calculated by the length of the photographed shadow.

Here is a contribution to peace-time activities and interests of vast importance; accurate, detailed maps of cities, such as can be made in this manner at small expense, now cost hundreds of dollars a copy; millions of government money may be saved by using this method to map the public domain; its usefulness in the oil-fields, in surveying timber-lands, and in a thousand ways that need no further elaboration is obvious.

For the more accurate determination of elevations the stereoscopic principle is applied to aerial photography. Every one is familiar with the stereoscope, the device that enables one to look at a photograph—or, rather, two photographs—through simple prism lenses and, instead of seeing the picture in a flat plane, get the effect of viewing the actual object, which appears to stand out in relief. This is accomplished by taking two photographs simultaneously with the two lenses set at the distance from each



THE MARLIN AIRCRAFT MACHINE-GUN

This weapon is fixed to the fuselage, so the pilot has to aim his whole machine. He sights through the telescope with rubber-padded eye-piece, attached to the left of the gun. By a hydraulic transmission from the engine, the gun fires at the exact instant when the bullet will pass between the whirling propeller blades.

other of the average human eyes—about three inches; by means of the prisms the two pictures are seen as one and the effect of depth results. In aerial stereoscopic photography the two pictures may be taken a couple of miles apart; the airman sets his camera at an angle and makes an oblique picture as he approaches his object; then he turns and photographs it at the same angle from the opposite side. When the two pictures are viewed together the precise height of every elevation and the depth of every depression are determined accurately.

To send an aerial observer aloft in the face of the enemy, no matter how perfect his airplane and his photographic equipment, without providing him with weapons of attack and defense and training him in the use of them, would, of course, be merely condemning him to death without a chance for his life. In addition to the photographic equipment, therefore, each of our observation-'planes has four machine-guns, all of them American inventions. The two forward guns on a De Havilland-4 are Marlin guns. These are fixed guns; that is to say, they are rigidly attached to the airplane so that they can be aimed only by aiming the 'plane itself. And since these guns point directly forward and the propeller of the airplane is at the forward end, these fixed machine-guns can be fired only at the instant when neither of the blades of the propeller is in the line of fire.

There has been no more marvelous, yet simple, combination of mechanical devices invented for war purposes than the apparatus and method of firing fixed machine-guns from an airplane automatically, and so synchronizing their discharge with the revolutions of the propeller that the bullets will never hit the propeller blades, but always pass between them. How exacting the timing must be to accomplish this result must be obvious when one considers that the propeller shaft on a De Havilland 'plane equipped with the Liberty motor revolves at the rate of 1,800 revolutions per minute. One or the other of the two propeller blades, therefore, passes in front of the gun sixty times a second, and in the trifling fraction of time between the passage of one blade and that of the other the bullet must clear the space. Otherwise, the pilot would "shoot up" his own propeller and come crashing to earth.

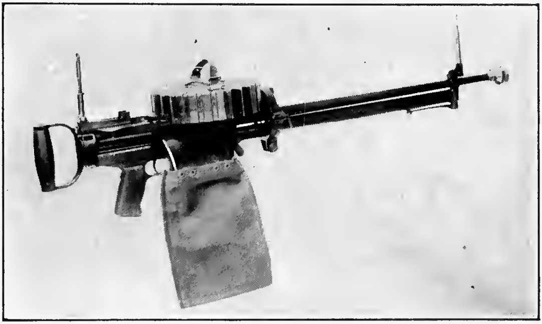
To solve the problem of synchronizing the Marlin gun required the most careful and painstaking calculations and the construction of apparatus which

THE GUN THAT SHOOTS BOTH WAYS

The problem of using weapons larger than machine-guns on aircraft is how to absorb the recoil without carrying too much weight. The Davis gun, shown in photograph, fires a one-pound naval shell. At the same time a charge of fine birdshot of the same weight is fired over the gunner's shoulder, through the other end of the gun. The two explosions offset each other and the airplane is not even jarred.

would, under all circumstances, be absolutely reliable and at the same time add as little as possible to the weight which the 'plane must carry in the air and be capable of adjustments as delicate as those of a high-grade watch. Since the firing of these fixed guns must always depend upon the rate of speed of the propeller, regardless of whether the plane is traveling fast or slowly, the trigger mechanism had to be connected with the crank-shaft of the engine. No merely mechanical connection would answer, for even the slightest wear in a bearing or the infinitesimal stretching of a chain or wire might pull the trigger prematurely and send the bullet through the propeller instead of between its blades. So recourse was had to what is known to engineers as the most efficient and reliable means of transmitting power—the hydraulic method. Attached to the main shaft of the engine is a tiny rotary oil-pump, completely inclosed, opening only into a metal tube, filled with oil, which leads to the trigger mechanism of the gun. This pump makes a stroke at every revolution of the shaft and this pump-stroke is communicated through the oil in the tube to the trigger of the gun. The pilot has under his control, so placed that he can operate it with either his hand or his foot, the trigger release, which controls the firing of the fixed gun. When this trigger release is pressed, the gun automatically fires continuously, one bullet for every revolution of the propeller shaft, so long as there are cartridges in reserve. When the pilot relaxes his pressure on the trigger release, the firing ceases. He can fire one shot or a "burst" of shots, or fire continuously up to 100 rounds, which is the capacity of a single belt of cartridges.

It was with fixed guns of this sort, synchronized to fire through the propellers, that most of the great air duels of the war were fought. For single-seat pursuit-'planes, this type of gun had been adopted by all of the Allies in the last year of the war. There were many delicate mechanical problems besides the synchronizing involved in equipping our airplanes with the fixed machine-guns. To find a way of discharging the empty shells overside without hitting the pilot or the observer in the after cockpit as they swept through the air at 135 miles an hour involved careful study, experiment, and calculation. The disintegrating belt for feeding the cartridges into the machine-gun was another Yankee device that proved highly



THE LEWIS AIRCRAFT MACHINE-GUN

This weapon is used by the observer in the rear cockpit of a two-plane machine. He has a pair of them and both can be fired at once. The cartridges are in the circular magazine; the bag catches the empty shells.

efficient. The links of this belt are so hooked together that when filled with cartridges, one cartridge to a link, it remains a continuous belt or chain; after the cartridge has been fed into the gun, however, the link is automatically disconnected and drops out of the way, so that there are no unnecessary coils of chain to impede the pilot's movements and interfere with the guiding of the 'plane.

The machine-gun equipment of the observer, whose post is in the cockpit behind that occupied by the pilot, consists of two Lewis machine-guns. This weapon, invented by Brig.-Gen. Isaac N. Lewis, U.S.A., is the only machine-gun that does not require a belt or web of cartridges. The Lewis gun magazine is a cylinder revolving horizontally about a vertical axis. Like other machine-guns, the cartridges are loaded into the barrel and fired by the force of the recoil. While the operator keeps his finger on the trigger the gun will continue to load and fire automatically so long as there are cartridges in the container. The Lewis gun, which had been adopted before we went into the war by the United States navy and the British army, but not by our army, had a container capacity of forty-seven rounds. For aircraft purposes this container and the gun itself were redesigned, giving it a capacity of ninety-seven rounds. By an ingenious method, the two Lewis guns are mounted so that the observer can aim either or both of them at will in any direction, from straight up to almost straight down and around a horizon range of nearly 300 degrees. Both guns may be fired with a single trigger. Both the Lewis aircraft gun and the Marlin aircraft gun had to be provided with ammunition of special type. The ordinary infantry cartridge is not enough for aerial fighting. There must be provided armor-piercing incendiary bullets, since one of the surest methods of bringing down the enemy's 'plane is to pierce his gas-tank and set the contents on fire, but also so-called "tracer" bullets, missiles which leave a trail of smoke behind them as they pass through the air, thus enabling the man at the gun to observe the accuracy of his own aim. There were devised methods of loading the cartridge-belts and containers for aircraft machine-guns so that at fixed intervals between the shots of ordinary bullets tracer bullets would be fired, and at other fixed intervals the armor-piercing incendiary bullets. And there is a basis for legitimate pride in the achievement of the Yankee engineers and manufacturers who, between our declaration of war and the signing of the armistice, had perfected these machine-guns and their accessories and actually

THE BROWNING AIRCRAFT MACHINE RIFLE

One or two machine-guns are mounted on the flexible mount for the use of the observer in a two-seated 'plane.

manufactured and shipped in less than twelve months 30,000 of the Lewis guns and 25,000 of the Marlin fixed-type machine-guns.

Equipped with guns of such flexibility, precision, and power, a pilot and observer in a De Havilland-4 could go aloft to take photographs of the enemy's works with reasonable security, provided they had learned how to shoot. For the training of aviators in the use of the machine-guns of both types, characteristically American methods were devised and adopted.

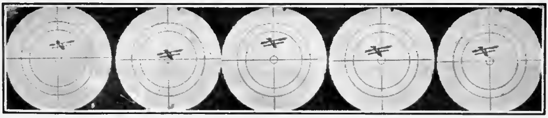
For practice in accurate aiming at moving targets, the popular sport of clay-pigeon shooting was adopted for the beginners at the aviation camps. Miniature model airplanes, towed through the air at the end of a long string attached to the 'plane, were fired at with machine-guns placed on top of elevated towers. But neither of these methods exactly simulated actual aerial combat.

It would obviously be wasteful of both 'planes and aviators to have the men in training actually shooting at each other in the air, but by means of the photographic gun a way was found in which all the conditions of war in the air, except the actual discharge of bullets, could be precisely simulated, and, moreover, an exact record of the results of each student's marksmanship be made.

The first gun-camera was used by British aviators. Upon our entrance into the war the Eastman Kodak Company, at whose laboratories in Rochester most of the war-time advances in photograph technic and apparatus were perfected, set about improving the photo-gun. The British model, which was a long, heavy, cumbersome device that had to be especially mounted in the 'plane, was entirely discarded. Instead there was devised a camera that could be fastened to the actual Lewis gun, so that in "shooting" with it the aviator was handling precisely the identical weapon he would use in real warfare.

This camera-gun weighs 13 pounds and has a lens barrel 8 inches long and 2½ inches in diameter. The magazine of film which it carries is designed to fit in place of the cartridge magazine on the Lewis gun, and contains film for 100 exposures. Ordinary motion-picture film is used. By means of a spring, wound up like the spring of a phonograph motor, power is obtained for actuating the film-moving device so that as long as the operator keeps his finger on the trigger the photo-gun continues to "shoot," just as the machine-gun continues to shoot so long as the trigger

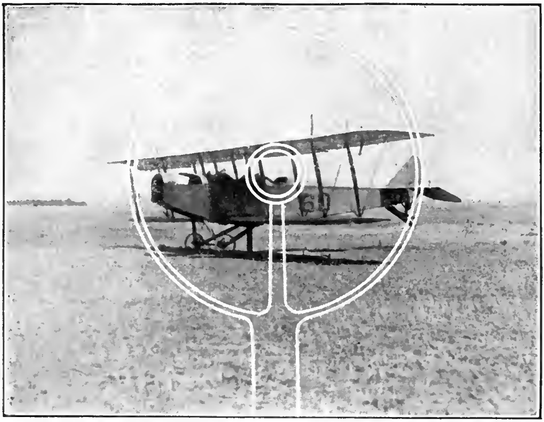
SHOOTING WITH PHOTO-GUN



A STRIP OF PHOTOGRAPH MADE WITH THE PHOTO-GUN, SHOWING THE OPERATOR HAD "GOT THE DROP" ON THE OTHER 'PLANE

is held down. The same sights by which the machine-gun is aimed serve for aiming the photo-gun. Equipped with this weapon, the airman shoots at another machine in the air and the circular photographs on the strip of film show exactly the position of the other 'plane and determine at once whether or not he would have hit it in a vital spot had he been firing bullets instead of taking snapshots. Later there was added to the photo-gun an ingenious timing mechanism, consisting of a split-second stop-watch, so placed that its dial was reflected into the camera, so that every photograph made with the photo-gun carried also a record of the exact fractional part of a second of time when the picture was made. Two student aviators so equipped, sent into the air for a mock aerial duel, brought back photographic records which showed exactly which one "got the drop" on the other, and whether one would have been disabled in actual warfare before he could have inflicted vital injuries upon the other.

For the efficient operation of airplanes flying at the previously unheard-of heights and speeds made necessary by war conditions, instruments of greater delicacy and perfection than had ever before been made in quantities had to be devised and manufactured for our aerial forces. The four most important items of information which the pilot must have constantly at hand are his altitude, the direction in which he is flying, the speed at which his 'plane is traveling through the air, and the number of revolutions per minute that his engine is making. Each of these requires a separate mechanism and a separate recording device on the instrument board in front of each pilot and observer. The air-speed indicator is a device as delicate as a watch. By means of a Venturi tube, through which the air passes, an indicator is moved on a dial set in the instrument board. While the airman has no means of determining wind velocity, and therefore cannot calculate his speed with relation to the ground, he can always tell exactly how fast he is traveling with relation to the air; thus, if his air-speed indicator registers 125 miles an hour, and he is traveling before a fifty-mile wind, he is actually going 175 miles an hour with relation to the earth; if he is flying *against* a fifty-mile wind, he is actually



HOW AN AIRPLANE LOOKS WHEN SEEN THROUGH THE SIGHTS OF A MACHINE-GUN

covering only 75 miles of distance per hour. To test these air-speed indicators by placing each one of the nearly ten thousand which we turned out before the war ended upon an airplane would have involved an immense number of experimental flights. Recourse was had to the wind-tunnel, the ingenious device invented by the late Wilbur Wright, and perfected under the direction of Glenn H. Curtiss. Originally designed for testing airplane models, this wind-tunnel, in which an air velocity as high as 200 miles an hour can be obtained, served admirably for the calibrating of the air-speed indicators.

How the General Electric Company in eight weeks from the beginning of operations was producing 250 airplane compasses a week and made more than 11,000 in the few months; how the tiny chains for 21,000 aneroid barometers which serve as altimeters for determining the height above ground by means of air pressure were obtained from Switzerland; how the National Cash Register Company developed the tachometer, the device that records the engine speed, and made 21,000 of these devices—about each one of these remarkable industrial achievements a whole chapter might be written. Then for each 'plane there had to be provided two clocks, a radiator thermometer, and a fire-extinguisher, oil-pressure and air-pressure gages for the oil- and gasolene-tanks; the problem was not only how to make and produce these devices in quantities, but even the manufacture of the self-luminous radium dials for all of these instruments, making it possible for the airman to fly at night, involved difficulties that only the utmost resourcefulness was able to overcome.

And still the equipment of the military airplane was incomplete. Flying at terrific altitudes, sometimes for hours at a time at a height of between three and four miles, airmen are exposed, even in mid-summer, to temperatures below the zero mark, and at the same time are required to exert themselves in an atmosphere so rarefied as to make breathing difficult. Anybody who has ever crossed the Great Divide knows what it means to climb in a day from the altitude of the plains, perhaps six or seven hundred feet above sea-level, to that of Denver or the higher passes farther west, from a mile to a mile and a half high. Few persons cross the Rocky Mountains without experiencing difficulty in breathing, even though the ascent has been slow and gradual. To climb in an hour from the earth to a height of three miles subjects the airman to strains which few endure for a long period successfully. Many of the fatalities in the early days of the war are now attributed to dizziness and loss of control caused by the lack of oxygen in the air at these high altitudes, and one of the most important contributions of America to the whole aviation problem was the development and perfection, under the direction of Brig.-Gen. T. C. Lyster, of the medical section of the Department of Military Aeronautics, of apparatus to insure a sufficient supply of oxygen to aviators at whatever altitude that they might fly.

The great necessity of efficiently maintaining fliers was demonstrated by a study of the English air casualties during the first year of the war. This study indicated that 2 per cent. of casualties were due to the Hun, 8 per cent. to the 'plane, and 90 per cent. to the men; these proportions clearly indicated that something was radically wrong with the personnel. A thorough study of this situation disclosed the fact that practically all of the flying personnel was suffering from what was known as oxygen fatigue.

To design an oxygen equipment which would be entirely automatic, one that would be reliable and efficient, necessitated the building of a device which embodied several instruments and one that would overcome many variable conditions. It was necessary to have a device that would work under variable tank pressures, from 100 pounds to 250 pounds per square inch, with a temperature of from 70 to 80 degrees Fahrenheit to 20 or 30 degrees below zero.

To overcome these variables necessitated a thorough study of temperature and pressure effects upon metals, and considerable experiment. In addition, the apparatus must deliver the required quantity to either one or two men at every altitude from 3,000 to 30,000 feet.

Both the British and French had been experimenting with oxygen apparatus for aviators before the United States entered the war. An original model of the French apparatus was brought to this country. On inspection, it proved to be a hand-made device, each part having been carefully fitted by an individual workman. We had neither the skilled mechanics for this sort of work nor the time in which to make the large quantity of this equipment required for our air forces. The development and engineering of an oxygen apparatus to meet American requirements and to be manufactured by American methods were undertaken.

The entire apparatus had to be redesigned, to take care of two men instead of one, to reduce the weight, to meet American methods of manufacture, and to make the apparatus more efficient and reliable. This work was started about the 1st of January, 1918. On May 3, 1918, six complete equipments, including apparatus, tanks, masks, etc., were sent overseas by special messenger to be actually tried out on the front. On May 31st the first production shipment of 200 sets of apparatus was made. By November more than 5,000 sets of apparatus had been manufactured and accepted by the government, more than 3,600 had been shipped to ports of embarkation, and more than 2,300 had been floated overseas, this production ranging from a rate of about 400 per month in May to 1,000 per month in October.

The importance of oxygen equipment necessitated the establishment overseas of a special oxygen equipment division, to take care of the application of these equipments to 'planes. All military 'planes flying above an altitude of 10,000 feet are equipped for the application of oxygen equipment.

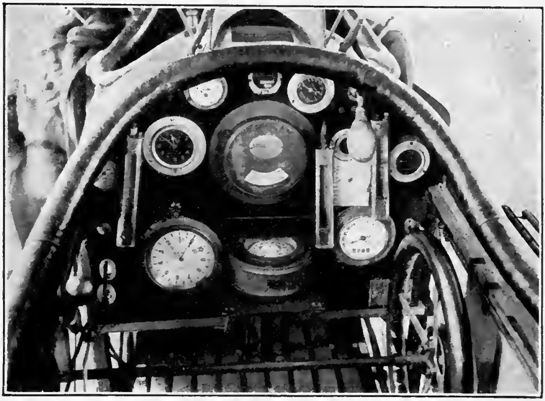
The intense cold at the high altitudes was a problem that had to be solved in a different way. Fortunately we had in America developed a considerable industry in the manufacture of electrically heated pads, blankets, etc., for the use of invalids, and by a simple adaptation of the same manufacturing methods we were able to provide electrically heated garments for the use of airmen. The production of these was just beginning at the signing of the armistice. A considerable number of these suits had been made, and they are now standard equipment for all American military aviators flying at high altitudes. To avoid reducing engine-power an ingenious device consisting of a tiny electric generator operated by a little windmill attached to the frame of the machine is used to generate the current for these electrically warmed garments, and also for warming devices to prevent the mechanism of the machine-guns from jamming, due to the stiffening of the oil at low temperatures.

For signaling purposes, every military airplane had to be equipped, in addition to its navigation lights, red, white, and green, arranged as they are on a ship, with rockets of different colors which could be fired from a specially made pistol having a bore of about an inch and a half, and with smoke-rockets for daylight signaling; another part of the equipment is the parachute-flare, used for night landings. As the airman approaches the earth, a little parachute is dropped over the side. It opens and floats gently earthward. A powerful magnesium light which illuminates the earth in a wide circle is suspended from the parachute, enabling the pilot to make a landing almost as readily at night as by day. The same bluish flares are used to light the target in night bombing. Neither of these devices is an American invention, but the ingenuity and resourcefulness required to find means of producing them in large quantities under pressure was a distinct American triumph.

While the army was working out these devices, the navy was developing airplane appliances and equipment designed to render the navigation of seaplanes and flying-boats easier and safer when out of sight of land. Three radically new and immensely valuable devices were developed before the termination of the war, the application of all of which to peace-time air navigation is of incalculable importance. These are the aerial sextant, the drift indicator, and the course-and-distance indicator.

In the aerial sextant, known as the Byrd sextant, invented by Lieut.-Com. H. L. Byrd, a bubble in a tube takes the place of the sea horizon for observations. A specially constructed lens is used in sighting the bubble, which is reflected in a mirror. The sun is reflected in another mirror. The observer brings the sun tangent to a line at the same time he brings the bubble tangent to the line. That gives the altitude of the sun. This is of especial value, as the aviator is often above the clouds, and even when flying at low altitudes the horizon is too dim to be seen clearly. With this new aerial sextant the curvature of the earth does not have to be taken into consideration in calculating position. The bubble is lighted at night, so that night observations of the stars may be taken.

New methods of astronomical calculations have been devised which enable the navigator to make his calculations in a fifth of the time that was formerly necessary. A projection-chart of the Atlantic



THE INSTRUMENT BOARD OF A NAVY SEAPLANE

The pilot must understand and constantly consult this array of instruments, which tell him how many revolutions per minute his propeller is making, his speed relative to the wind, whether or not he is on an even keel, his altitude, the temperature and barometer pressure, the point of the compass toward which he is heading, the air pressure in his petrol-tank, the amount of gas and oil still available, and the temperature of his radiator water. The instruments not illuminated by electric lights have radium-coated figures making them luminous for night use.

Ocean has been specially constructed for this purpose. This chart—a new invention—does away with difficult mathematical calculations, enabling the aviator to determine his position in a few minutes.

Another great problem of the sea-air navigator is the calculation of the speed and direction of the wind, both day and night. The compass can only give the course upon which the craft heads, and in determining the true course proper allowance must be made for the sidewise drift caused by the wind. For example, a wind blowing thirty miles an hour toward the side of the 'plane will blow it thirty miles an hour out of its course. This fact alone makes the navigation of the air far more difficult than the navigation of the sea.

To overcome this difficulty bombs have been invented which ignite upon striking the surface of the water and give a dense smoke and bright light for ten minutes. An instrument is used in conjunction with this bomb which enables the navigator to determine the velocity and direction of the wind by sighting on the smoke in the daytime and on the light at night. This instrument, called the speed-and-drift indicator, has proved successful.

When the navigator has found the speed and direction of the wind, he must then be able to calculate the course to steer to allow for this wind. To do this an instrument has been designed to solve the triangle of forces, thus doing away with cumbersome mathematical calculations.

Perhaps the most important of all new inventions in aviation equipment, the radio telephone, is distinctly a product of Yankee ingenuity. Every American service-'plane built after we went into the war was equipped with one or another form of radio-telephone apparatus. The stories of this marvelous invention and of the radio compass are told in another chapter.

VI

THE CHEMICAL CONQUEST OF THE AIR

ONE of the inspired writers of the Old Testament poetically refers to Satan as "Prince of the Powers of the Air." To those who look upon the war just ended as that Armageddon foretold in Holy Writ, the final earthly clash between good and evil, it is of more than passing interest to note that when Germany precipitated the conflict, in 1914, the Kaiser could rightfully, in more senses than one, boast himself "Prince of the Powers of the Air."

Not only was Germany the only nation that had developed the airplane into an effective military weapon and built dirigibles capable of extensive aerial navigation; it was the only country in the world that had at its command the power of extracting from the very air itself the one essential element without which modern warfare could not be waged, nitrogen. And it was not until Germany had perfected processes for the fixation of atmospheric nitrogen and accumulated a huge supply of nitrates and nitric acid that the wheels were set in motion for the campaign of world conquest of which the Prussian had so long dreamed.

Nitrogen is the basis of all explosives. The commonest of all the elements, perhaps, constituting four-fifths of the air we breathe, it is difficult to trap and almost impossible to hold in confinement when combined in the proportions that make explosives. It is, moreover, the one indispensable fertilizing element without which there could be no plant growth and for the lack of which the whole world would speedily starve were there not available means of restoring nitrogen to the soil. Until Germany developed processes of taking nitrogen from the air and combining it with other elements, either as ammonia or nitric acid, the world relied almost entirely for its supply of nitrates, for war or for peace, on the saltpeter beds of Chile, the one known great natural deposit of nitrogen salts.

Germany knew that a general European war would result in a blockade that would cut her off from the Chile nitrates, and she would not have dared to go to war without some means of supplying the need. The sending of Admiral von Spee's squadron to operate against commerce in South-American waters was Germany's attempt to cut off the Allies from the Chile nitrate supply. Every merchant-ship sunk by a submarine reduced by that much the tonnage available to bring nitrates to America and the European Allies.

No single item of America's war program was as audacious in its conception as the preparations which the War Department began immediately upon our entrance into the war for the immediate development, on a scale surpassing even Germany's ambitious undertaking, of processes and plants for the extraction of nitrogen from the air. Nothing more forcibly demonstrated the confidence in and reliance upon the resourcefulness and ability of American scientists than the government's decision to beat Germany at her own game. None of the nation's undertakings for the prosecution of the war has left the country such a valuable heritage in the shape of tangible, material additions to our national wealth.

How important nitrogen is in the composition of munitions is apparent if one considers for a moment what the various explosives are made of. Ordinary black powder is a mixture of charcoal, sulphur, and saltpeter, saltpeter being nitrate of sodium. Guncotton is nitrocellulose. Smokeless powder is also a nitrocellulose compound. Dynamite is nitroglycerin mixed with an inert substance to form a solid mass. TNT is tri-nitro-toluol; TNX is trinitro-xyol. The explosive charge used in grenades for trench warfare is ammonium nitrate. Picric acid, the base of the British lyddite, the French melinite, and the Japanese shimose, is the result of the treatment of carbolic acid with nitric acid. And in all of these the nitrogen element is the one essential to their explosive qualities.

The extraction of nitrogen from the air as a laboratory experiment was well known to all chemists. There was not in the United States a single plant for doing this commercially. In Canada, at Niagara Falls, there was one company engaged in the work, using a process that was different from that upon which Germany mainly relied. An American company owned the rights to the principal German process and had devised some modifications. A dozen chemists of national repute had proposed other methods, none of them beyond the laboratory stage, and there were the patents in our Patent Office of the German process.

With this inadequate equipment the War Department began the construction at Sheffield, Alabama, of a gigantic plant for the fixation of atmospheric nitrogen, while a technical board of experts was appointed to determine the process to be used. Sheffield was selected because there were some factory buildings already available there and because it is close to Mussel Shoals, where the government had begun the development of a huge water-power project. All nitrogen-fixation processes depend upon the availability of large amounts of electric current, the decomposition of the air being accomplished by passing it through an electric arc, or by some other means subjecting it to a temperature of from 3,000 to 6,000 degrees. On the technical board were representatives of the Department of Agriculture as well as of the army and navy, since the plant is to be used for the production of nitrates for fertilizer when the military necessity for its operation no longer exists.

First $30,000,000, then another $30,000,000, and at last much more than $100,000,000 was made available for the nitrate plants, the one at Sheffield and four others in different parts of the country. There was no time to wait for the development of water-power; great steam-engines were installed to produce the enormous volume of high-voltage electric current needed for any of the processes. And while the necessary machinery for a limited production of nitrogen products by the Canadian process was being assembled, and other machinery was being built with which to produce more nitrogen from the air by the American-owned modified German process, one group of scientific and technical men was wrestling with the American patents on the original German process, which was known to require much less power per unit of production than any of the other known methods of inducing nitrogen to separate itself from the oxygen of the air and combine with soda or other common bases. Another group of scientists was examining the experiments of the dozen or more American chemists who had worked out nitrate-fixation processes in their laboratories.

The story of the unraveling of the German method of making artificial nitrates, through the most patient experimenting, lasting more than a year, with the patents taken out in America by the German chemical trust, is only one of scores of similar tales that some day will make a book as fascinating as any detective story of fiction. Under the patent laws of the United States, the purpose of which is to give to inventors a monopoly limited to a brief term of years and then to throw their inventions open to public use, drawings and specifications filed with the patent application must be so explicit that, as the law reads, "those skilled in the art may reproduce the device or process" by a mere examination of the papers. Study of this and other patents taken out by Germans in America, all of which were thrown open to the use of Americans when Germany and the United States went to war, proves that for many years German inventors and scientists have been practising deliberate deception in their American patent applications. The general principles involved were stated, it is true, but the detailed instructions were unintelligible, even to "those skilled in the art."

An expert chemist of the Bureau of Chemistry, an electrical engineer of national reputation and a practical electrician from the Washington Navy Yard, a man with twenty years of electrical experience behind him, tackled the problem. The working of the process called for a pressure of 1,500 pounds to the square inch inside of a tightly sealed cylinder heated to 1,170 degrees Centigrade. It was easy enough to get the pressure, easy enough to get the temperature; how the two could be achieved at once was the puzzle. The drawings accompanying the patent specifications showed an electric wire running to the outside of the cylinder and ending there! The three experts took this clue as their starting-point. After nine months they had discovered the secret in principle. They built a small-sized plant, and the electric-wiring burned out. The navy yard electrician found a way to overcome that; now the government has, in addition to its other processes, an actual working plant producing nitrogen from the air by the economical German method.

While this untangling of German trickery was going on still another process, all American and differing in many important respects from anything that had been done before, was developed at the expense of the government from the laboratory experiments of its inventor, Prof. John E. Bucher, of Brown University. Professor Bucher's method of nitrogen fixation is simplicity itself. It does not require an expensive electric installation, and it produces not only the essential nitrogen compounds, but many valuable by-products.

By the Bucher process, soda ash and powdered coke are mixed with powdered iron or with iron ore—either will do—and heated in an ordinary furnace through which air is passed. The result is cyanide of soda, with the iron uncombined, it having acted, as Professor Bucher phrases it, "as a chemical parson to unite the nitrogen of the air with the soda and the coke." This mysterious but effective chemical process, by which the mere presence of a substance that does not in any way enter into the combination is nevertheless essential to the formation of the combination, known to chemists as "catalysis," forms an important part of most of the processes for fixing atmospheric nitrogen and converting the derived products into other chemical forms.

The cyanamide process, the first method adopted by the government, is based upon the fact that calcium carbide may be induced with comparative ease, at a temperature of 2,000° F., to absorb nitrogen which has been liberated from liquid air. When the liquid air begins to rise above its normal temperature of −380° F., pure nitrogen boils off. This is pumped to the electric ovens and absorbed by the carbide, leaving the oxygen of the air as a by-product. The compound of calcium carbide and nitrogen, known commercially as cyanamide, is itself valuable as a fertilizer, and by treatment with superheated steam its nitrogen may be released to enter into combination with the hydrogen of the steam, forming ammonia. This is the process invented by Doctors Frank and Caro, and developed by the German electrical trust. From 400,000 to 600,000 tons of cyanamide are now being produced annually in Germany.

Through the development and application of these various processes for obtaining nitrogen from the air, coupled with the speeding up of nitrate importations from Chile, the United States was not only able to produce gunpowder and high explosives faster than we ourselves and the European Allies could use them up, even in the most intense period of the war, but we have now available a permanent source of nitrogen supply of the highest possible value and importance to agriculture, and as a reserve for munitions against future wars, and there have been established, as part of the necessary work in the manufacture of explosives, industries which can produce and are producing the materials for the manufacture of dyestuffs and a

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thousand other chemical products for which the world formerly depended upon Germany, but which America can now supply to all comers.

Every one of the processes with which our government is working gives as its final product, not nitric acid, which is the form in which nitrogen is required for explosives, but ammonia, which is the nitrogen product most easily adaptable to fertilizing purposes. The conversion of ammonia to nitric acid is simple enough as a laboratory experiment, but to do it on a commercial scale is quite a different matter. So, too, nitric acid is of comparatively little value as a basis for fertilizer, because of the expensive manipulations necessary to make it usable. There is a process of nitrogen fixation that gives nitric acid as its finished product—the electric-arc method of decomposing air by passing it through an enormous flaming arc, best known through the Birkeland-Eyde plants in Norway. This process, which involves temperatures up to 6,000° F. at a power-cost quite prohibitive except in Norway, has been the best advertised of all the air-nitrogen methods. The wide publicity given to these Norway plants, always coupled with the perfectly truthful assertion that the process could not be economically operated elsewhere, now appears to have been due to a definite German propaganda having for its double purpose the discouragement of nitrogen-fixation attempts in other countries and the diversion of attention from the military value of the Haber and cyanamide processes. For since the European war began it has been disclosed that these Norwegian plants, even at three dollars a year per horse-power, had never been commercially self-supporting, but had from the beginning been subsidized by Germany, which was thus enabled to accumulate a huge store of nitric acid for munitions while ostensibly giving all of its attention to the development of fertilizer resources by other processes. But these other processes, cyanamide, the Haber process, and the methods of producing by-product ammonia, are now known to the rest of the world, as they have long been known to Germany, to be equally available for the production of nitric acid. The simple method that produces this result is the invention of Prof. Wilhelm Ostwald. Pass a mixture of ammonia and air through a heated chamber, at the end of which is a platinum screen, serving as a catalyst, and, presto! the oxygen of the air replaces the hydrogen of the ammonia and we have nitric acid.

This bit of chemical wizardry was duly patented in the United States and Great Britain, with the customary German camouflage. British chemical experts found out how to do it, and now Great Britain and France are each producing something like 200,000 tons of nitric acid from atmospheric nitrogen annually, mainly by the medium of the cyanamide process, to supplement their supplies of Chile nitrates and their imports of explosives from America. And that is what our government is doing in the Sheffield plant for the oxidation of ammonia. We are now able to utilize nitrogen from the air, fixed by any process, for we have at hand the means of converting it readily into nitric acid for war purposes, while in its ammonia form it is readily usable in a variety of combinations for fertilizer. Nor does all of the ammonia have to be oxidized to make it available for purposes of death and destruction. By using a part of the nitric acid in combination with ammonia, forming ammonium nitrate, we have a prime explosive of peculiarly deadly force. Much of the American supply of by-product ammonia, all of which was commandeered by the War Department, was utilized in this way, the nitric acid required being obtained from Chile nitrates. The hand-grenades which figured so largely in trench warfare derive their explosive quality from ammonium nitrate.

The remaining step in the nitrate program, that of encouraging and stimulating the production of by-product ammonia, furnishes another illustration of the way in which the elements of the closely knit German industrial scheme dovetail into each other. Germany developed the coal-tar color industry, based on the discoveries of Sir William Perkin, as well as the coal-tar drug industry, and, by subsidized manufacture and price-cutting, discouraged the utilization of coal by-products in other countries. And in the process of saving the tar for these purposes there is also recovered from coal a considerable volume of ammonia, either as such or as ammonium sulphate. The proportions of by-products per ton of coal coked by the modern retort process are around 20 pounds of ammonium sulphate or its equivalent in ammonia, 15 gallons of tar, and 2 gallons of benzol and toluol, the latter being the basis of the most powerful explosive yet devised, tri-nitro-toluol or, more familiarly, TNT. Moreover, every ton of coal converted into metallurgical coke in the old-fashioned "beehive" coke-ovens results in the waste of about 5,000 cubic feet of gas and the loss of 200 pounds of coke.

We have made great progress in by-product coking in this country since the Germans invaded Belgium. The end of this war found the United States, from this by-product source alone, far more independent of other nations for its essential nitrogen supply than it probably would have become in a hundred years of peace.

VII

POTASH, SULPHURIC ACID, AND DYESTUFFS

WHILE the establishment of processes of fixing atmospheric nitrogen is the most important single chemical development of the war so far as America's future is concerned, it is but one of hundreds of new processes or adaptations of old processes that had to be worked out and applied for the first time in America on a commercial scale in order to insure an adequate supply of munitions, or of commodities of which war conditions had deprived us; nearly all of these war-born chemical industries, moreover, have definite and valuable importance to the peace-time commerce of the nation.

Listen first to the story of potassium, the chemical element represented in the symbolism of science by the letter "K" and discussed here in terms of its oxide, K_2O, under its English name of potash, or its German equivalent, *Kali*. For you cannot discuss potash in any language or in any quarter of the globe without reference to Germany. Potash has for years been one of Germany's trump cards in that nation's game of *Weltpolitik*. No less an authority than Prof. Wilhelm Ostwald, winner of the Nobel prize in chemistry in 1909, author of *Energetische Grundlagen der Kulturwissenschaft*, is sponsor for the boast that Germany, through her control of the only known large deposit of potash salts, could say which of the "uncultured" nations should eat and which starve. And until Germany, in January, 1915, placed an embargo on the exportation of potash, practically the entire commercial supply of the whole world was obtained from the mines of Stassfurt, in the Prussian province of Saxony. Not a pound of German potash was added to the stocks on hand between that date and the spring of 1919. These stocks were soon exhausted not only in the United States, but in the rest of the civilized world. We did not starve, but even allowing the usual 90 per cent. discount for "swank" from Professor Ostwald's claim, we did face a situation that was serious and that would have been more serious if American inventive genius had not found at least the key to permanent independence of the German *Kali* monopoly. For while potash is one of the most widely distributed of the elements, every attempt for the last forty years to produce it in commercial quantities from any of the natural deposits has been blocked by the "dumping" of potash from Germany at prices that made competition impossible.

The United States, in normal peace times, used an average of about 250,000 tons of German potash annually. The demand has been steadily increasing. Agricultural Department estimates of the normal annual need was around 500,000 tons. In the first two years after the German embargo went into effect we had used up all the reserve stock on hand, together with a considerable quantity re-exported from South America as the price obtainable here climbed from $40 to $500 or so per ton, and throughout 1917 we had no potash except what we produced ourselves. This 1917 production amounted to around 30,000 tons—about one-eighth of the pre-war normal average and one-sixteenth of the estimated 1917 need!

There was somewhat more than this available for 1918; there was still more available for 1919. By 1919 it seemed apparent that it would be possible within three or four years so to establish certain of the processes of potash production that whatever Germany might attempt in the way of unfair competition could be met with profit to the producer and the full benefit of comparative prices to the consumer.

While it is probably true that the use of potash in the past has been excessive, due to the very effective propaganda for a generation and more of the German Kali Syndicate, it is nevertheless true that the sandy soils of the Atlantic seaboard states require this element, under present agricultural conditions, in larger quantities than nature provides through the constant breaking down of the micas, feldspars, and green sands which are the universal reserve. The citrus fruits of Florida, the cotton and tobacco of Georgia, the Carolinas and Virginia, the potatoes and garden truck of the eastern shore of Maryland and south Jersey, cannot be grown commercially without potash. By the beginning of 1918 the Department of Agriculture reported the crops in these and other sections where potash formerly was used freely were showing signs of potash hunger; 1917 crops were smaller per acre, the plants less vigorous. Texas needs no potash for its cotton, Maine can produce potatoes without it; tobacco, on the other hand, wherever grown, absorbs potash as a sponge does water.

As I have said, there is plenty of potash; the problem was to make it commercially available. Many sources of potash, unprofitable to work in peace times, contributed to the small available supply of 1917–18. Most of it came from the alkali lakes of western Nebraska and southern California. Some came from the Great Salt Lake. Some was produced from the alunite deposits of southern Utah. A good deal was obtained from the kelp-beds of the Pacific coast. One source of potash supply only has given evidence of probable ability to meet all the requirements of permanent potash independence for the United States, namely, practically inexhaustible supply of raw materials, low enough cost of production to withstand competition under any conditions, and geographical distribution such as to minimize transportation costs. This is the process of recovery of potash from cement-kiln and blast-furnace dust.

Like many other important discoveries, what the inventor of the electric precipitation method of recovering potash from cement and blast-furnace dust found was not what he was looking for. Columbus set out to find a short route to India and discovered America; F. G. Cottrell undertook to preserve the orange-groves of Riverside, California, from destruction by dust from a cement-plant and discovered a new industrial and agricultural resource. It has long been known to chemists that limestone, coke, iron ore, and clay, the ingredients used in cement kilns and blast-furnaces, contain much potash, in the form of insoluble silicates. When Mr. Cottrell, who is now chief metallurgist of the United States Bureau of Mines, found that the way to prevent the dust from a cement-kiln from being carried out through the stack and devastating the vegetation of the surrounding countryside was to pass the furnace fumes through a series of charged electric wires, the problem of what to do with the quantities of dust thus accumulated at the kiln came up next for solution. Analysis of the dust disclosed, as had been anticipated, that it contained a very high percentage of potash, but more important than that fact, its atomic affiliations had been so readjusted by the heat of the kiln that it was now readily soluble and could be recovered by a simple process of leaching.

The process of precipitating the cement-kiln dust and extracting the potash content has already found wide application. It furnishes at once a solution of the problem of dust disposition, which every manufacturer of Portland cement confronts as state after state makes it illegal to discharge the dust into the air, and of preventing the alkaline potash carried in the fumes from eating out the linings of the flues. Cement manufacturers have for years been trying to use as small a proportion as possible of potash-bearing ingredients. Now those plants that have installed the Cottrell method find they can add substances heretofore discarded and obtain a more profitable by-product.

The annual production of Portland cement in the United States is about 90,000,000 barrels. The average amount of recoverable potash, as determined by a very thorough and careful survey that took in 104 American plants and nine in Canada, is about one and three-quarter pounds to the barrel of cement produced. Without making any allowance for improved methods of recovery, or for the increased output made necessary by rebuilding after the war, here is a potential supply of 75,000 tons a year of potash on a basis that will compete with the German product on any sort of terms, and which is mainly produced in the sections of the country where it is most needed, thus saving transportation expense.

The blast-furnaces of the United States offer a vastly greater supply of potash, awaiting only the replacement of their present gas-washing apparatus with electric precipitation devices. In this industry, as in the cement industry, the main question is one of installation of the necessary equipment. Extensive experiments by the Bethlehem Steel Company have demonstrated the presence of a very large percentage of recoverable potash salts in the waste gas from the furnaces, now used as fuel and for gas-engines. This gas, in blast-furnace practice, requires washing to rid it of impurities, of which potash is one. The electric precipitation process purifies it better than washing does and leaves a hot, dry gas instead of a cold, wet one. The equipment of blast-furnaces now in operation for this purpose will necessarily be slow and expensive, because of the war demand for steel products and their consequent high price and the difficulty of getting any sort of new machinery for any but war purposes. But sooner or later, it now seems clear, a very large part of our supply of cheap potash will come from these heretofore wasted supplies.

Let us turn from the science of husbandry back to the art of war. The United States had to supply explosives not only for ourselves, but for the Allies of Europe. To some extent the Allies could use our powder and explosives, but most of their demands were for explosives of somewhat different type, for which their guns and methods were particularly adapted. The British use a smokeless powder based on nitroglycerin, for example; ours is made of nitrocellulose. It was a distinct compliment to the quality of American powder when, early in 1918, the British High Command issued an order that thereafter all barrage fire should be conducted with American nitrocellulose powder, because its uniform quality minimized the danger of shells falling short and killing their own men. For the purposes for which we use TNT the British use principally picric acid.

Picric acid is made by the action of sulphuric acid on carbolic acid. Carbolic acid, up to the beginning of the war, had been chiefly made in England, from the coal-tar derived from the manufacture of illuminating gas. The need for explosives compelled the shutting off of exports of coal-tar and its products from England, and in this country we had no important coal-tar supply. Very few American communities have illuminating-gas plants—none but the oldest and largest cities. And even in these as much petroleum as coal is used in gas manufacture. And whereas in Europe great quantities of coal-tar and other by-products of coal have long been obtained from specially designed ovens used for the preparation of metallurgical coke, the United States, in spite of its huge steel industry, was still producing most of its coke from the old-fashioned, wasteful "beehive" coke-ovens, the tar and their valuable by-products going to waste.

But we had to have carbolic acid, we had to have toluol and the other coal derivatives, so one set of scientists, under government direction, began the installation of plants to recover these precious wastes from gas-works and coking-plants, while others studied the problem of new methods of converting these derivatives into the forms requisite for war. A Newark chemist, who had never been especially interested in carbolic acid, discovered a method of producing this valuable chemical by the treatment of benzol with nitric acid. Mr. Edison financed the greatest carbolic-acid plant ever built.

Soon we were manufacturing it and converting it into huge supplies of picric acid for the British and French, and incidentally providing the raw material from which phonograph records are made. The tough, hard disks used in all makes of talking-machines nowadays, as well as some of the most important insulating materials and substitutes for wood and metal where extreme hardness and durability are required, of which bakelite is the best known, are made from carbolic acid in combination with other materials. This whole field of applied science is the result of research by American chemists.

To the uninitiated layman the fact that the activity of German submarines and the consequent increase in freight rates and scarcity of ships made it almost impossible to import Spanish pyrites had no especial significance. To the industrial chemist it meant that we could no longer manufacture sulphuric acid unless we found some other source of available sulphur; to the manufacturer in almost every branch of industry this meant that he must close down his plant, for sulphuric acid is not only the one universally indispensable industrial chemical, but in the manufacture of explosives its use is imperative.

We have in the United States the largest and purest known deposits of sulphur. These sulphur-beds of Louisiana and Texas are all but inexhaustible, but because the manufacture of sulphuric acid from pure sulphur is more costly and complicated than that of obtaining it from certain sulphur compounds, the greater proportion of our sulphuric-acid production had for many years been from the pyrites imported from the Rio Tinto mines. Under war pressure, however, means were found for converting the pure sulphur into acid economically; incidentally there was developed a process of making "fuming" sulphuric acid in any quantity and cheaper than ever before dreamed of. Moreover, the stimulus of the war demand led to a great increase in the volume of sulphuric acid produced by the treatment of the fumes from smelters treating sulphur-bearing ores. Almost all gold, copper, and zinc ores mined in this country contain sulphides. At almost every smelter the sulphur content is neglected and allowed to escape into the air, not only with a direct economic loss, but in some localities ruining the adjacent countryside by the fumes, which are highly destructive to vegetation, as evidenced by the barren landscape of Butte, Montana. As a result of efforts for the prevention of atmospheric pollution, notably the action of the state of Georgia against the state of Tennessee for the suppression of fumes from a smelter situated close to the boundary line, processes for the recovery of these gases and the conversion of their sulphur content into sulphuric acid have been so perfected that even under normal conditions they pay well for their installation. Several such installations were made, one with a capacity of 1,000,000 tons a year.

To turn back again from war to peace, let us consider a paradox—war's contribution to the physical loveliness of the world. There is no more wonderful transformation known to science than the conversion of the sticky tars and vile-smelling oils obtained from the slow combustion of coal into the brilliant dyes that furnish forth the palette of the artist, clothe the fair sex with the tints of the butterfly's wing, and lend beauty to the works of man surpassing even the beauties of nature. Not only colors, but perfumes and a wide variety of invaluable drugs are also derived from coal.

An Englishman, Sir William Perkin, first discovered that this could be done; the Germans developed the coal-tar industry and by unfair underselling drove the indigo-planters, the madder-growers, and other producers of natural dyestuffs out of business and obtained a world monopoly. One of the greatest triumphs of applied science is the building up in America of a dyestuff industry, using the crudes and intermediates produced from coal by the same processes that were devised for munitions manufacture, and by patient and costly experiment discovering the German processes of converting these into every color, shade, and tint known to commerce.

In the dyestuff field, as in other chemical industries, the myth of German invincibility was firmly fixed in the public mind. Subsidized German plants sold their products below cost until their foreign competitors were put out of business. As soon as this had been accomplished, it was no longer necessary for the German exporters to sell at or below cost. The tendency to this result was recognized by the German government from the first, and every facility was afforded to the growing export trade. It was fully realized by both the civil and military authorities that if a world monopoly in the dyestuff industry could be built up the military strength of Germany would be colossally enhanced, since it alone, of all the great powers, would then be in a position to secure immediate supplies of the vast quantities of munitions likely to be needed in a modern war.

Up to August, 1914, the American industry in dyestuffs and coal-tar drugs consisted of little more than a series of rather small assembling-plants. In spite of the fact that enormous supplies of coal-tar were available and that several of the crudes could be secured in this country under most advantageous conditions, hardly any of the necessary intermediates were made here, and the manufacture of dyes was almost entirely confined to working upon intermediates imported from Germany. The shutting off of the supply of dyestuffs by the British blockade forced American manufacturers to attempt to supply the demand. The most important processes, however, essential to the production of the most valuable and useful dyestuffs were covered by American patents taken out by Germans. These patents formed a colossal obstacle to the development of the American dyestuff industry. Under the Trading with the Enemy Act, however, power was given to the Alien Property Custodian to take over and sell these German dyestuff patents. And in order to protect the new American industry which this action was intended to develop, the patents were sold to an organization known as the Chemical Foundation, in which practically every important American manufacturer was a stockholder, the stock being placed in the hands of a voting trust of eminent citizens, and the charter was so framed that under the patents non-exclusive rights only can be granted on proper terms to all proper applicants, and must be granted to the United States free of cost. Approximately 4,500 dyestuff and drug patents were sold to the Chemical Foundation for $250,000, thus making it possible for any genuine American, whether a stockholder of the company or not, to secure the benefits of these patents on fair and equal terms. These patents, now being owned by Americans, enable their owners, the American dyestuff and drug manufacturers, to forbid and prevent the importation of German-made products covered by these patents or made by processes so covered.

Here, again, when the effort was made to follow the instructions given in the German patents, was disclosed evidence of Hun trickery. Information absolutely essential was omitted or stated in such a misleading fashion as to necessitate weeks or even months of painstaking chemical research before success was achieved. There is nothing so complicated in all industry as the manufacture of dyes; so complicated and various are the chemical processes involved that there is no single chemist who can by any possibility operate all of them.

A lifetime of study enables a chemist to learn how to make some of the "intermediates"; other chemists, whose life-work has been in entirely different fields, must develop the remaining processes. Chemists who can make synthetic indigo, for example, which is now being produced in America from the same raw materials that are used in making picric acid and lyddite, may have no familiarity whatever with the processes for making sulphur black. Each step in the process of converting the raw material into the finished dyestuff is, indeed, an industry in itself, and from five to ten different steps, each requiring its own independent plant, are necessary.

How completely American chemical manufacturers have solved the dye problem, with the co-operation of the government and the utilization of the coal by-products industries established under war pressure, is shown by the fact that a range of 175 different colors, including all that are staple for every sort of fabric, are now made in America equal in every way to the best that Germany ever made. In the four years of the Great War the value of American-made dyestuffs increased from $3,000,000 annually to $87,000,000. We used to import $9,000,000 of dyestuffs from Germany every year, but in 1918 we exported $20,000,000 worth to the markets Germany once claimed as her sole and exclusive property.

VIII

POISON GAS

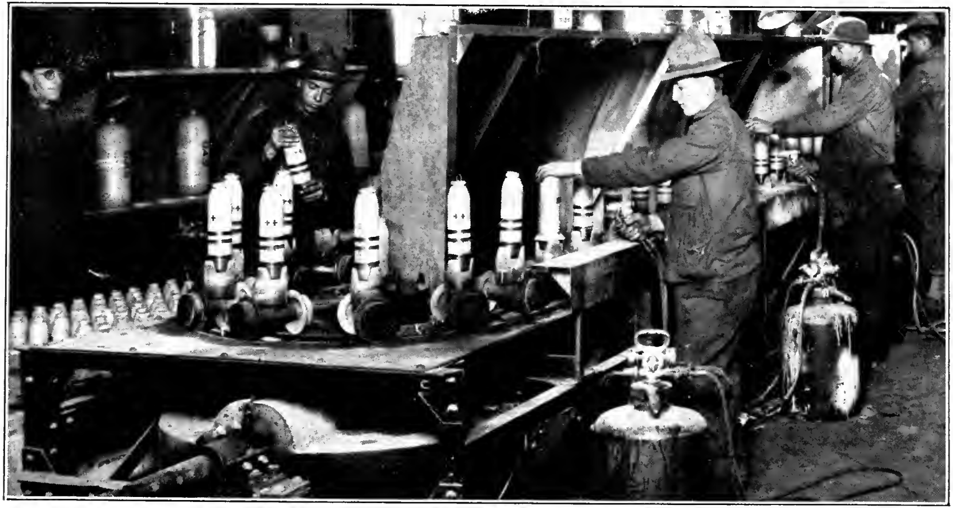
THERE is no phase of applied science in which German supremacy at the beginning of the war was so definite as in the field of chemistry; there is no field in which Germany's defeat has been so complete and so permanent. Prior to 1914 Germany had for nearly forty years been the world center of chemical industry. Few important chemical discoveries were ever made by German scientists, but with the aid of government subsidies great industrial enterprises, based upon the researches of scientists of other nations, were developed, competition by other nations was crushed by means of underselling and sharp trade practices and an absolute monopoly was established in scores of chemical products which modern civilization had accustomed the whole world to regard as necessaries of life.

All the huge industrial machinery devoted to chemical manufactures in Germany was at the disposal of the German government. When the war began not only the physical plants, but the skill and resourcefulness of tens of thousands of chemists, trained for just this emergency in the German technical schools and universities, were thrown into the scales against the Allies. In a sense, the greatest victory of the war was won when American and Allied chemists matched science against science, not only in the game of war, but in the intensive application to the arts of peace of the knowledge which Germany fatuously believed she alone possessed.

German chemical science went down to defeat all along the line. In the direct shock of battle Allied chemistry met German chemistry and overwhelmed it; behind the lines America and Great Britain built up their defenses against the "war after the war" and established once for all the independence of the rest of the world in chemical industry. There is no other industrial development due to war pressure that is fraught with such lasting importance as the development of new chemical industries in America, and none that so immediately and directly touches the lives of everybody.

The most spectacular and dramatic challenge by German chemistry was the use of poison gas as a weapon of war. A wave of indignation swept over the civilized world at the news from the battle-field of Ypres, when five thousand Canadian soldiers were suffocated by gas on April 22, 1915. The Allies were slow to retaliate in kind; respect for the rules of civilized warfare set forth in the Hague conventions, of which the use of poison gas was in direct contravention, restrained them for more than a year. But when the basic law of self-preservation at last compelled them to meet the enlarged volume and increasing deadliness of German gas by the use of the same weapon, there were no half-way measures taken. The United States had never signed the clause of the Hague Convention forbidding the use of gas, although Germany had ratified it on September 4, 1900. We were violating no pledge, therefore, in using poison gas to the limit.

By the summer of 1918 the Allied and American



PAINTING THE LOADED GAS-SHELLS

The different gases are distinguished by stripes of different colors. The paint is sprayed on in rings by air-brushes.

forces were delivering against the Germans daily five times as great a volume of poison gas as the Germans were using. The stopping power and deadliness of the gases used on the Allied side were, moreover, definitely greater than the German gases possessed.

Not only did the Allies analyze, match, and improve upon every form of poison gas the Germans used, but American chemists developed a poison gas having at least seventy-two times the killing power of the deadliest German gas!

It is literally true that had the war gone on to the spring campaign of 1919, upon which America's preparations were being focused, we would have been able, by the use of this new gas, actually to smother the German army by divisions at a time. Not only this most lethal of all known poisons was at our disposal, but we had in preparation huge mobile guns for hurling bombs of this gas incredible distances and, even more wonderful, we had all but perfected and were preparing to manufacture automatic apparatus for dropping containers of this new poison from the air, at a distance of a hundred miles or more from our farthest front. When one of these containers or bombs burst there would have remained no living thing within a radius of a mile or more a few minutes later.

The chemical secret of this new gas has not been disclosed. It is the invention of Prof. W. Lee Lewis, who left the chair of chemistry at Northwestern University to serve as a captain in the Ordnance Department of the army, and was assigned to duty with the Bureau of Mines. While working in the laboratories at American University, Washington, Captain Lewis succeeded in putting together a chemical compound such as had never before been recorded and which, in its peculiarly toxic effects, acts upon the human system in a manner different from any known poison. It is related in Washington that Captain Lewis, while a student of chemistry, had by accident effected this or a similar compound and nearly lost his own life as a

ONE OF THE POISON-GAS PLANTS

The soldiers are sending 75-millimeter shells into the chamber where automatic machinery fills them.

result, so his Washington discovery was not an accident, but the result of an almost forgotten personal experience.

The story of "lewisite," as this deadly gas is now known, is one of the most romantic of all the stories of Yankee ingenuity in the war. It was half a year and more after the signing of the armistice before there was any official sanction for the publication even of the fact of its existence. No secret of all the war secrets was more carefully guarded. The substance itself was known in the official records only as "G-34." When any curious inquirer wanted to know what "G-34" stood for he was told it was "methyl," a word which had no relation to the actual stuff. Even in the Division of Chemical Warfare few officers except those actually engaged in the manufacture of "methyl" had any conception of its potency and purpose.

Lewisite is an oily liquid of an amber color and with the odor of geranium blossoms. It is highly explosive and on contact with water it bursts into flame. Let loose in the open air, it diffuses into a gas which kills instantly on the inhalation of the smallest amount that can be measured by science. A single drop of the liquid on the hand is sufficient to cause death after a few hours; persons poisoned by lewisite die in fearful agony. The pain on contact is acute and almost unendurable. It penetrates through the skin and poisons the blood. It affects the kidneys first. Then it hardens the cell-tissues of the lungs, causing strangulation and contraction of the heart.

When the armistice was signed the Chemical Warfare Division had on hand 150 tons of lewisite, enough to have killed half the population of the United States if the containers had been opened at strategic points. To-day there is none of the stuff in existence except a few carefully guarded samples in the possession of the Bureau of Mines and the War Department, and even the buildings where it was made and the machinery used in its manufacture have been utterly destroyed.

Lewisite was manufactured at Willoughby, Ohio, a suburb of Cleveland, in a plant known to the men who worked in it as "the mouse-trap." Every man who was taken into this plant to work was required to sign an agreement that he would not leave the inclosure, surrounded by a high, tight, barbed-wire fence, until the war was over. The signing of the armistice released from their voluntary prison eight hundred men, many of whom had not been outside of the "mouse-trap" since work at the plant was begun on July 26, 1918. It was on July 12th that orders were given to proceed with the manufacture of lewisite. On July 19th, Col. F. M. Dorsey, who had stepped into uniform from the post of chemical engineer of the General Electric Company, had taken over the abandoned plant of the Ben Hur Motor Company at Willoughby and put officers in charge; by the 26th there was an armed guard of twenty-five men about the place, the inside of the building was being fitted up for work, and laboratory equipment was arriving on passenger-trains as baggage. Within three months lewisite gas was being produced at a rate that soon reached a possible output of ten tons a day. Two of the five steps in the process of manufacture as it was originally worked out by Captain Lewis were eliminated after the plant was in operation. Many of the necessary materials were exceedingly difficult to obtain, and additions had to be made to the plant for their manufacture on the premises.

The utmost pains were taken to guard the secret. The men in the plant were selected with the greatest care, after their records had been carefully scrutinized. They could write letters, but were not permitted to give any address but that of a locked box in the Cleveland Post Office, through which all mail was passed. Telegrams were sent through Nela Park, Colonel Dorsey's headquarters. The hours were long and the work hard; the risk was tremendous. The workers were supplied, however, with ample reading-matter, with a phonograph and grand piano, and kind-hearted people in the neighborhood sent in fruit and pies, so life in the "mouse-trap" was not without some compensations. And in spite of the frightfully poisonous nature of the stuff they were making, not a single man was poisoned; the only death in the plant occurred from influenza. To protect the men while at work there was devised a mask and overall suit that rendered the wearers absolutely immune. Masks that gave full protection against the most powerful German gases were useless against lewisite. Chemists of the Chemical Warfare Service declare that in the event of another war it would take an enemy a year or more to discover a method of protection against lewisite. Ordinary gas-masks would be as useless as mosquito-netting.

Speedily as the "mouse-trap" was built, it was demolished even more speedily. To leave evidence that might enable some prying Hun, by examining machinery, tanks, and apparatus, to guess the secret of G-34 would be as dangerous as to allow the stuff itself to remain in containers that might at any time spring a leak and poison a whole community. So the whole stock on hand, except for a few small samples, was placed in heavy iron containers and loaded on a freight-train, probably the most extraordinary train that ever passed over a railroad. Under an armed guard, traveling on a special schedule, unaccompanied by any railway employees except the engine-driver, it took two days to travel from Cleveland to the Edgewood Arsenal, near Baltimore. There the containers were loaded on a ship and taken out to sea, where they were gently lowered into the water at a point where the Atlantic Ocean is about three miles deep. The slow corrosive action of the sea-water will eventually eat through the containers, the liberated lewisite will mingle with it and combine with the chemicals

FROM LEFT TO RIGHT: AMERICAN, BRITISH, FRENCH, AND GERMAN GAS-MASKS

of the ocean to form new and non-toxic substances. Even the fishes in the vicinity, the chemists believe, will not be poisoned.

Two days after the armistice was signed workmen began tearing down the "mouse-trap." By February 1st there remained not a trace of the whole extensive system of barracks and laboratories where once the most deadly chemical compound ever put together by human ingenuity had been made.

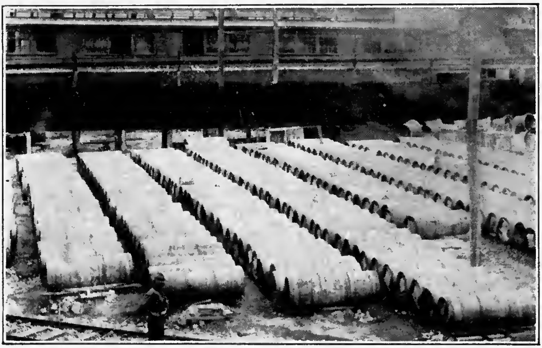
I have said that this new gas is estimated to be seventy-two times as deadly as "mustard" gas; let me try to convey an impression of just how deadly it is.

Mustard gas, as made in the Edgewood Arsenal, near Baltimore, where our war-gas production was centered, penetrates the clothing and shoes of men exposed to it, causing frightful burns. A single drop of the concentrated, liquefied gas has been known to cause a fatal burn. Only the most perfect ventilating system and the wearing of masks, rubber gloves, and rubberized protective clothing by those engaged in the dangerous processes of its manufacture made it possible to make it at all. Even with these precautions the casualties at the Edgewood Arsenal ran an average of three per cent. a day, and when the armistice was signed there were three hundred men in the camp hospital suffering from mustard-gas burns, and many others had been invalided to reconstruction hospitals.

A soldier who had been handling some of the ingredients of mustard gas brushed a mosquito from his ear without first removing his gloves; two days later his ear had literally been burned off.

An officer came out of the laboratory into one of the offices. Carelessly, he rested his glove-incased hand at the back of a swivel-chair while he chatted for a few minutes. The next day the officer who sat in the chair felt a burning pain in the upper part of his back; two days later he was dead. The mustard gas had burned into his spinal cord. It takes two pounds of mustard gas to load a seventy-five-millimeter shell; at the signing of the armistice we had on hand 419 tons of this stuff—enough to load 419,000 shells. The charge of one shell is calculated to put out of action every one within fifty yards when it explodes.

Mustard gas is one of the finished products of our war preparations for which there is no peace-time use. The great plants built to produce the chemicals that enter into its composition, however, and the huge supply of those chemicals, are a distinct addition to the nation's industrial assets. There was no way of disposing of the supply of mustard gas on hand at the close of the war but take it out to sea and sink it, containers and all; the action of sea-water, as the gas slowly leaks out of the corroded containers, neutralizes its poison properties. It could not be dis-



CONTAINERS OF POISON GAS READY TO SHIP TO FRANCE

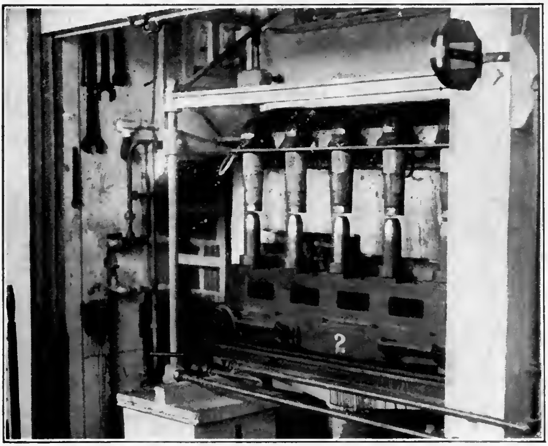
charged into the air anywhere on the face of the earth without the risk of destroying life. More than once, while hostilities were under way, there were many tons of mustard gas in New York harbor, enough to kill every person in Manhattan if it were let loose with the wind blowing in the right direction.

The basis of mustard gas, as of the other war gases, is chlorin. The first gas used by the Germans at Ypres, in fact, was probably pure chlorin. It has a commercial use as a bleaching agent, and electrolytic processes for its production from sodium chlorid—

common salt—were well known; but there was not enough being produced annually in the whole United States when this country entered the war to supply the army's needs for a week. So at the Edgewood Arsenal there was built a huge plant for the decomposition of brine by electricity, and the collection of the products of decomposition—chlorin, caustic soda, and hydrogen. This plant, the largest in the world, is said, by American and foreign chemists who have inspected it, to be also the most efficient and economical in operation. Its capacity of one hundred tons a day of chlorin will be, it is expected, available for commercial purposes.

The process of making mustard gas had to be worked out by scientists after unexploded German gas-shells containing this new poison had been analyzed by other chemists and the exact nature of the gas ascertained. Whether by reason of a better process or purer raw materials, American mustard gas is more powerful than the German. Gas-masks that provided perfect protection for our troops against the most powerful German gas were not enough protection against our own, for the workers in the Edgewood Arsenal had always to be prepared to respond to a gas alarm. So a new gas-mask was invented and issued to our troops, as well as to the gas-workers.

To trace back the constituents of mustard gas and the other poison gases to their sources and describe the new methods and processes that had to be developed before we could make a ton of "dichlordiethylsulphid," which is the technical name for mustard gas, would make an interesting book in itself. First there had to be insured an ample supply of pure sulphur, through which the chlorin could be passed to make chlorid of sulphur; then processes devised of producing ethylene, a constituent of coal gas, but which may also be made by treating sulphuric acid with pure alcohol. For these and other war purposes there have been wonderful developments in the pro-



LOADING GAS-SHELLS BY AUTOMATIC MACHINERY

duction of sulphur and of alcohol, concerning which I tell some of the interesting phases elsewhere.

Picric acid, the high explosive that forms the basis of the British lyddite, the French melinite, and the Japanese shimose, was being manufactured in large quantities in this country for the British before the United States entered the war. It was made by treating carbolic acid with a mixture of sulphuric and nitric acids; we had to develop a carbolic-acid industry to supply the demand from this and other sources that had formerly been filled from Germany. Then the Division of Chemical Warfare devised a combination of chlorin and picric acid, known as chlor-picrin, which answered the same purpose in warfare as the early German gases, in that it put men out of action without necessarily killing them unless they were exposed to it for a long time.

There is no particular use in industry for the 511 tons of chlor-picrin we had left on hand when the war ended, but the picric-acid industry, now firmly established in America, is of great value. Picric acid was not used as an explosive until very recently; as a dyestuff it has been known for 150 years. It is, in fact, the very first of the synthetic chemical dyes to have become commercially successful. With an ample supply of picric acid available, the yellow dyes for which the world was formerly dependent upon Germany can now be made in America; with the utilization of other products which the war compelled us to learn to make, it may fairly be said that we are already independent of Germany in the matter of dyes.

Most valuable of all the products of the Edgewood Arsenal in its peace applications, as well as constituting in its production a distinct economic triumph, is phosgene. In point of military effectiveness phosgene ranks between chlor-picrin and mustard gas; it is the gas of which the largest quantity was used by the Germans, and when the armistice was signed the United States had the largest plant in the world for its manufacture and 1,308,000 pounds of this gas on hand. Its name, phosgene, is of Greek derivation and signifies "light-born"; it is made by combining chlorin and carbon monoxid in sunlight.

At Edgewood Arsenal the chemists drawn into the service from the Bureau of Mines and from all the universities and chemical research laboratories of America to work under the direction of Col. William H. Walker, who left the chair of chemical engineering at Massachusetts Institute of Technology to take command of gas production, devised and installed

GENERAL VIEW OF THE EDGEWOOD ARSENAL NEAR BALTIMORE WHERE GAS-SHELLS WERE LOADED

new processes for the production of carbon monoxid and its combination with chlorin to make phosgene, and produced enormous quantities of the latter at a cost of less than fifteen cents a pound. This is less than one-tenth of the former commercial price of phosgene, which has long played an important part in the dyestuff industry and used to sell in quantities for $1.50 a pound.

"A value to the United States equal at least to the whole cost of the Chemical Warfare Division for the period of the war can be credited to the cheap and simple method of producing phosgene developed at Edgewood Arsenal," said an officer who is a chemical engineer when not in uniform. "The government has distributed samples of phosgene large enough to be used commercially to a large number of industrial concerns, together with complete detailed formulas. Nothing could be more helpful in the establishment on a permanent basis of the dye industry than to have this knowledge available."

Phosgene is the basis of a wide variety of colors. Numberless greens, brilliant scarlet, yellows, violets, and blues are all made by means of aniline combinations with phosgene in different proportions and ways. It also has the property of attacking iron oxid and utterly absorbing it. Brickwork at the Edgewood Arsenal has been bleached almost white where phosgene has come in contact with the iron oxid which gives ordinary bricks their red color. Another extremely important use of this gas is in destroying the brownish tones of glass, due to the presence of minute quantities of iron oxid in the sand from which the glass was made. Part of the success of American glass-makers in producing a clear optical glass for photographic and other lenses was due to the use of phosgene for this purpose.

Besides the gases already referred to, the two thousand expert chemists and ten thousand and more soldiers and special employees who took part in the work of the "offensive" section of the Chemical Warfare Division devised ways for producing on an unprecedented scale such interesting commodities as white phosphorus, which bursts into flame on the least contact with dampness—even ordinary damp air—and gives off an intense white smoke, used for filling incendiary and smoke bombs; stannic tetrachlorid, the product for which we were all urged to save tin, a gas that was found most effective for driving Boches out of their dugouts, and titanium tetrachlorid, equally lethal. Note the "chlor" syllables in the names of all of these gases, indicating chlorin as part of their composition, and their derivation from common salt. White phosphorus is made from bones after they have been boiled to extract all the gelatinous matter for glue. We had 1,320,000 pounds of this material on hand when the war ended, 606,000 pounds of stannic chlorid, and 306,000 pounds of titanium tetrachlorid.

A HORSE GAS-MASK

It is easier to protect horses than men. The horse never breathes through his mouth. Horses have survived mustard gas after several hours' exposure.

The three last-named chemicals were made in outside laboratories and shipped to the Edgewood Arsenal to be placed in shells and bombs for shipment overseas. Nothing could be more ingenious or effective than the immense, almost completely automatic plants for filling shells with these deadly chemicals. There were no precedents to go by. Everything had to be designed from the blank paper before construction could be even begun, but so effective was the machinery, when once installed, that nearly two hundred thousand shells, bombs, and grenades were being filled every week when the war ended. Every precaution that human ingenuity could devise was installed to make it possible to do this work with the least possible risk to the man engaged; nevertheless, it was so difficult to obtain civilian help that finally it was all, or practically all, done by soldiers detailed for the purpose.

Here are some figures from the confidential records of the War Department that give perhaps as impressive an idea as can be obtained of the full scope and extent of our gas-warfare preparations. When the armistice was signed we had on hand, finished and loaded, or ready for loading, 1,556,886 75-millimeter gas-shells; 92,496 gas-shells for 4.7-inch guns; 629,910 gas-shells for 155-millimeter guns and howitzers; 739,854 hand-grenades filled with stannic tetrachlorid, and besides a miscellaneous supply of other kinds of gas-shells and bombs and gas-projectors there were ready for use 48,349 gas-shells for 8-inch seacoast guns. And on this later item hangs one of the war secrets that could not be disclosed while hostilities were in progress.

It was not until after the end of the war that it was learned that 14-inch navy guns on railroad mounts had been used by the American forces on the western front. Then it was announced that the navy's experiment with these guns had been so successful that the army had in readiness or preparation a considerable number of large-caliber guns mounted on railroad trucks for use in the spring campaign. Still later it was revealed that these 8-inch seacoast guns were to be used to hurl the largest gas-shells ever made twelve or fifteen miles, if need be, and the charge of lewisite each shell would carry would literally wipe out an entire regiment of Germans.

Originally designed for coast defense, these guns are of high power and long range. Mounted on railway trucks, they can be moved quickly from point to point behind the lines, and the mounting is so designed that the gun is ready to fire within five minutes after arriving at the designated spot. It does not take a very vivid imagination to picture the havoc that half a dozen well-placed shots from one of these weapons, the shells charged with the most deadly gas yet devised, would have worked on the German morale.

Our government possessed even a more efficient means than this, however, for smothering the Germans with poison gas. This was the automatic airplane, a device which was kept so secret that even six months after the signing of the armistice only a few of the higher officials of the War Department knew of its existence and most of these did not understand the principle by which it operated. Only one of these machines was built, but its success proved the possibility of constructing cheaply and speedily a fleet of airplanes the flight of which can be controlled without having a human being on board, and which can be relied upon to drop bombs of poison gas at a distance of fifty or one hundred miles from their starting-point and to drop them within half a mile of the point previously determined upon as the objective!

A bomb is not likely to be efficient at the range of half a mile; bombs of such effectiveness would make too heavy a load for any but the largest aircraft. The lewisite gas, however, has a range limited only by the direction and velocity of the wind with relation to the point where it is set free. Half a dozen lewisite gas-bombs weighing three hundred pounds or so each, exploded to windward of the city of Berlin, would have killed the entire population of the German capital. And by the use of the automatic airplane for dropping these bombs, all danger to the attacking force would be eliminated. The worst that could happen would be to have the 'planes themselves brought down by the enemy, who would get the surprise of his life when the lewisite gas began to circulate in his vicinity.

The automatic airplane was a development under army direction of the navy's "aerial torpedo," designed for dropping high-explosive bombs upon hostile war-ships. The conception of an airplane guided automatically by means of a gyroscope originated with Elmer E. Sperry, the American inventor of the gyroscopic compass and the gyroscopic stabilizer for ships; an airplane equipped with a stabilizer of this type flew without control around the Eiffel Tower before the war. When the war ended Mr. Sperry had developed an aerial torpedo entirely controlled by gyroscopes, intended for navy use, while the army had adapted it for overland purposes by combining with the Sperry gyroscope the Wright stabilizer, invented by Orville Wright, consisting of pendulums so attached that any deviation of the plane from a normal flying angle automatically adjusts the ailerons and elevators and the craft is thus brought back into a normal course. Mr. Wright had flown over a circular course for more than an hour with a machine so equipped, without touching the controls, a year or so before the war. The apparatus was mounted in a very small and simple airplane and connected with a timing mechanism operated by clockwork and designed to turn the 'plane around and bring it back to its starting-point after a given number of hours and minutes; this timing mechanism was also designed to operate the trigger of a release mechanism for dropping a bomb or a series of bombs at a predetermined moment. It could be so adjusted that the machine would fly around a mountain, if necessary.

Numerous experimental flights proved the entire practicability of this device; the most spectacular of them demonstrated that the machine so equipped had automatic stability in the air beyond anything its makers had dreamed of.

The machine was sent up at the Wright flying-field near Dayton. It had flown but a short distance when a sudden gust of wind caught it and the control mechanism became jammed for a moment. To the alarm of the spectators, the nose of the 'plane pointed straight up into the air; it paused there a moment as if about to drop in a tail spin; then, as gracefully as Vedrines himself ever did it, it "looped the loop" and resumed its horizontal course. But in "looping the loop" the clockwork control mechanism fell out. It had not been thought necessary to anchor it in place. So instead of coming back, after making a short turn over the neighboring countryside, the machine swung wide in a great circle over the city of Dayton. Back it came toward the flying-field and once more around, a mile high in the air, its creators on the ground watching in helpless wonder as Frankenstein must have watched the monster his inventive genius had involved. Four times the uncontrolled 'plane circled over the city and back to the flying-field, until, having traveled more than one hundred miles alone in the air and its gasolene-tank being emptied, it glided earthward and landed with a crash in a near-by field.

When those in charge of the experiment hurried to the spot they found a crowd of farmers and officers trying to lift the machine off the ground in order to rescue the aviators who were supposed to be buried in the wreckage. For a moment there was great danger that the secret of the automatic airplane would leak out, until one of the observers with rare presence of mind announced that the pilot had made a parachute jump just before the crash!

Although this device was perfected too late to be of use before hostilities ceased, the fact of its existence gives added weight to the words of General Gouraud, the famous French commander, who has declared that, brutal and savage as was the Great War, the next war will be even more brutal and savage. It would be difficult, however, to imagine a more potent discourager of war than the knowledge that the enemy possesses such weapons and resources as lewisite gas and the automatic airplane. If, in addition to the enormously valuable contributions to peaceful industry which I have indicated, America's preparations for chemical warfare prove a deterrent of future wars, they will have easily been worth all they have cost us.

IX

A REVOLUTION IN SHIP-BUILDING

WHEN the United States declared war on Germany the German submarines were sinking merchant-ships faster than all the yards of Great Britain, the United States, and the rest of the world could build them. It was patent at a glance that it would be perfectly useless for us to raise, train, and equip armies unless there were ships available to take them across to France, and to transport the enormous quantities of supplies which would be needed.

To the question, "What can America provide that will be of the greatest value to the Allies?" put to Premier Lloyd George of Great Britain, the answer came back without an instant's hesitation:

"Ships, ships, and more ships!"

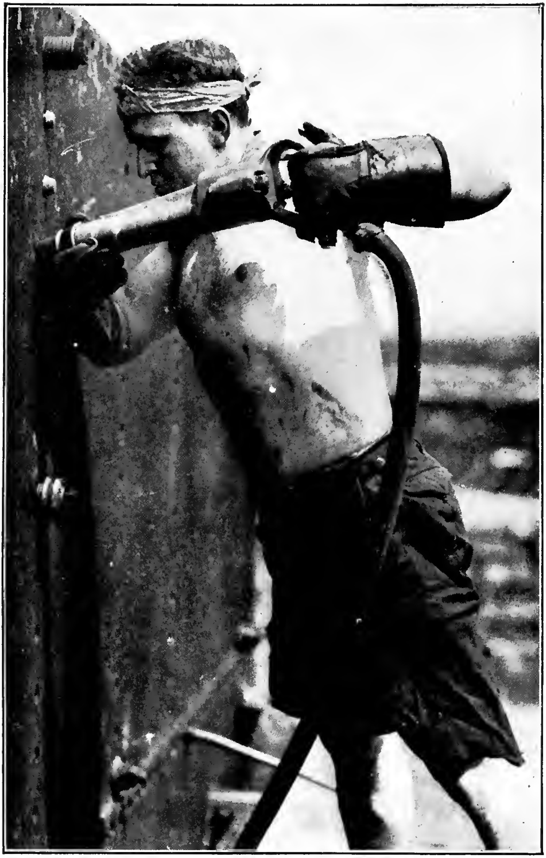
How we were going to supply ships was a problem for which no answer seemed to be in sight. Once the foremost ship-building nation in the world, with our fast sailing packets flying the gridiron flag in every port of the seven seas, we had almost forgotten the art of ship construction. When the iron ship began to replace the wooden vessel, steam to crowd out sails, and the screw propeller to displace paddle-wheels, we were busy with a Civil War; by the time we began to recover from it Great Britain had developed the ship-building industry to a point where competition seemed impossible. We of America decided to let her keep it and invest our capital in other forms of industry.

To-day the United States government is the largest ship-owner in the world. On April 6, 1917, there were but 61 shipyards in the United States, of which only 37 were equipped to build steel ships; when the armistice was signed there were 341 yards, which were building ships for the government on 1,284 ways, as compared with 142 available ways in 1917. Gigantic new shipyards owned by the government were built, five of them for steel and seven for concrete ships; from these and privately owned yards 496 new ships with an aggregate dead-weight tonnage of 2,828,781 had been added to our merchant fleet; 399 of these were of steel. There had been launched 285 more ships and the keels had been laid for 743 more. What with the German and Austrian ships seized and other foreign-owned and American ships chartered, there were, by September 1, 1918, under the control of the government, 1,656 vessels with a total dead-weight tonnage of 7,219,823.

New ships were being delivered at a rate rapidly climbing above 400,000 tons a month, and there were contracts outstanding for 1,475 ships, aggregating 10,835,491 tons, with every assurance that these ships could and would be built and delivered on schedule time.

From less than 45,000 men employed in the ship-building yards of America, more than 380,000 were so employed when the war came to an end; in the boiler and engine works and other industries allied to the ship-building trade were another quarter of a million.

On July 4, 1918, the United States of America



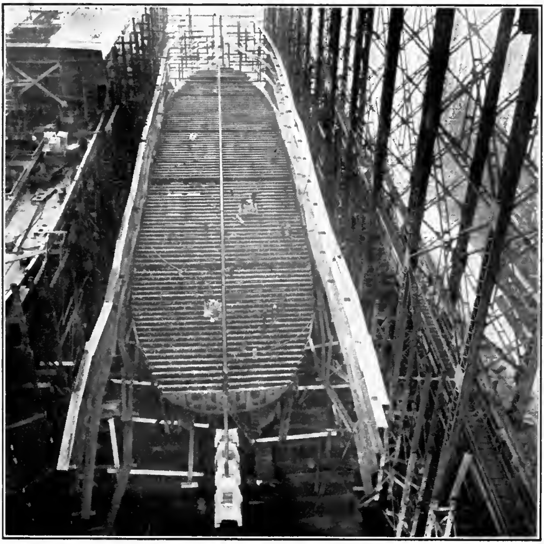
THE GUN THAT BEAT THE HUN

The pneumatic riveter, known to shipyard workers as the "air-gun," is a Yankee invention that alone made possible our great ship-building program.

celebrated its one hundred and forty-second birthday by launching in a single day more seagoing ships than had ever been launched from our shores before in a whole year. Ninety-six vessels, having a total capacity of nearly half a million tons, went overboard. Besides this enormous tonnage of merchant-shipping there were many launchings of destroyers and other naval craft.

To establish in such an incredibly short time an industry of such gigantic size from such a trivial beginning meant the development of new methods of building ships. It meant that new ways, too, had to be found to train ship-builders, since we had no considerable body of workers who had ever had anything whatever to do with any phase of ship construction. Ships are now built by the same distinctively American method of manufacture that we have become familiar with in the production of automobiles and a thousand other articles, the method which is America's most important contribution to the world's industry, known as "quantity production."

Quantity production, whether of shoes or ships or sealing-wax, means, first, deciding on a single size, type, or design of product to be made in a particular plant, then fabricating the parts that go into that product in quantities exactly alike, so that when assembled there will be no essential difference between any two of the finished articles, and doing all of this with machinery specially designed for the purpose and so automatic in its operation that even the unskilled laborer can perform the necessary manual operations. That is precisely the plan followed in our entire shipbuilding program. For the first time in the history of the art, ships exactly alike in every detail were and still are being built by identical methods, from identical plans, out of parts fabricated in quantity, hundreds, even thousands of miles from the yards where they are assembled. There are several different sizes of these standard ships, but all of the 5,500-ton ships



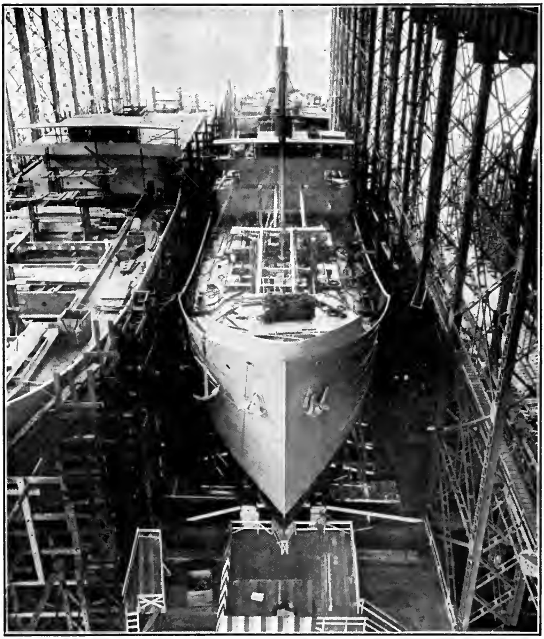
THE SHIP THAT WAS BUILT IN TWENTY-SEVEN DAYS
View of the *Tuckahoe* on the third day, showing floors in place.

are alike, all the 7,500-ton ships are interchangeable in every part, each with the other, all the 10,000-ton craft contain the same number, size, and shape of parts. This had never happened before. Even when ships have been built from identical plans, so much of the "fairing" of the lines has been left to the engineer or marine architect in charge of construction that the finished ships would differ, as in the case of the *Lusitania* and *Mauretania*, sister ships that differed in length, in beam, and in other dimensions. The *Olympic* was in commission a year and more before the *Titanic* was launched, but it was not until the *Titanic* was actually afloat that the builders were able to tell her exact length and draft, which differed substantially from the *Olympic*.

Now every beam, angle-bar, plate, or other part of a standard ship is finished at the fabricating plant, even down to the correct bevel of the edges and the punching of the innumerable rivet-holes. Speed in ship-building, as well as economy of cost, is made possible by the fact that when these parts reach the yards there is nothing to do but to rivet them together.

Building a modern steel ship is, after all, different in no essential particular from building a bridge or a skyscraper. A steel ship does not depend for rigidity upon the strength of the keel, as does the old-fashioned wooden ship, but upon the proper construction of its entire frame, exactly as does a bridge. It is really, from an engineering viewpoint, merely an inclosed girder, built of structural steel shapes and plates riveted together and covered with a skin or "shell," as the ship-builders term the outer sheathing, of steel plates riveted to each other and to the frames. These plates may be anywhere from five-eighths of an inch to an inch or more thick, depending on the size of the ship and where they are used; the bottom plates are the heaviest.

When one considers that in a 5,000-ton steel ship there are something like half a million rivets, in a 7,500-ton craft nearer a million, the part the riveter plays in the assembling of the ship is of manifest importance. The plates and beams that form the keel have to be riveted together. To these are riveted the "floors," the transverse members that form the frame of the bottom of the ship and extend crosswise from the keel; these may be as much as five feet high on



THE "TUCKAHOE" ON THE TWENTY-SEVENTH DAY

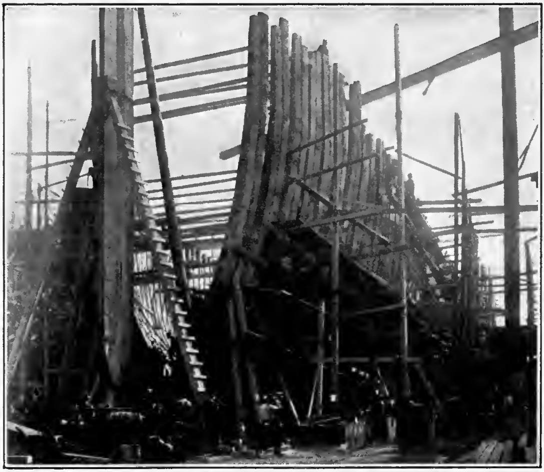
All ready for launching, upper works finished, engines installed, even the anchors in place.

a large ship. To the ends of the floors are riveted the frames; the deck-beams are riveted to the frames, and the decks to the beams; then the bulkheads have to be riveted to beams, frames, and floors, the outer skin or shell riveted on, a plate at a time, each plate secured to each other plate where it joins at the ends by a row of three rivets, along its edges by a double row of rivets to the adjoining row or "strake" of plates, and wherever it crosses a frame, floor, or beam, riveted fast with a close row of rivets. The rule in steel ship-building is, "Wherever two pieces of steel touch, rivet them." Then there is the inside skin, or "cieling," to be riveted into place, the deck openings to be strengthened by the riveted hatch coamings, or "strongbacks," and by this time there are not more than ten or fifteen thousand more rivets to be driven for the tanks, shaft-tunnel, deck-houses, and other parts of the ship, without counting those that hold the boilers together.

When it is considered, also, that practically every rivet must be water-tight in its hole and hold the plates together with a water-tight pressure, and that for tanks they must also be oil-tight, it looks like a job for skilled workmen. But the "air-gun," as every shipyard worker calls the pneumatic hammer, enables unskilled men to become expert riveters in a short time. It strikes a thousand blows a minute on the nose of a red-hot rivet with the force of one hundred pounds behind every blow.

When the "boys" at the Port Newark yards of the Submarine Boat Corporation got to discussing, late in March, 1918, just how many rivets were really a good day's work for the standard "gang," composed of riveter, "passer-up," and "heater-boy," they little dreamed they were inaugurating a new form of international sporting contest that would prove to be as important, at least, if not as prominent a feature for the society page, as polo, yacht-racing, tennis, or golf.

In three months the title of champion riveter of



VIEW OF THE WOODEN SHIP "ABERDEEN" TAKEN FORTY-NINE HOURS AFTER THE KEEL WAS LAID, SHOWING STERN IN PLACE

the world crossed the Atlantic three times, was held by an Englishman, a Scotsman and an Irishman, and by three different Americans.

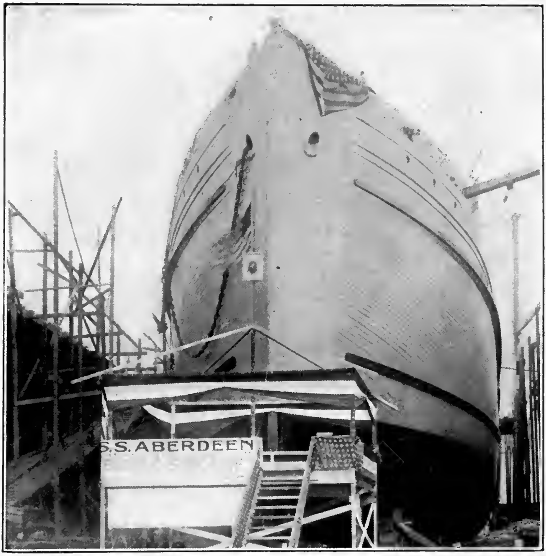
Four hundred rivets a day was regarded as a good day's job, on straightaway work in easily accessible positions, as on the frames of a ship, where the riveter and the "passer-up" or "holder-on" can work together like one man. Some of the Port Newark boys thought it might be possible to get six hundred or even more a day. Others disagreed, and immediately it became apparent that there existed that difference of opinion without which, Mark Twain says, there could be no horse-races. Bets were accordingly made, and, greatly to the surprise even of the winning gang, a record of 836 rivets for a nine-hour day was made. A few days later another gang in the same yard topped the thousand mark. The men in other shipyards heard of these performances, scoffed at first, then tried it, and before the end of April several gangs had succeeded in driving about 2,000 standard seven-eighths-inch rivets in a single working-day.

At the Baltimore Drydock and Shipbuilding Corporation, "Finner" Shock, an expert riveter, heard of these records of 2,200 and 2,300 rivets a day. One day, with a picked team that had worked with him for months, he extended himself a bit and put 2,720 "hot pins" in place in nine hours. Then he laid off for a day or two, and when he went back to the yards he found himself an international figure. The news of his performance had been cabled to England, received there with incredulity, and the British workers had been challenged to beat it. Pretty soon an Englishman did beat it, topping the 3,000-mark in a yard on the Thames. The English papers crowed for forty-eight hours or so; then a Scotsman with an Irish name, working in the Dalmuir yards on the Clyde, stretched himself and drove a few more than 4,300 rivets in a nine-hour day!

"That will hold the Yankees for a while," the British remarked, and a London ship-builder wrote a letter to *The Daily Mail* offering a prize of £25 to any riveter, bar none, who would beat the

Scottish figure. Lord Northcliffe was named as the referee.

Charles Knight, a colored riveter, who worked at the Bethlehem Steel Corporation's "Penn-Mary"



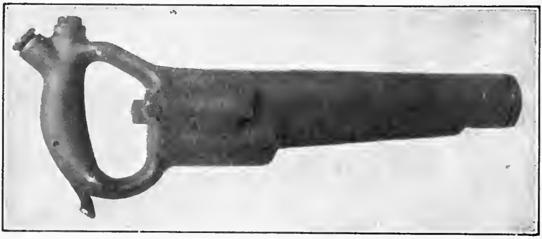
THE WOODEN SHIP "ABERDEEN"
Built and ready for launching in seventeen days from the laying of the keel.

plant at Sparrow's Point, near Baltimore, heard of that Scottish record. Also his eye caught the notice of a fifty-dollar bonus for the first riveter in the Sparrow's Point yards who would top it. He and his gang put in a couple of easy days practising team-work, just to get limbered up, and then told the foreman that if it was a good day to-morrow they reckoned they'd go after that record, if he'd be kind enough to let them work on some of the hatch strongbacks that were waiting to be riveted up. The foreman agreed, the weather was clear, and in the pres-

INSIDE THE HULL OF THE "ABERDEEN"
The record-breaking wooden ship, looking toward the bow.

ence of officials of the company and of the Emergency Fleet Corporation, Charles and his gang drove 4,472 seven-eighths rivets in nine hours!

"Jus' cable that news to King Gawge, please, suh," grinned Charles, as he laid down his air-gun. The news was cabled, and back came a cable from Lord Northcliffe authorizing Chairman Hurley of the Shipping Board to award the £25 prize to Charles Knight. With the bonus and the extra pay the day's work netted $277 for Charles and his gang. The customary distribution is 50 per cent. to the riveter, 30 per cent. to the "passer-up," and 20 per cent. to the "heater-boy"; but Charles used an extra man, so he had both a "passer-up" and a "holder-on," and had to



A "CLOSE-UP" OF THE AIR-GUN

divide a little differently. It was fair wages for a day's work, however.

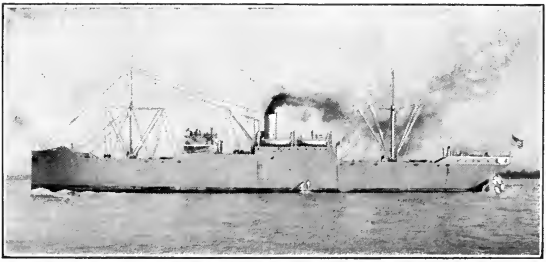
This performance put the Britishers on their mettle and set the American shipyard men to looking for a "white hope" who could beat Knight's record. The white hope appeared in the person of John Corrigan, at the Wyandotte yards of the American Shipbuilding Company. John cut loose one day early in June, and when the day's score was tallied it showed 7,028 "hot pins"! But even while this was being cabled triumphantly to England word came from Belfast, heralding John Mowry, a veteran workman of the Harlan and Wolff yards, as world's champion, and a day or two later John Moir, in the same yards, claimed and was accorded the incredible performance of 11,209 standard seven-eighths rivets in the floors of a standard ship in a nine-hour working-day!

Of course these records were made under exceptional circumstances, and while they had a noticeable effect in speeding up riveting generally, they proved not the best way of stimulating rivalry for effective production increase. The Shipping Board worked out a competitive plan, based on the average performance per gang per hour for a month. This gave the big yard with 250 or more riveting-gangs no better chance than the little yard with only a few gangs. A blue pennant was awarded every month to the yard making the best record the previous month, and men working in the winning yard won the right to wear specially designed badges. Under the stimulus of this and other forms of carefully fostered friendly rivalry between yards and between different gangs in the same yard, steel ships were built faster than any one had ever dreamed it could be done.

To train riveters, schools were opened at the shipyard. Perfectly green workers learned the art in a surprisingly short time. Three "rookies," none of whom had ever driven a rivet before he went to work in the yard, after six weeks of training drove in an eight-hour day 2,803 rivets, of which only twelve failed to pass the inspectors. One recruit, who had never seen a shipyard before he went to Hog Island, drove 867 seven-eighths rivets, flush, in the side shell of a ship in a single day after three months' experience. Another, after seven days' instruction in the school and three weeks in the yard, drove 1,327 three-quarter-inch rivets, flush, in a day. Ninety per cent. of all the riveting at Hog Island was done by men who had never handled an air-gun until they went to work there.

THE PRODUCT OF HOG ISLAND

Standard steel ship of 7,500 tons, built by the Emergency Fleet Corporation.



THE "SAGAPONACK"

One of the standard 7,500-ton steel cargo ships turned out at Hog Island.

Riveting is not all there is to ship-building. First the steel must be "placed," each beam and plate lifted by overhead cranes and firmly fastened with bolts run through rivet-holes into the exact position where it is to be permanently fastened with rivets. The spirit of rivalry in "placing" was also stimulated in the yards. Such feats as laying the keel of a ship, containing 200.05 tons of steel, in 7½ hours proved a spur to emulation. By such methods steel-ship production was speeded up and moved up to the end of the war with increasing momentum. All fear of an insufficient supply of skilled labor vanished. And in the wooden-ship field the tradition that only trained ship-carpenters could build them was exploded. There was found to be not the slightest difficulty in training average intelligent workmen to put wooden ships together, while pneumatic hammers and drills greatly lessened the work of making the holes for the four-foot steel drift-bolts that hold the six-inch planks to one another, and for the black locust treenails or "trunnels" that pin them to the ribs, and in driving these home.

Up to the signing of the armistice the total number of wooden ships added to the American merchant marine since the United States went into the war was eighty-four with an aggregate dead-weight tonnage of 298,200. Fifty of these ships were built to the designs of the two young engineers, Hough and Ferris, whose simultaneous conception of the wooden ship as a cheap, quick, and efficient way to get tonnage and lots of it was one of the most radical, yet practical, contributions toward the winning of the war. Neither Hough nor Ferris was a ship-builder, but each was a construction engineer who recognized that modern ship-building is neither an occult mystery nor a work of art. Each of them, without knowledge that any one else was doing the same thing, worked out a design for wooden ships that could be quickly put together out of practically green lumber, and would serve every purpose of a ship. That is to say, they would

A RECORD-BREAKING JOB AND THE MEN WHO DID IT

Eighty full frames of this wooden ship were set in thirty-four working-hours at Portland, Oregon.

float, would hold a lot of cargo, could be propelled by their own engines, and were designed with due regard to possible stresses and strains, viewed from an engineer's standpoint. Speaking in engineering terms, a ship is merely a box girder; if it is strong enough to bear its own weight and that of its cargo when suspended at either end, as it often must be when the waves are running high, it is a good-enough ship for emergency purposes. The wooden ships built as a war emergency measure are really better than that description would imply; how long they will last, however, depends upon many conditions that cannot be determined in advance. There are wooden ships afloat that are more than one hundred years old and still giving good service; one was recently overhauled in Norway and put back into trans-atlantic service that is more than two hundred years old.

Hough and Ferris went to Washington, each with his design for a wooden ship. The then chairman of the Shipping Board, Edward Denman, was greatly impressed with their project, and it was immediately adopted by the board. Then General Goethals was detailed to direct the building of ships, as head of the Emergency Fleet Corporation. General Goethals could not see the wooden ship, except as a trivial and unimportant by-product. He did not think it good policy to spend time and energy building ships of such perishable stuff; steel and concrete, such as he used in the Panama Canal, were good enough for him. The board was insistent, the general rebellious. In the same speech in which he expressed his conviction that boards were uniformly "long and narrow and made of wood," he remarked that the birds were still nesting in the trees from which he was expected to build wooden ships. The resultant publicity was followed by the dismissal of both Denman and Goethals by the President. The wooden ships have been built, however. General Goethals was right — the birds *were* nesting in the trees from which the ships launched less than a year later were constructed. He was wrong only in assuming the project to be impractical. Nor are these ships built of green lumber. The same Forest Service method of kiln-drying lumber in two weeks that made possible the enormous production of spruce for airplanes was availed of for ship-building as well.

Substantially all of the wooden ships are of the same size—3,500 dead-weight tons. The largest are 4,700-tonners, built at Orange, Texas. The great majority of the wooden ships were built, naturally, on the northern Pacific coast, where timber of sizes suitable for ship construction is plentiful. In all, 508 keels for wooden ships had been laid and 227 hulls launched when the armistice was signed. Not all of these were completed as steamships; when the war emergency had passed it was regarded as more economical to fit some of them out as sailing-ships and use some of the hulls as barges.

The spirit of competition was invoked to speed up the wood-ship builders, too. While there is no opportunity for such spectacular performances as were made by the champion rivet-drivers, there was room for rivalry between yards and between gangs in single yards in such matters as speed in keel-laying and frame-erecting.

The keel of a Ferris-type ship consists of five large timbers, laid end to end, dovetailed and bolted together. As soon as a ship was off the ways it became a point of pride to get a new keel, the timbers for which had already been sawed and cut to shape, laid and bolted up as quickly as possible. A Pacific yard did this in 20 minutes and boasted about it; at the next launching at an Eastern yard this time was cut to 10 minutes; another followed with a record of 6½ minutes; soon that record was cut to 90 seconds by a Savannah yard, and a later report from the same yard gave the incredible time of 11 seconds for a keel-laying!

Erecting the frames, also, is an operation that permits of speed records. A Pacific yard started this sport by putting up the complete set of frames for a hull in 44 working-hours; to occupy the spare time left after this performance they did half a day's work of planking in an hour. A few days later the same yard set up the entire set of 80 frames in 34 hours, and crowed so loudly about it that one of the Gulf yards took a hand and did the same trick in 30 hours and 35 minutes. Even this record was bettered later.

X

SOME EXTRAORDINARY SHIP-BUILDING FEATS

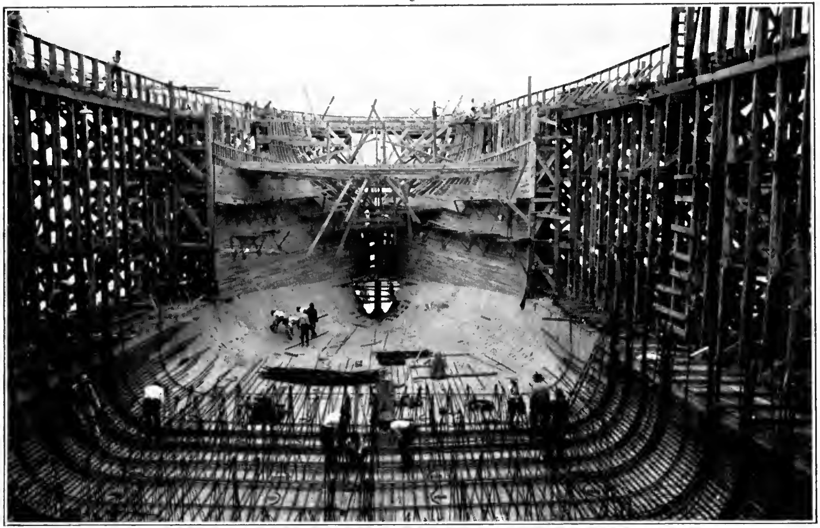
YANKEE ingenuity and resourcefulness in ship-building did not exhaust itself with the construction by novel methods and unheard-of speed of the steel and wooden ships referred to in the previous chapter. We built composite ships, wooden planking on steel frames. We performed the unheard-of feat of building huge ocean-going, cargo-carrying, 5,000-ton ships out of stone—for concrete is, after all, simply artificial stone. I have told how we trained unskilled men into the fastest riveters in the world, but at the signing of the armistice we were beginning to fasten the steel plates of ships together by electric-welding devices operated by women! And there is nothing more typically illustrative of Yankee ingenuity than the methods resorted to for building ocean-going ships a thousand miles from the ocean and floating them from the Great Lakes to the seaboard, even though they were twice as long as the locks of the Welland Canal!

In the shipyards of Buffalo, Cleveland, Detroit, Chicago, and Duluth steel cargo-ships six and seven hundred feet long and having cargo capacities up to twenty thousand tons had been built for years. Every one of these ships, however, was confined to a cruising radius of 1,500 miles, the distance between Tonawanda on the Niagara River above the Falls and the

Duluth-Superior port at the head of Lake navigation. While there are two water connections between the upper Lakes and Lake Ontario, the larger of these, the Welland Canal, with its series of forty-four locks, like a flight of stairs, will admit the passage of no ship larger than 260 feet in length, 44 feet beam, and 14 feet draught. There had been, a number of years ago, a half-dozen or more ships cut in two and towed through the canal in separate halves, afterward being patched together at one of the Lake Ontario or St. Lawrence River ports. It was regarded, however, as a hazardous experiment, and there was a feeling among shipping-men that the operation weakened the vessel and tended to render it unseaworthy.

So pressing was the need for merchant tonnage, however, that it was obviously wasteful to let the huge ship-building capacity of the Great Lakes yards remain unutilized in the emergency. They were put to work at once on the construction of ships of dimensions that would pass through the Welland Canal locks, but as it speedily became apparent that the greatest need was for larger ships, which are much more economical in their operation, the attention of the Emergency Fleet Corporation and the ship-builders engaged in this work was focused on the devising of safe and certain methods of cutting these Lake freighters in two and then fastening the two halves together again on the lower Lakes.

At one time, in Detroit, I saw three different classes of ocean-going ships in process at one time. One big Lake carrier was being fitted with the water-tight bulkheads, higher freeboard, and stouter upper works required for ocean craft, preliminary to being sawed in two amidships for transportation through the canal locks; at an adjoining yard steel freighters of 4,200



THE MEN IN THE FOREGROUND ARE PLACING THE REINFORCEMENTS, WHILE IN THE BACKGROUND THE WOODEN MOLD IS BEING FINISHED FOR A 7,500-TON CONCRETE SHIP tons dead-weight capacity, the very largest ships that could be taken through the locks intact, were being built, while at the third yard they were building ships 260 feet long, each of which was equipped with an additional one hundred feet of midship section—keel, frames, beams, and plates—so that on reaching sea-level it could be taken into dry-dock, cut apart, and lengthened by one hundred feet.

One of the greatest difficulties in the way of utilizing the big Lake carriers for ocean service was the absence of dry-dock facilities at the lower Lake ports of Toronto, Montreal, and Quebec. While it has been done, it is a risky operation to attempt to tow half a steamship out through the Gulf of St. Lawrence and down the Atlantic coast to an American seaport. But there were only two dry-docks available in the St. Lawrence River, and they could handle only about four ships a year between them. The problem, then, was to devise a method of rejoining the two halves of a bisected ship without putting it in dry-dock. There were plenty of docks on the upper Lakes where they could be cut apart and temporary bulkheads placed in the open ends of the severed halves. Indeed, some ships were taken through the canal with the open ends filled with water, no temporary bulkheads being necessary.

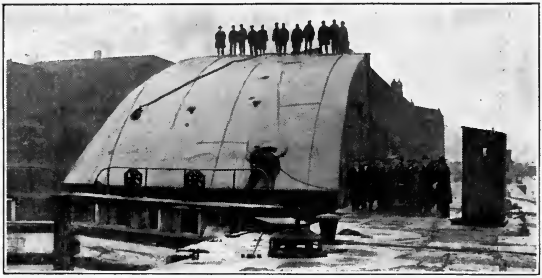
The problem was turned over to E. A. Eustis, a special agent of the United States Shipping Board and an expert ship-builder, having headquarters in Cleveland. Skilled engineers were called in and a method was devised by which twelve of the largest Lake ships were reunited while floating in the harbor of Montreal. Each of these ships was cut in two on the upper Lakes, the separate halves "stepped down" through the Welland Canal, and when the two halves were brought together the ship was in every respect as strong as before, and in the opinion of some engineers even stronger. The method consisted of placing temporary frames of six-by-six-inch angle-irons around

CUTTING A LAKE SHIP IN TWO PREPARATORY TO TAKING IT TO SALT WATER

Showing the *Frontenac* being pulled apart at Cleveland.

both sections of the ship at the point where it was cut in two, in such a way that they could be closely brought together when the ship was rejoined. These angle-irons were bored for two-inch fitted bolts. When the two sections of the ship were floated together each end was trimmed by water ballast until they were floating as nearly as possible at the same level. Then, by driving drift-pins through corresponding holes in the angle-irons of the two halves, they were held in the proper relative position while fitted bolts were inserted and the ship thus held firmly together. Plates that had been removed in the sawing-in-two process were put on and refitted, down to the water-line. Then the ships were floated over a caisson ingeniously devised so that it would fit closely around the hull at the two ends of the cut. When the water was pumped out of the caisson it pressed so firmly against the bottom and sides as to keep the water out from the midship section, so that men could work all the way under the ship in replacing plates, while the keel and floor-beams were strengthened by heavy plates riveted on both sides.

Still, the very largest Lake ships could not be brought down to the ocean even by this means, for while a ship more than five hundred feet long could pass through the Welland locks if sawed in two, the halves could not pass the locks if the ship were more than forty-four feet wide, the extreme width of the canal prism. This limited the size of Lake ships that could be brought to the ocean to vessels of about 6,000 tons. Nevertheless, a way was found of bringing a 10,000-ton ship, the *Charles R. Van Hise*, through the Welland locks, although it was 460 feet long, 50 feet beam, and 33½ feet deep. This was accomplished by first sawing the *Van Hise* in two across the middle, stopping the open ends of the cut with temporary bulkheads to make each half as buoyant as possible, and then turning each half on its side, so that the 50-foot dimension was not crossways of the lock, but vertical, and there was a width of only 33½ feet to clear the 44-foot width of the locks. This was a daring experiment; it is regarded by shipping-men as one of the most remarkable feats of engineering ever attempted. It was entirely suc-



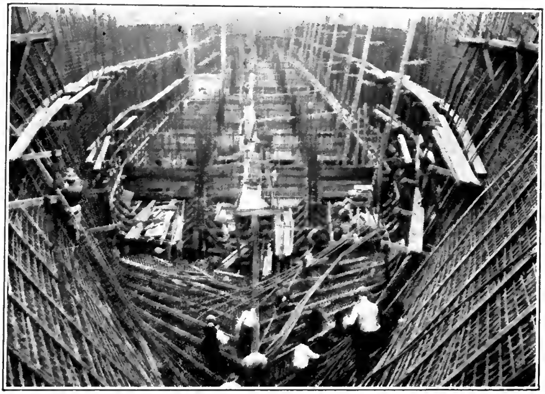
FORWARD HALF OF THE "CHARLES R. VAN HISE" TURNED ON ITS SIDE SO THE 10,000-TON LAKE SHIP COULD BE FLOATED THROUGH THE WELLAND CANAL

cessful, and had not the war come to an end within a few days after this had been done, there is no doubt that many more of the larger Lake carriers would have been brought into ocean service by the same means.

Even more spectacular, from the ordinary landsman's point of view, or, for that matter, from the viewpoint of the sailor, was the development and success of the concrete ship. Concrete as a ship-building

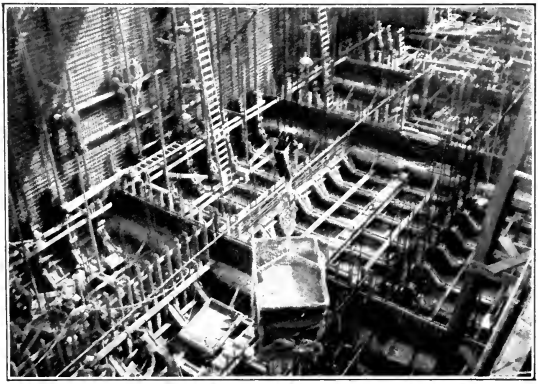
TURNING THE AFTER HALF OF THE "CHARLES R. VAN HISE" ON THE SIDE FOR TOWING THROUGH THE WELLAND LOCKS FROM LAKE ERIE TO LAKE ONTARIO material was not entirely unknown. Several years before the European war began a Baltimore concern built a number of harbor barges of concrete; in Norway a very small concrete steamship had been constructed. That a reinforced-concrete ship of 5,000 tons capacity could be built that would prove seaworthy in every respect was a matter of serious doubt in the minds of most ship-builders and engineers. The San Francisco Shipbuilding Company, however, decided soon after America's entry into the war to try the experiment. This first concrete ship was appropriately christened the *Faith*. She was built exactly the way a reinforced-concrete structure on land is built—that is, wooden molds were made for the inside and outside of the ship, steel reinforcing rods were put in place, and the liquid concrete poured into the mold. When it had hardened and set engines and boilers were installed, and the ship was launched. Even the uprights supporting the deck-beams, the beams, and the decks themselves were built of concrete.

On her first voyage the *Faith* ran into a terrific storm off the Oregon coast, encountering weather which put the craft to the severest possible test. The ocean was swept by a ninety-mile gale, and most ships were tossed about like corks, but according to the officers and men of the *Faith* the craft rode on a practically even keel and did so little rolling that it was scarcely noticeable. On account of the weight of the ship, the waves broke over her instead of lifting her, and a water-tumbler on a shelf in the galley did not fall off during the worst of the storm. The *Faith's* first voyage was from San Francisco to Seattle, then back to San Francisco, then to Peru and Chile, then through the Panama Canal to Havana and to New York.



BUILDING A CONCRETE SHIP IS MUCH LIKE BUILDING A CONCRETE BRIDGE

First there must be constructed a mold for the outside shape and then the steel reinforcements bent and wired in place.



POURING THE CONCRETE INTO THE MOLD AND AROUND THE REINFORCEMENTS

The result is a one-piece ship of artificial stone.

So successful was this experiment that the Emergency Fleet Corporation immediately arranged for the construction of many more concrete ships. The second craft of this construction was the *Atlantus*, built at Brunswick, Georgia, of 3,000 tons capacity, being slightly more than 260 feet long. Lessons learned in the construction of the *Faith* were utilized in the building of these later concrete ships, and, surprising as it may seem, it was found that whereas a wooden ship of 3,000 tons has planking 19 inches thick, a 5-inch concrete wall was sufficient and the resulting ship actually weighed less than a wooden ship of the same dimensions. The hull of the *Atlantus* was cast in one week's time. Chemical experts were engaged for research in the composition of cement, with the result that instead of the crushed stone and gravel usually used for concrete, a special aggregate produced by the burning of clay was adopted, with the resulting saving of more than 28 per cent. in weight. At the time of the signing of the armistice there were forty-two ocean-going concrete ships of nearly 300,000 tons capacity under contract, and many of them under construction for the Emergency Fleet Corporation; many of these were of 7,500-tons capacity.

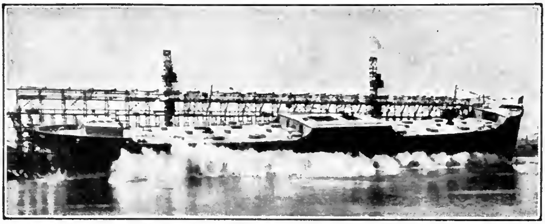
So successful did the American development of the concrete ship prove that the British Admiralty encouraged Scotch and English shipyards to work along similar lines, although no concrete craft built or laid down up to the close of the war approximated in size even the smallest of the American-built ships of this material.

To put a 5,000-ton ship together requires about 450,000 rivets; a 9,500-ton ship requires from 600,000 to 700,000 rivets. Every rivet is a possible source of weakness; every rivet-hole a possible point of leakage. Ships have been known to scrape bottom and come off the bar uninjured except that they had sheared

THE "PALO ALTO," FIRST CONCRETE SHIP OF ITS SIZE; IT IS OF 7,500 DEAD-WEIGHT-TON CAPACITY

off the rivet heads holding the bottom plates in place, and the bottoms literally dropped out of them on reaching deep water. For this reason the bottom rivets on battle-ships and many other naval craft are countersunk, so that the heads are flush with the plates. Moreover, the rivets in a 9,500-ton ship weigh 500 tons, and if they could be eliminated the ship could carry 500 tons more cargo.

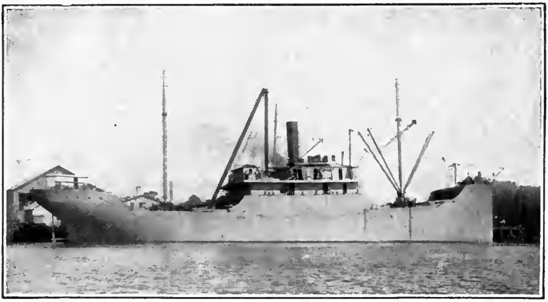
These are among the considerations that led engineers and electrical experts, early in America's program of ship construction, to study the problem of building steel ships by welding the plates together electrically. Electric welding is a distinctly American invention. Prior to the war it had gained an important place in many industries. It was obvious that if it could be applied successfully to ship construction, making the entire ship actually one solid piece of steel instead of a large number of pieces fastened together by rivets, there would be an enormous gain in strength and security, possibly in time of construction and of labor cost. Mr. A. J. Mason, of Chicago, Consulting Engineer for the United States Shipping Board, whose previous inventions had given him a high standing among marine engineers, and Prof. Comfort A. Adams, of the faculty of Harvard University and the Massachusetts Institute of Technology, chairman of the Electrical Engineering section of the National Research Council and president of the American Institute of Electrical Engineers, were appointed on the Electric Consulting Committee by the Emergency Fleet Corporation, to investigate and propose methods of applying this process to ship construction. Several years before the war, a steel tugboat 60 feet long was built at Ashtabula, Ohio, by the electric process. This was the first electrically welded vessel of any size built in the world. In June, 1918, there was launched in England a 275-ton barge built by the same process, and in the autumn of 1918 work was begun at the yards of the Federal Shipbuilding Cor-



LAUNCHING THE "PALO ALTO," A 7,500-TON CONCRETE SHIP, AT OAKLAND, CALIFORNIA

poration at Kearney, New Jersey, on a 42-foot midship section for a 9,600-ton ship fastened together by electric spot welding instead of by rivets.

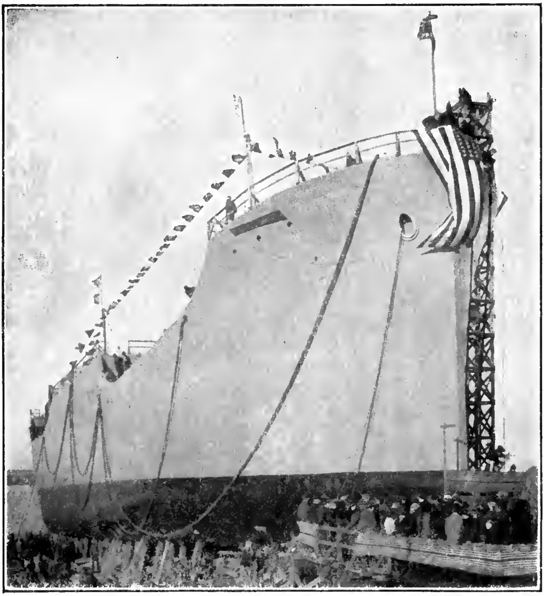
There are two principal methods of electric welding. The "arc" welding process consists of bringing a wire about one-eighth of an inch in diameter into contact with the metal to be welded at the point where it is desired to join the two parts. A powerful



ONE OF THE 3,000-TON CONCRETE SHIPS BUILT AT BRUNSWICK, GEORGIA, BY THE EMERGENCY FLEET CORPORATION electric current is passed through both the wire and the metal to be welded. The wire is then pulled away from the work and the electric current, jumping the gap, forms the arc and generates heat sufficient to melt the end of the wire and fuse the surface of the metal parts. The molten metal from the wire is deposited in the joint and fills it up, becoming an integral part of the plates or beams.

It was by the use of the arc-welding process that the German ships taken over by the United States government on our participation in the war were repaired and made useful at the end. Before surrendering the ships, the German crews cracked the cylinders of the engines, chiseled off the heads of rivets holding plates to frames, bent the piston rods, plugged up boiler flues, and in a hundred ways attempted to make it impossible for the ships to put to sea. They openly boasted that they had done such damage that the Yankees could never repair them. They honestly believed that only German workmen in German shipyards could ever make these German ships seaworthy again. But in less than six months every one of the German ships, from the huge *Vaterland*, renamed the *Leviathan*, down to the smallest freighter, had been completely repaired, and in most cases the machinery was stronger and better than before. Cracked cylinders were made whole by the arc-welding process, which makes the joints stronger than the original metal, and at a minimum of cost in money and in time America had at command a huge fleet of passenger- and freight-ships which had once flown the German flag.

The other method of electric welding is known as "spot" welding. This is purely an American process, and is applied to heavy plate-work. By means of a



LAUNCHING A CONCRETE SHIP

One of the 3,000-ton stone craft built for the Emergency Fleet Corporation at Brunswick, Georgia.

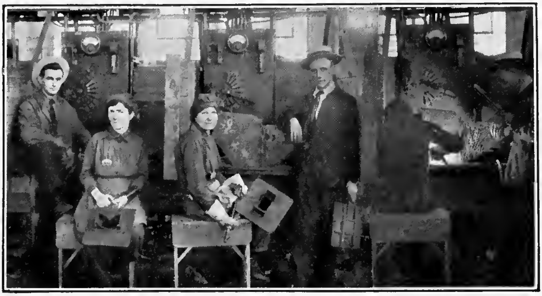
powerful clamp exerting a pressure of about twenty-five tons the plates are secured together and an electric current passed through them at the point of highest pressure. The heat actually melts the two plates together. This is just like riveting, except that there is no punching of holes and there are no rivets. Instead of being continuous, this welding is done in spots, and is consequently known as "spot" welding.

It takes about fifteen seconds to weld two ship-plates together at each spot, and after considerable experimenting with the method devised by Mr. Mason, Professor Adams reported that practically everything done on a ship by rivets could be done by means of spot welding. Portable spot-welders for use in fastening plates to frames were devised, but the natural field for spot welding is in the fabrication-shop, where stationary spot-welders can be employed.

One great advantage of welding over riveting is that while the work of riveting required great physical strength, welding can be done by women as well as by men. Even one-armed men can do electric welding. At Hog Island, where an electric-welding class was established, one of the first pupils was a woman, Miss Sara A. Irwin, who took up the work and did actual ship construction.

No record of Yankee ingenuity as applied to war-time ship-building would be complete without some mention of the unsinkable ship, the *Lucia*, which was sunk by a German submarine. Paradoxical as it may seem, it was the verdict of shipping experts that the *Lucia*, although sunk, was a successful demonstration of a method of making ships unsinkable! The *Lucia* was a steel ship 418 feet long, 54 feet beam, with a dead-weight capacity of 10,650 tons. Inside the *Lucia* between the ribs or side-frames and in the spaces between the deck-beams were fitted 6,000 water-tight wooden boxes, each 3 feet long, 2 feet wide, and 1 foot deep. Approximately the same number of larger boxes were fitted into cargo space that would otherwise be left empty when the ship was carrying a full cargo of coal. These buoyancy boxes weighed 1,400 tons, but with the boxes in place she was able to carry a cargo of 8,179 tons.

The theory of the buoyancy boxes was that, no matter, how large a hole was blown in the hull, the ship would still float. On the evening of October 17, 1918, the *Lucia* was eastward bound across the Atlantic with four other vessels, but without a convoy. A torpedo struck squarely in the engine-room section amidships, killing four men and injuring several others. The *Lucia* remained afloat for twenty-



WOMEN SHIPYARD WORKERS LEARNING ELECTRO WELDING

As the war ended, the method of fastening steel ships together by spot welding instead of riveting had just been developed to the point where its usefulness was proved.

four hours. The engines having been demolished, the vessel could make no headway, and wallowed in a gradually rising sea. In the afternoon of the following day the rolling of the ship became so violent that the deck-load of motor-trucks broke loose. The five-ton trucks, threshing about on the deck, endangered the lives of the crew, so that the vessel was abandoned at five o'clock in the following afternoon, though still afloat and showing few signs of sinking. Several of the trucks went over the side, giving more room for the others to thresh about, and finally two of them smashed through the deck structure, tearing open the hatches and permitting water to flow into all the holds. It was not until this that the *Lucia* sank. But for the damage done by the motor-trucks, it is considered doubtful that she would have sunk at all.

XI

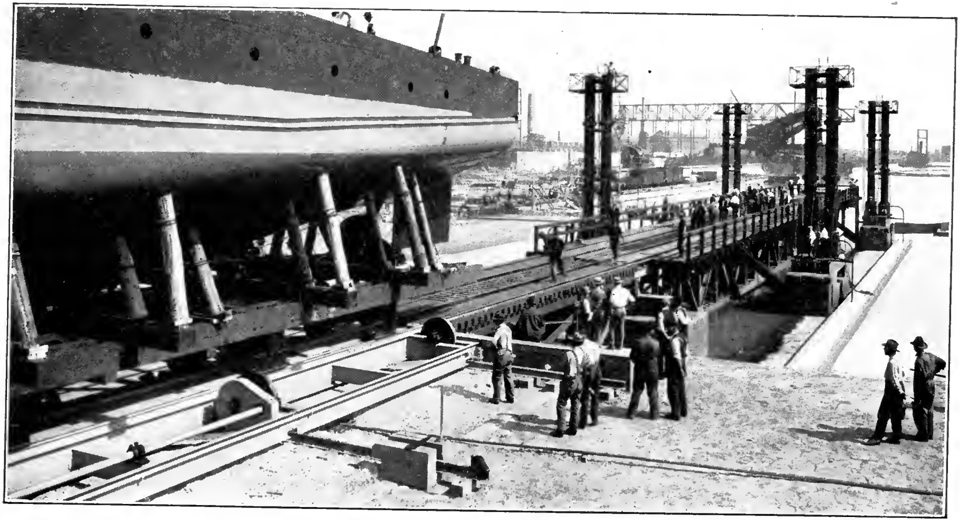
THE "EAGLE" BOATS

TRULY and typically American in both conception and execution, the Eagle boats built for the navy by Henry Ford rank very high in the list of examples of Yankee ingenuity and resourcefulness as applied to war problems. After two lengthy and detailed inspections of the Ford ship-building plant, from the raw steel to the finished ships, I came away not at all sure which was the most amazing aspect of the whole business, the Eagle boat itself, with its radical departures from every accepted canon and tenet of naval architecture, the audacity of the conception of building ships by the same program and method that produces the ubiquitous Ford car, or the truly miraculous speed with which the huge ship factory in which they were being made had arisen, Aladdin-like, on the banks of the River Rouge.

The Eagle boat was first thought of in January, 1918. Mr. Ford began to make plans for the construction of the boats and the erection of the factory for making them in February. I first visited the plant in the first week of June; it was completed in every detail except the launching mechanism, and half a dozen ships were in process of construction. And they are real ships; any vessel more than 200 feet long is entitled to be called a ship, and the Eagle boats are longer than that; they are within 25 feet or so of being as long as the standard 3,500-ton wooden ships built for the Emergency Fleet Corporation, although, of course, their tonnage is very much less. Comparison of the Eagle boats, however, should be with naval rather than with merchant craft. They are not so large as the new destroyers, but they are a good bit larger than the old familiar type of destroyer that formed the backbone of our "mosquito fleet" before we went into the war.

The Eagle boat is, in fact, a destroyer without torpedo-tubes and with less engine power and, consequently, less speed than the new high-powered little bull-terriers of the sea, with their 27,000 horse-power and thirty-knot gait. It has speed enough, though, to run circles around the fastest submarine cruiser, running either submerged or awash, and carries exactly the same guns and depth-bombs that the destroyers carry, which experience has proved sufficient to "get" any submarine that shows a periscope within range. The Eagle boat is not so pretty to look at as a destroyer, but as the only people concerned with its appearance were expected to get their view of it through a periscope, the matter of looks was distinctly a secondary consideration in its designing.

Historically, the Eagle boat is a development of the "chaser," the new class of naval craft brought into being by the menace of the U-boat. The "chaser," though first introduced to public notice by the British navy, is distinctly an American craft. When the submarines first began to menace the British coast everything that would float was commandeered into the submarine patrol service; motor-launches and yachts were equipped with guns and sent to sea in pursuit of Fritz. This method of defense proved



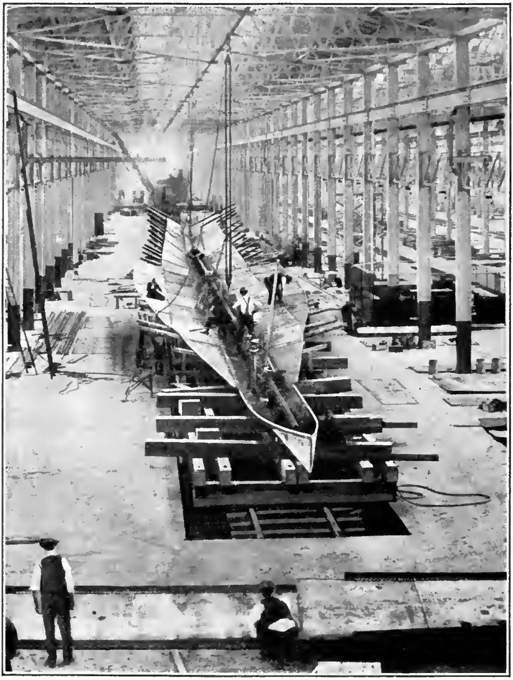
LAUNCHING AN EAGLE BOAT

This ship is being rolled onto the big hydraulic elevator, supported by columns of water under pressure in the four towers.

so effective that orders were given to an American ship-building company for 550 specially designed motor craft, officially known as "submarine chasers," and until the new British destroyer program was substantially completed and the American mosquito fleet was able to supplement it, which two events occurred about the same time, these "chasers" were almost the main reliance against the U-boat.

These 85-footers, however, proved frightfully "wet" boats in any kind of heavy weather and not large enough to cover the enlarged cruising area made necessary by the appearance of larger German submarines. One of the first things our Navy Department did when we entered the war was to place orders for a large number of "chasers," of a similar type, but twenty-five feet longer. These "hundred-and-tens," as the navy refers to them (officially the "C" class), gave a good account of themselves on inshore duty about the British Islands and in patrol service on our own coasts, but they were subject to the many limitations of the motor-boat, and it quickly became apparent that something bigger was needed.

The "hundred-and-tens" were built of wood, chiefly at Lake ports, partly because they could be built more quickly of wood and partly because the steel shipyard capacity of the whole nation was needed for merchant-craft and larger naval vessels. What was needed, however, was a steel vessel so designed that its component parts would not require the diversion of any steel production needed for other war purposes, big enough for any weather, fast enough to catch any submarine, and a manufacturer who would undertake to produce it in quantities faster than ships of any size were ever built before. If the manufacturer couldn't be found, the ships couldn't



THE KEEL AND GARBOARD STRAKES OF AN EAGLE BOAT IN PLACE

be built, and for a time it looked as if the project would have to be abandoned or laid aside. Then Henry Ford dropped in to see the Secretary of the Navy one day. Their conversation ran somewhat like this, it is said:

"I wonder if you couldn't build these new boats for us," suggested the Secretary. Mr. Ford looked at the plans, and said that he could.

"How fast can you build them?" inquired Mr. Daniels.

"How fast do you want them?" asked Mr. Ford.

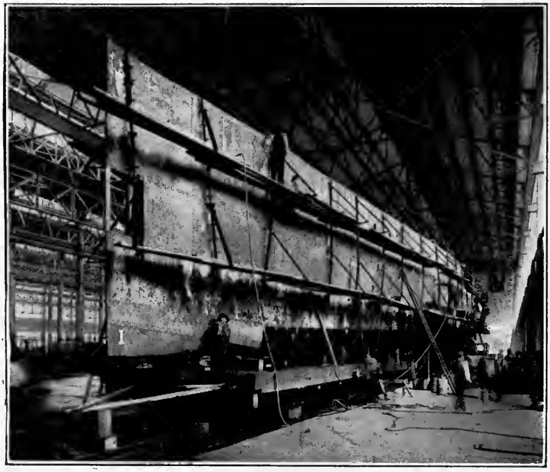
"Begin deliveries next summer and give us the whole two hundred by this time next year!" suggested Mr. Daniels.

That was in February. Mr. Ford thought a minute. It meant constructing a complete plant, buildings, machinery and all, from the ground up, in less than four months; inventing ways to fabricate and assemble the parts of the new boats; designing and constructing special tools to do the job on a scale that would make it possible to turn out a ship a day after the plant got into operation. Most manufacturers would have wanted a year to get ready to begin making boats; several had, in fact, looked at the plans and specifications, shaken their heads, and declined. Mr. Ford had never built any ships, but he had built four thousand automobiles a day, and he has absolutely no sense of any limitation to the ability of his organization to do anything he wants it to do.

"I'll do it," he said.

The design of the Eagle boat was worked out in the Navy Department. It took only three weeks to make the plans, build a model, and test it for stability and speed in the testing-tank at the Washington Navy-Yard, and to draw up specifications for the construction of the ships. In its lines the Eagle boat (that is the official designation of the entire class) does not exactly resemble anything else that floats. Viewed from above, it is much more like a flounder than a mackerel; the midship cross-section bears a strong family likeness to the lines of a canal barge. Its stern is uncompromisingly square and blunt. Save for the curve of the bilge and the necessary "fairing" of the horizontal plan, it is composed entirely of straight lines and plane surfaces. But the bow tapers down to a razor-like stem that looks as if it could slice through a submarine at a pinch and be none the worse for it, and there is a fine sweep to the lines aft that gives all the speed the craft is ever likely to require, flat-bottomed and awkward though it looks out of water. Utility was the first and ruling consideration, low-cost production the second, with comfort and beauty merely incidental, if they came into consideration at all.

With a length of 204 feet, the Eagle boats easily

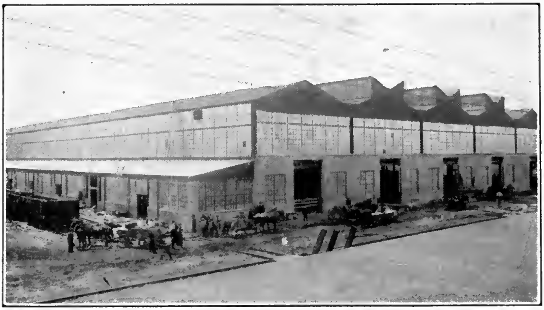


HULL OF EAGLE BOAT ALMOST FINISHED

passed through the Welland Canal locks, which will take ships up to 230 feet long. But the Eagles' beam and draught were purposely made small enough to permit them to travel to seaboard by way of the New York State Barge Canal, as did the "C" boats. The Barge Canal locks are 310 feet long, 45 feet wide, and have 10 feet of water over the sills. The Eagles draw 8 feet when fully equipped and ready for sea, and they have a beam of considerably less than the width of the locks.

The motive power of the Eagle boat is a steam-turbine geared to the propeller shaft, on which is mounted a single three-bladed screw of rather steep pitch. Crude-oil fuel is used to generate the steam, and the tank capacity of the Eagles is sufficient for a steaming radius of at least the distance across the Atlantic. Mr. Ford built the engines in the same Detroit factory where he builds automobiles, in an addition to that ninety-six-acre shop, constructed for this particular work. They are of a somewhat different type from the turbine-engines generally used in marine installations, and will generate in the neighborhood of 3,000 horse-power. Turbines were adopted for the Eagle boats, as they have been for the new destroyers and many of the ships of the new merchant fleet, because they occupy less space for the same horse-power than reciprocating engines, are simpler and quicker to build, and take very much less metal.

Only the war emergency could have made it possible to put into execution the daring project of building a fighting-ship entirely out of sheet-steel stampings, but that is exactly what was done in the Eagle boats. Not that it is not a perfectly sound and sane way to build a ship, from the viewpoint of an engineer or



WHERE THE EAGLE BOATS WERE BUILT

The huge " Crystal Palace," a third of a mile long, on the bank of the River Rouge, near Detroit.

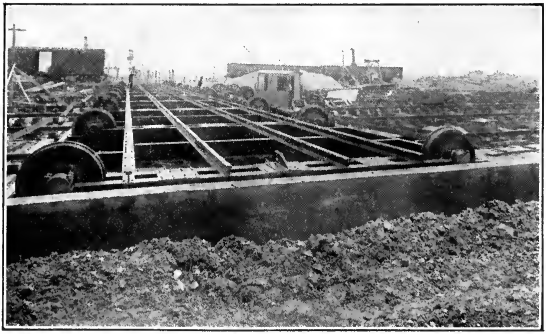
POWER PLANTS OF EAGLE BOATS

Some of the 2,500-horse-power steam-turbines built in the Ford plant ready for installation.

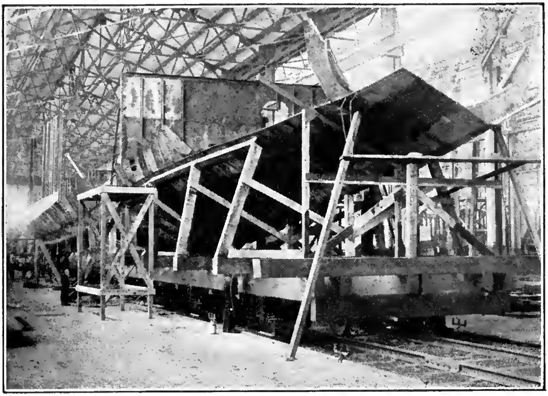
a manufacturer, but it had never been done that way before, and in the navy it is extremely difficult, in peace times, to do anything except in the way in which it has always been done. In the Eagle boat, however, there is not only an entirely new type of naval craft, built on entirely new lines, but the method of construction is radically different from anything that has ever been attempted before.

There is not a forging or a rolled beam or shape in the whole ship. Everything—keel, floors, frames, beams and angles—is pressed from sheet metal, cold, by means of automatic machinery that cuts every piece to an exact pattern, then punches the rivet-holes, thirty or forty at a time, and bends every part to its precise final shape. Building a ship by this plan is merely a matter of placing numbered parts together and riveting them fast; it takes no more skill in the actual construction work than can be imparted to an ordinarily handy laborer in a couple of weeks' instruction. And the builder of this sort of ship does not have to wait on half a dozen steel mills for special shapes or parts; all he asks is to have a sufficient continuous supply of standard-sized steel sheets delivered at his back door, and the finished ships can be turned out of the front door as rapidly as automatic machinery can fabricate the raw steel into the necessary parts.

Precisely and literally, that is the way Mr. Ford built the Eagle boats, by taking in steel plates at one door and turning out finished ships at another door, for these craft were constructed entirely indoors, in one huge room, big enough to house twenty-four of them at once and still leave so much space that one had to walk for an appreciable part of a minute to get from one ship to the next!



THE ROLLING PLATFORM THAT CARRIED THE EAGLE BOATS FROM THE FACTORY TO THE LAUNCHING ELEVATOR

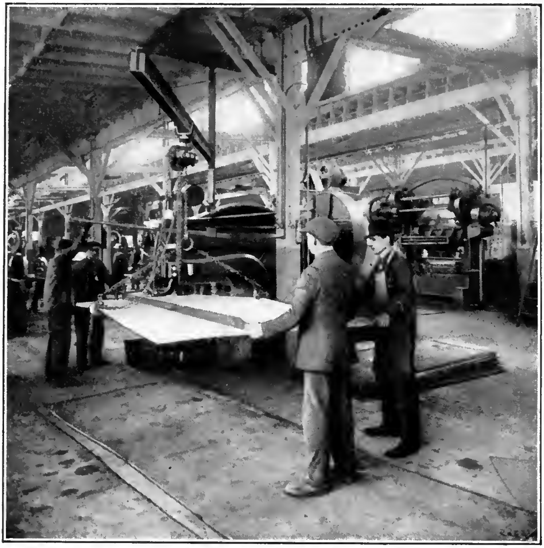


NOTHING COULD BE SIMPLER THAN THE METHOD OF BUILDING THE EAGLE BOATS

I do not think it possible to do justice in words to the gigantic building in which two dozen Eagle boats were made at one time. Where it stands was utterly vacant land in February. In the following June the visitor approached a building which, seen from the highway a quarter of a mile away, looked big enough, in all conscience, but which, as one drew nearer, took on the aspect of a mammoth crystal palace, its glass-inclosed sides and roof suggesting something ethereal and phantasmagoric, as if it might dissolve into thin air if one should happen to utter the right magic formula. I could think of nothing, as I approached it, but Keats's

> Charmed magic casements, opening on the foam
> Of perilous seas, in faery lands forlorn.

Stretching its length a third of a mile along the banks of the River Rouge, this steel, glass and concrete building, 350 feet wide and 100 high, covers more than thirteen acres in one room. It is so big that, looking from one end of it at a 200-foot ship at the other end is like looking at a figure on the stage through the wrong end of an opera-glass. There were six Eagle boats under construction the first day I visited this plant, and for a full minute after I entered the door and looked around I thought the place was empty! Then I spied the nearest of the ships and walked interminably across acres of floor until I reached it. With more than twice as many ships in the place, a couple of weeks later, there was still that compelling sense of emptiness, so enormous were the spaces, so expansive the areas, in this titanic ship-factory. And these ships, it must be remembered, are longer than a city block, bigger than many an ocean-going craft that is counted a fair ship even in these days, many times bigger than the caravels of Columbus. Seen in their vast environment, however, they looked like toys until one got close enough to look up at the men at work high above, then to



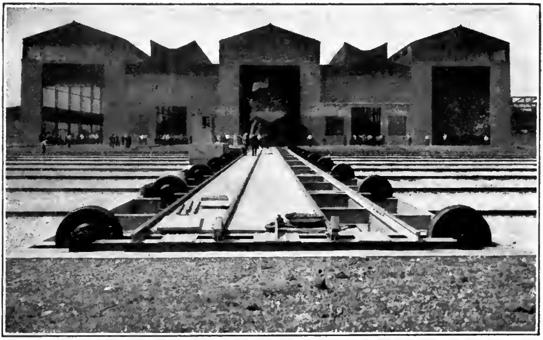
PUNCHING THE PLATES FOR EAGLE BOATS

climb up on the deck and realize that this was no plaything, but a real, man-sized ship of war.

If Mr. Ford had done nothing else than to put up this single building in less than four months, he might have regarded it, in ordinary times, as something to brag about; as a war measure, however, it was just one of hundreds of similar marvels that were performed all over the country. It was the things being done inside the building that counted. And the visitor who failed to be impressed with the idea of tremendous achievement when he had seen and studied the system and method by which the building of the Eagle boat moved with orderly progress from the railroad cars that brought the steel plates, at one end, to the finished ships, at the other, must have been incapable of being impressed by anything this side of the supernatural.

Here at one end was a shed under which the steel was stacked in orderly piles. The thinness of these plates impressed one, though they are actually only a trifle thinner than the plates of regular destroyers. They are not built to withstand a shell, these Eagles; one realizes, of course, upon reflection, that neither are the destroyers. Only cruisers and battle-ships are armored. Farther along, upon a big, open floor, men laid down patterns on sheets of steel and marked them for the cutting- and punching-machines. Big stamping-presses bent certain of the sheets and strips into angles and channels. As the visitor moved toward the main building he passed an inclosure in which there were rows upon rows of draftsmen working at their desks. Close to the door were the punches, making thirty or forty rivet-holes, each at a point precisely determined in advance, in the edge of a steel plate. As one entered the assembling-room one passed under a wide gallery; up above were the offices of the naval officers detailed to supervise and inspect the construction of the Eagles.

The place is so big that the noise of a hundred pneumatic riveting-hammers going at once made only a pleasant sort of beelike droning unless one hap-

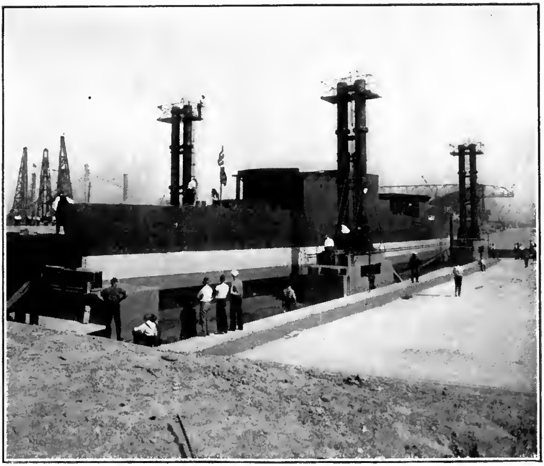


HAULING THE EAGLE BOAT OUT OF THE SHIP-FACTORY

In the foreground is the rolling platform that carries the ship, with its supporting trucks, down to the launching elevator.

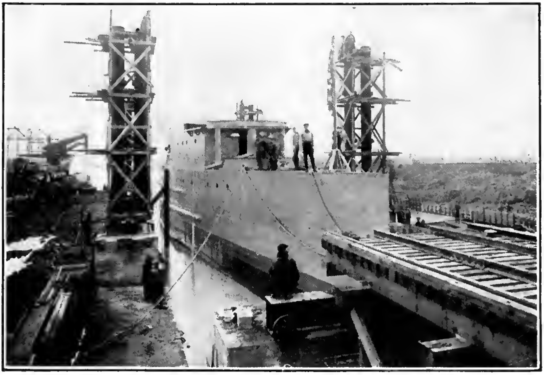
A SQUADRON OF EAGLE BOATS BEING FITTED OUT pened to be standing close by. After the first shock of surprise at finding the plant so different from what had been anticipated was over, one involuntarily compared it with a railroad station, not only because of its size, but because of the six lines of railroad track running through its length. There were trains of flat-cars, apparently, standing on three of the tracks. On close inspection, however, what seemed to be a train proved to be a single huge flat-car or platform, 200 feet long and perhaps 20 feet wide, mounted on an uncountable number of railway trucks. It was upon these rolling platforms that the Eagle boats were built. As the bottom strake of one was being laid out by the workmen, on the next the floors and frames were being set up; on a third platform, farther down the same line of rails, the shell plating was being riveted on, so thin and flexible that the operation looked almost like hanging wall-paper. At the far end the upper works of a ship were being finished, the deck had already been riveted on, and alongside lay the rudder and the propeller, waiting for the big overhead crane to pick them up and swing them into place. On each of the three assembling-tracks eight Eagle boats could be under construction at one time, twenty-four in all, and the work was so laid out that each ship moved down the line in orderly progression, as each ship ahead of it was launched, ready for the next set of operations to bring it one more step toward completion.

Great, rolling iron doors close the openings at the end of each track. The rails outside connect with rails which are laid on a big, heavy-framed platform as wide as a bay of the building and as long as an Eagle boat itself. This platform is, in turn, mounted on car wheels, which run on rails placed at right angles



"GOING DOWN"

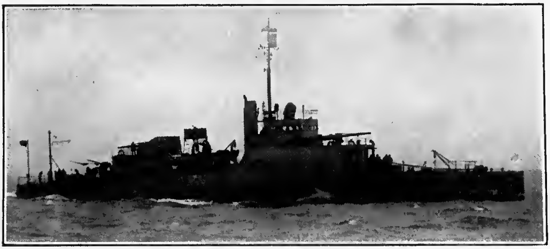
An Eagle boat on the hydraulic elevator being lowered into the launching basin. As the water in the towers is slowly released the ship, trucks, platform and all, descends.



ON THE ELEVATOR

The first Eagle boat being lowered into the River Rouge.

to those running into the building; these transverse rails extend several hundred feet beyond the building. When an Eagle boat was ready for launching a locomotive hauled it, platform, trucks, and all, out onto this transfer table. That, in turn, was hauled across until the rails supporting the boat came opposite a pair of rails that led to another platform, apparently



AN EAGLE BOAT IN COMMISSION

These "Tin Lizzies of the Sea" were built in quantities in the same manner as Ford cars.

supported between four great concrete pillars. This is the launching elevator. It is an ordinary hydraulic elevator, supported by four columns of water inside the concrete pillars. The Eagle boat's supporting platform is rolled onto the elevator, a valve is opened, and the descent into the launching basin is easy and simple and safe as coming down from the Woolworth Tower, and doesn't take any longer! Elevator, platform, and all continue to go down until the boat floats. Then the elevator brings the empty platform back to the main level by hydraulic power, the platform on its trucks is shunted to the farther end of the building, and in half an hour the seven other Eagle boats on this particular line of track have been moved up a notch and the platform is back at the end of the line, ready to receive the keel and bottom strake of another Eagle.

Nothing could be simpler than the whole process; nothing less direct and machine-like in every detail of its operation could possibly produce two hundred U-boat chasers like these in a year's time. And, at the same time, nothing more spectacular or amazing than the whole scheme, from the conception of the Eagle boat and its method of manufacture to the construction of the plant and the actual building of the ships, was undertaken in the course of our entire preparation for war.

Only about sixty Eagle boats were actually built, as the contract was canceled on the signing of the armistice. The achievement stands, however, as perhaps the most striking example of what America can do under pressure.

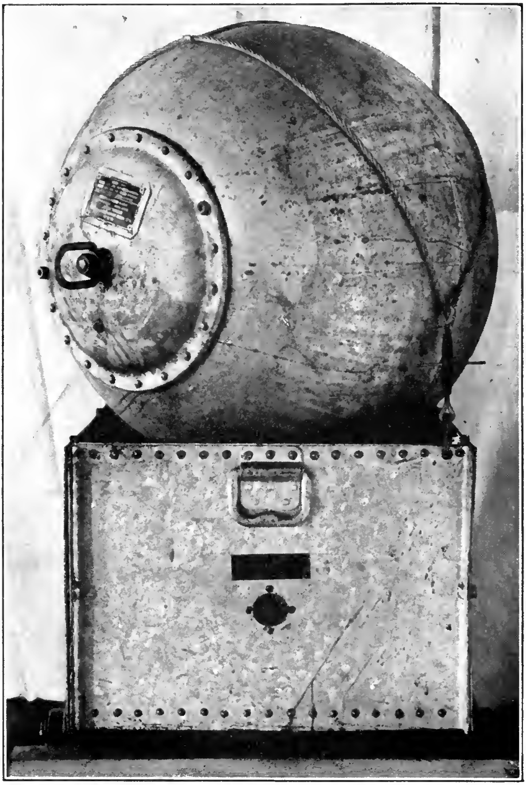
XII

SOME YANKEE TRICKS IN UNDERSEA WARFARE

IT is hardly going too far to say that the most important collection of scientifically trained minds ever assembled in one place and set to work upon a single group of related problems was the organization of scientists, inventors, and technical engineers gathered at the Navy Department in Washington, known as the Naval Consulting Board, headed by the most famous inventor in the world, Thomas A. Edison. Very few persons in the Navy Department, even, realized that for practically the entire period of America's participation in the war Mr. Edison made his personal headquarters in a room close to that of the Secretary of the Navy.

He spent almost all of his time, day and night, as is his custom, working upon scientific and technical problems which were under consideration by the Naval Consulting Board; to his genius not only as an individual scientist and inventor, but as a guide and inspiration to others, were due many of the devices and methods adopted by our navy, both for offensive and defensive purposes, which proved of immeasurable value in the destruction of German submarines and in keeping the German fleet bottled up at Wilhelmshaven and Helgoland.

Before the armistice was signed the quarters of the

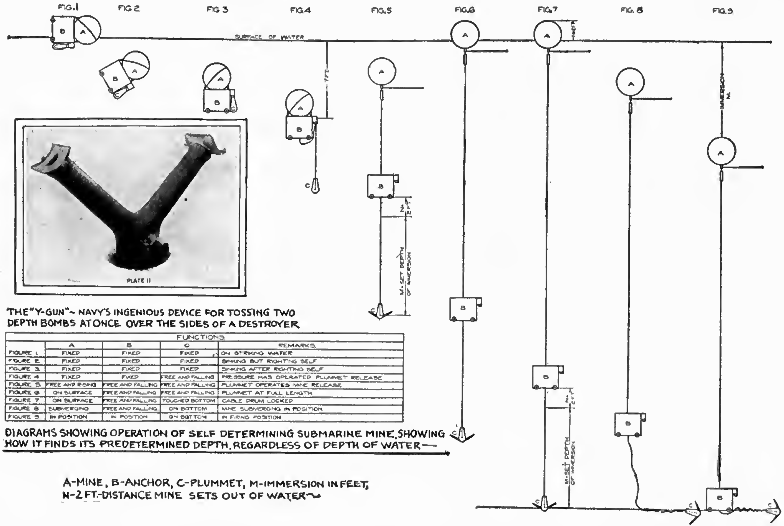


THE AMERICAN NAVY TYPE OF AUTOMATIC DEPTH SUBMARINE MINE, WITH BOXLIKE ANCHOR THAT CONTAINS MECHANISM THAT REGULATES THE DEPTH. HUNDREDS OF THOUSANDS OF THESE WERE LAID IN A BARRAGE ACROSS THE NORTH SEA

Naval Consulting Board and its staff of technicians had expanded until they occupied almost an entire wing of the gigantic new Navy Building in Washington, that wonderful piece of solid concrete construction containing forty-three acres of floor space, which was built, figuratively speaking, overnight, by the Navy Bureau of Yards and Docks. Many of the scientific discoveries and inventions which had their practical applications developed by the Naval Consulting Board are still secrets and will continue to be secrets, revealed only to the officers and men charged with responsibility for their operation.

Our army is now demobilized; its military activities are terminated for the time being at least, and, in the hope of every American, permanently. But even a League of Nations cannot relieve a country with a seacoast like ours from the necessity of policing our own shores; a League of Nations, indeed, may conceivably require America to participate in the organization, maintenance, and operation of an international sea police that will call for even greater naval resources than the signing of the armistice found us possessed of, efficient and extensive as those were.

So while the concern of the public, other than mere curiosity, with the scientific achievements of the army is centered chiefly and properly upon the possible application of these technical developments to the pursuits of peace, the matter of our naval strength is one of continuing interest in peace as well as in war. So even though there may be little or no direct application to industry and commerce resulting from the scientific researches and developments of the Naval Consulting Board, some of these secrets which can now be disclosed have an interest and importance



	FUNCTIONS			
	A	B	C	REMARKS
FIGURE 1	FIXED	FIXED	FIXED	ON STRIKING WATER
FIGURE 2	FIXED	FIXED	FIXED	SINKING BUT RIGHTING SELF
FIGURE 3	FIXED	FIXED	FIXED	SINKING AFTER RIGHTING SELF
FIGURE 4	FIXED	FIXED	FREE AND FALLING	PRESSURE HAS OPERATED PLUMMET RELEASE
FIGURE 5	FREE AND RISING	FREE AND FALLING	FREE AND FALLING	PLUMMET OPERATES MINE RELEASE
FIGURE 6	ON SURFACE	FREE AND FALLING	FREE AND FALLING	PLUMMET AT FULL LENGTH
FIGURE 7	ON SURFACE	FREE AND FALLING	TOUCHED BOTTOM	CABLE DRUM LOCKED
FIGURE 8	SUBMERGING	FREE AND FALLING	ON BOTTOM	MINE SUBMERGING IN POSITION
FIGURE 9	IN POSITION	IN POSITION	ON BOTTOM	IN FIRING POSITION

DIAGRAM IN OUTLINE WITH EXPLANATORY TEXT SHOWING HOW MINES ARE "PLANTED" AT DETERMINED DEPTHS. PLATE II, INSERTED, THE "Y-GUN" FOR THROWING DEPTH-BOMBS OVER SIDE.

extending beyond their usefulness in the war which terminated on November 11, 1918.

Heretofore all wars have been fought on the surface of the land or sea. In the Great War, for the first time, men fought miles above the earth and hundreds of feet below the surface of the sea. And just as the submarine itself was a Yankee invention in the first place, so it was Yankee inventions that played the most important part in the war against the submarine, after Germany had initiated the ruthless use of the *Unterseeboot*, the German word for submarine which we shortened in English to "U-boat." It was Yankee ingenuity, too, that made it possible literally to build a fence across the entrance to the North Sea that effectually prevented the German navy from coming out into the high seas, had it shown any inclination to do so.

The submarine depth bomb, devised by the United States navy's experts, proved the most potent of all weapons against the U-boat. The depth charge itself looks like nothing so much as an ordinary galvanized ash-can. It is a cylinder, 30 inches high and 20 inches in diameter. It contains in its interior about 75 pounds of trinitroxylol, an explosive even more powerful than the famous TNT.

The mechanism by which this explosive is set off is simple and sturdy enough to be practically foolproof, and yet at the same time can be regulated with such delicacy of adjustment that the charge will inevitably explode at precisely the predetermined depth, as indicated by a scale and an adjustable pointer on the exterior of the bomb. Water is not admitted to the interior until the external pressure has reached a point which depends upon the depth below the surface. The instant this depth is reached, however, whether it be 30 feet or 300 feet, the explosion occurs, and so precise and accurate is the operation of the depth charge that there is not recorded a single failure to perform exactly as planned.

Depth bombs are fired in pairs from the Y-gun. In the beginning of their usefulness they were simply

AS THE DEPTH BOMB EXPLODES

A Yankee destroyer using the "ash-can and tar-barrel" method of "getting" submarines. As the depth charge is thrown over the craft moves away at full speed, sending up a smoke-screen to hide its movements from the enemy.

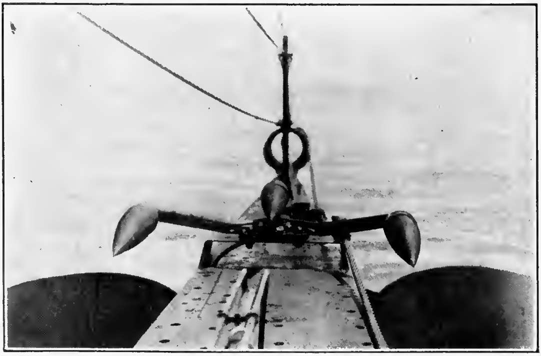
dropped overboard from the stern of a destroyer or submarine-chaser, which immediately proceeded to go away from there at full speed. By means of the Y-gun, two depth charges at once are tossed overboard, striking the water a sufficient distance from the vessel to minimize the danger, although at no time do naval men care to linger long in the neighborhood where a depth charge has just been dropped.

The Y-gun looks like nothing so much as the familiar "Siamese coupler" seen in front of tall buildings, to enable the fire department to attach two lines of hose to a single standpipe. It is merely a gun with two barrels, set at an angle of about 90 degrees to each other, both barrels being fired by a single charge which is placed in a chamber in the neck of the Y. The depth charge is laid on its side in a cradle shaped to hold it in position, the cradle having attached to it a stem or arbor which exactly fits the bore of the Y-gun.

The powder charge used to fire the Y-gun is not so great as that used in the ordinary one-pounder naval quick-firing gun. Nothing could be simpler and, as demonstrated by the experience of our destroyers and submarine-chasers, all of which are equipped with the Y-gun and a supply of depth charges, nothing could be more effective for the destruction of submarines, once their presence has been detected, than the depth charge. From the view-point of military effectiveness the depth charge and the Y-gun probably rank first among the scientific achievements of the Naval Consulting Board.

Locating submarines from surface craft was, in the beginning of the war, the most difficult piece of detective work ever undertaken. Finding the proverbial "needle in a haystack" is child's play compared with it. The problem was finally solved, and solved so successfully that, had the war lasted another six months, it is the belief of American and British naval experts that every last remaining German submarine would have been destroyed had it ever ventured out from its sheltered harbor.

Up to the entrance of the United States into the war no satisfactory method had been devised by the Allies for determining the presence or location of a submarine. The experts of the Naval Consulting Board appointed a special committee, early in 1917, to consider this problem and devise methods of solving it. Two groups of engineers and scientists set to work on it simultaneously, one group working at the submarine base at New London, Connecticut, and the other at Nahant, Massachusetts. A Boston concern, the Submarine Signal Company, had several years before perfected a method of signaling from ship to shore and from shore to ship by the transmis-



THE "BUSINESS END" OF THE SUBMARINE-DETECTOR

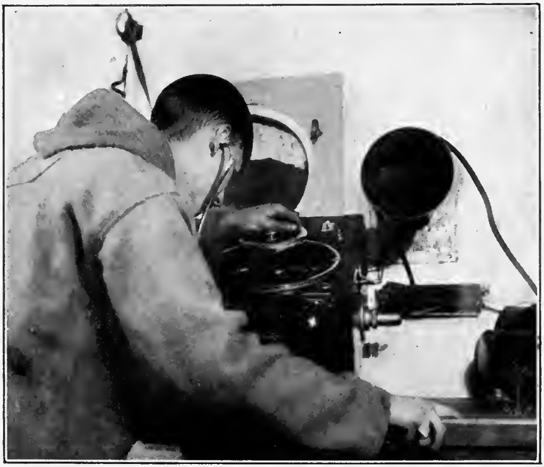
Each of the shell-shaped attachments contains a microphone which picks up sound waves traveling through the water and transmits them to telephone receivers inside the ship. The picture shows the device attached to an American submarine.

sion of sound waves through the water. This method had been successfully utilized both in transmitting danger signals from rocky coasts to approaching ships and also as a means of enabling vessels to enter difficult harbors by night. The Submarine Signal Company offered to disclose the results of its researches in assisting in the development of a submarine-detector, and into co-operation were brought experts of the General Electric Company and the Western Electric

Company, all of these working at Nahant. At New London, Col. R. A. Milliken, professor of physics in the University of Chicago and chairman of the Physics Committee of the National Research Council, headed the group working on the same problem. Other experimental stations were established, one on the Mohawk River near Schenectady, where all the facilities of the General Electric Company's research laboratory could be marshaled, and another on the Erie Canal.

Twelve weeks after experiments began the research workers had perfected a new device for detecting submarines. The principle on which the submarine-detector works is the same as that by which the human ears detect the direction from which the sound comes. Sounds of all sorts are transmitted to greater distances and with much more intensity through water than through air. But just as a person totally deaf in one ear is unable to determine from what direction a distant sound comes, so a submarine-detector must have two ears in order to locate the source of the sound. Full details of the method by which the submarine-detector operates are still a naval secret. The device was first intended to be hung overboard amidships, below the water-line, with the observer stationed on deck. It was later adapted to be attached to the hull of the vessel with the observer inside the hold, having electric connections leading through the side of the ship. Further experiments developed that in heavy weather the rocking of the boat and the slapping of the waves against the ship's sides confused the sounds reaching the observer's ears, and accurate observations could only be made with the engines stopped. All of these difficulties were overcome by long and patient experiment, and in the autumn of

1917 a squadron of submarine-chasers was equipped with the device and a number of American submarines were used as "bait" in order that a thorough test could be made. The machine worked perfectly; the



LISTENING FOR SUBMARINES

When the familiar sound of the U-boat's engines and propellers is of the same intensity in both ears, the indicator tells the precise bearing of the submarine from the ship.

exact position of the submarine when fully submerged was discovered without the slightest difficulty.

Then came the problem of differentiating the noise made by the submarine from the noise made by the propellers and engines of some other craft at a distance. A series of experiments proved that the sound of a submarine in the receiving apparatus is quite different from that of any other ship. Phonograph records were made which exactly reproduced the sounds made by different sorts of craft as heard in the receivers of the submarine-detector, and these phonograph records were used in the school for submarine listeners established at Nahant, which was attended by officers and enlisted men of the navy who were trained in the use of the device.

By the end of 1917 the submarine-detector had been so perfected that its manufacture was begun, and Capt. R. H. Leigh, U.S.N., was detailed to head a special party of American officers and enlisted men and civilian engineers to take a quantity of the apparatus to England and test it out under actual service conditions. The American submarine-detector proved its value at once. In December, 1917, from two to five U-boats passed through the English Channel daily. After July 1, 1918, when the entire submarine patrol fleet of the British and American navies had been equipped with the listening device, only one submarine is known to have passed through the English Channel. In June, 1918, according to Admiralty estimates, one out of every four submarines was destroyed. By October, 1918, five out of every twelve never returned to their bases.

C. P. Scott, of the General Electric Company, who was one of the civilian engineers sent over to supervise the installation of the submarine-detector, in an official report has described the operation of the device so graphically that I can convey an idea of its efficiency no better than by quoting him.

"The special party under Captain Leigh took over about ten tons of anti-submarine detection devices and had also worked out the tactics necessary for the detection, pursuit, attack, and destruction of the enemy submarine. A request was made of the British Admiralty for the use of three boats capable of making eighteen knots, on which this apparatus could be installed and a demonstration made. No vessels of this speed were available, so we were forced to accept three fishing-trawlers of nine to ten knots speed.

"The three trawlers were the *Andrew King*, *Kunishi*, and *James Bentole*. These trawlers were fully equipped with all the American submarine-detecting devices, radio telephones, etc., at H. M. dockyard at Portsmouth, England, and on December 30, 1917, we steamed out of the harbor for our first real patrol in English waters. The Channel lived up to its reputation of being the roughest body of water for its size in the world.

"A 'P' boat, a small type of destroyer developed for the war, with high speed, had accompanied us, as the Admiralty feared we might be attacked by the submarine coming to the surface, and detailed one of these vessels as an escort.

"The day after New-Year's we received a wireless from an airship that a submarine had been sighted. We steamed over, got our devices out, but couldn't hear a thing. Another message from the airship changed the sub's position, so we altered our course and obtained a clear indication from the listening device. The Hun was moving slowly up the Channel, submerged.

"We gave the 'P' boat a 'fix' [cross bearing] on the spot where our indication showed the submarine to be. She ran over the place, dropping a 'pattern' of depth charges, and soon we began to see tremendous amounts of oil rising to the surface. Evidently our first experience was to be successful. How successful we did not learn until afterward.

"A trawling device had been developed which indicated whether contact with a submarine had been made. After the oil came up we got out our trawling device and ran over the area for about an hour and finally got an indication. We threw over a buoy to indicate the spot and anchored for the night, as it was getting dark. Next morning we trawled again and got another contact within a hundred yards of the buoy. We had destroyed a submarine in our first test and the 'sub' was given out by the Admiralty as a 'probable.'

"The British after we came back thought so well of the device as demonstrated in the first test that many were ordered from the United States. We had taken over detailed drawings of all the apparatus, and pointed out to them that if the shipping facilities were such that some delay might occur in getting American-made devices overseas they could build them themselves.

"About May, 1918, our own ships began to come over with all these devices installed. They were also equipped with radio telephones, depth charges, and 'Y' guns.

"When the American submarine-chasers began to arrive they were assigned to the Channel, where the German submarine activities were greatest, and we did a good deal of patrolling in the early spring with these chasers. The second lot of chasers was ordered to Corfu, in the Adriatic, in June.

"We had thirty-six chasers based in a little bay on the island, and the barrage of boats extended across the Strait of Otranto, a distance of about forty miles. Conditions in the Adriatic were ideal for hunting submarines. The water was very deep, ranging from four hundred to six hundred fathoms, which meant that the submarines when hard pressed could not seek shallow water, as was their custom in the English Channel and the North Sea. Due to less shipping traffic in these waters, there was practically no sound interference, which made for very good listening.

"The main Austrian submarine bases were at Pola, at the head of the Adriatic, and Cattaro, farther down the coast.

"The German submarines leaving Pola were obliged to go through Otranto Strait to get to the Mediterranean, and once through they had things practically their own way, as there were very few patrol-boats in the Mediterranean. The tonnage sunk during the first three years of the war shows the condition that existed before the Otranto barrage was put in effect.

"Our submarine-chasers while on barrage were constantly in sound contact with enemy submarines, especially at night, as they usually attempted to get through during the dark hours. They would run down on the surface at their maximum speed and could be heard for an hour or two before they came to our line. The difference between the sound of an oil-engine and that of an electric motor is so distinctive that it was comparatively easy to tell when they changed from one to the other, which was necessary as soon as they submerged. As they knew approximately where our line was, they invariably submerged two or three miles before they reached the line.

"The course of the submarine was plotted to scale by the flag-ship of a unit from bearings given to it from the other two boats and also from its own bearings. When the submarine had approached sufficiently close, the unit was got under way and maneuvered into position for attack. The attack was usually made when the submarine was 400 or 500 yards ahead, and all three boats of a unit, steaming full speed ahead, would lay a pattern of depth charges over the area where the plotted position showed the submarine to be.

"Many successful attacks were made in these waters, one in particular being quite exciting. One of the ships in a unit heard what sounded like a submarine. In a few minutes all three listeners had picked him up and the bearing of his course was being plotted. The middle chaser, the flag-ship, was getting readings showing that the submarine was in a direct line astern and steaming toward her.

"The sound was very loud, as if the 'sub' must be very close. Suddenly the water began to slap the bottom of the boat so that every one could feel it, and the next moment the observer reported that his bearing on the submarine had changed from 180 degrees, which was dead astern, to 3 degrees, which was on our bows. The submerged submarine had passed directly under the center boat. All three boats were immediately got under way and the attack was delivered. After all the depth charges had been dropped the ships were stopped and observations again taken. A propeller was heard to start up and run for about thirty seconds, and then a crunching noise was heard. It was quite evident that the 'sub,' having been put out of control, sank to the bottom and had collapsed, due to the tremendous pressure at these depths. We went back to the spot the next morning and found an oil slick 2 miles long by 800 yards wide on the surface of the water. The submarine was doubtless put out of control, and after getting down to 300 or 400 feet in depth had collapsed, due to the tremendous pressure at these depths.

"We told the admiral at Brindisi, Commodore Kelly, about this attack and he was very much interested.

"'But,' he said, 'what we want is a few arms and legs with it. It is interesting enough to bring up a lot of oil, but you know how they are at the Admiralty—they want proof.'

"We replied that we wished we could do it, but under the circumstances the water was too deep. At the point where a submarine goes down out of control there isn't anything to come up. We were rather amused at reports that after a submarine was sunk how chairs and everything else came to the surface. For my part, I never saw anything the size of your hand on a submarine that would float.

"The addition of listening devices to all American submarines was of tremendous assistance to them when out on patrol. The American submarine base was at Bear Haven, Ireland, and submarines operated from there off the west coast of Ireland on the lookout for U-boats. Up to the time that we entered the war, submarines, once they submerged, were both blind and deaf. The development of the listeners for use with submarines gave them an added sense which they used constantly after they got into the war zone and began an anti-submarine warfare.

"The first trip the AL-1 made, after having had an American detector installed, was following a U-boat (which she had previously seen submerge about four miles distant) for four hours, both submerged, the AL-1 changing her course entirely by observations given to the captain by the listener. The Hun was unaware that he was being followed, 'blew his tanks,' and came up, all of which could be heard on the AL-1, and when the AL-1 rose to periscope height and 'took a look,' the U-boat was only 600 yards away and dead ahead. We shot a torpedo at him, but the torpedo 'broached' (came out of the water), and the German, who apparently was scanning the horizon rather carefully before coming entirely up, saw it coming and immediately made a crash dive to escape it. This is only one instance of what the added sense of hearing did for the submarines as patrol vessels. It also enabled them to stay submerged when surface craft were in the neighborhood."

A peculiar incident which happened early one morning in the Mediterranean near the entrance to the Adriatic Sea shows that complete evidence of the effectiveness of the depth charge was not always lacking. An enemy submarine had been caught in a net. A pattern of depth charges was laid around her and the trawler backed away to take an observation. One of the observers, who was operating the overboard listening device from his station on deck, felt a heavy object brush against the detector. A few minutes later he was dumfounded to see a German sailor climb on board. He had evidently been thrown into the sea by the force of the explosion and saved himself by grasping the detector as he drifted through the water!

The biggest single military job our navy did in the war was the laying of a mine barrage across the principal channels of the North Sea, a barrage which could have been and doubtless would have been extended, had the war continued, so as to make it absolutely certain that any attempt on the part of the German fleet to come out would have resulted in complete disaster. The speed and efficiency with which these mines were laid excited the wonder and admiration of the personnel of the British naval forces with which our navy was co-operating.

The mines themselves are marvels of Yankee ingenuity, as well as the method of laying them. A mine-laying ship could steam ahead at full speed and lay mines at exactly regular intervals, each mine being anchored in place and so attached to its anchor as to float at an exact predetermined depth below the surface of the water. Our North Sea barrage consisted of some hundreds of thousands of mines placed at three different depths in parallel rows, from seven to fifteen feet below the surface of the water.

How mines can be tossed overboard in a heavy

RAW MATERIAL FOR THE NORTH SEA MINE BARRAGE
Stores of mine sinkers, two deep, and, back of them, mine spheres, three deep, awaiting assembly, or "marrying." Inverness, Scotland.

sea, with the sure knowledge that they will remain floating at a fixed spot and at a fixed depth below the level of the water, is a puzzle that even many men in the navy who have been actually engaged in this mine-laying work do not fully understand. It is easy to understand how a certain length of cable may be attached to an anchor at one end and a mine at the other, and if the depth of the water is known of course the length of the cable can be adjusted to hold the mine at a certain depth below the surface. This is the old-fashioned method. It involves very careful soundings for every mine and a certain amount of guesswork and change. The water at the point where one mine is placed may be 100 feet deep; 20 yards farther on, where the next mine is planted, it may be 200 feet deep. Another 20 yards and the depth may be 300 feet.

These variations in depth make no difference whatever with the laying of the new American naval mines, the mechanism of which I shall attempt to describe as clearly as possible. The mine itself is a simple affair, consisting of a spherical buoyant chamber containing in its interior a quantity of high explosive, and so sensitized to sudden blows that a vessel striking the mine from any angle or on any side will immediately set off the explosive. The Yankee trick that enabled us to lay this great North Sea barrage lies in the mine anchor and the mechanism which it contains. The mine anchor is a cubical box of galvanized sheet-iron. It is weighted on the bottom sufficiently to furnish a firm anchorage, even in stormy weather, for the mine that floats above it and to which it is attached by a thin wire cable.

Inside the square box of the anchor is a reel, from which run two lengths of wire cable. One of these is attached to the mine itself and is long enough to reach from the surface approximately to the bottom in any depth of water in which it is practicable to lay mines. The other cable is attached to a solid lump of metal called a plummet. Before it is launched the mine nests in the open top of the boxlike anchor and is fastened by a simple catch which loops over a projection on the mine itself. On the bottom of the anchor box are four flanged wheels which run on rails laid on the deck of the mine-laying ship.

These rails lead to the stern of the ship and end there at a port through which the mine is launched overboard. Two, three, four, or more lines of rails, leading into the launching ports from switches and side-tracks inside the ship, where the mines are stored, make it possible to launch mines at the rate of two or three a minute, or even faster if necessary.

The trick that determines the depth below the surface at which the mine will float, once it is anchored safely at the bottom, is turned by adjusting the length of the cable to which the plummet is attached before the mine is launched. Is it desired to have the mine float at a depth of seven feet below the surface? Then the plummet-line is exactly seven feet long; and this is what happens when the mine, nested in its anchor box, is dropped overboard:

First the entire apparatus starts to sink, the weight of the anchor dragging the buoyant mine below the surface. A few feet below the surface the water pressure acts upon a trigger, releasing it and thereby unfastening the catch that holds the mine to the anchor box. The mine rises to the surface, the anchor box continues to sink, its downward progress now accelerated, since it is relieved of the buoyancy of the mine. But the solid plummet has reached the end of its cable and is hanging at the same distance below the anchor that it is desired to have the mine float below the surface.

So long as the weight of the plummet is suspended from the anchor box the windlass or reel from which the mine cable is paid out continues to function and the anchor descends, with the mine itself floating on the surface. The instant the plummet touches bottom the removal of the strain on the plummet cable releases a catch inside the anchor box, which locks the reel and prevents the paying out of any more cable.

If the plummet cable is seven feet long it is quite apparent that this locking of the reel will occur when the anchor is just seven feet from the bottom. But the anchor continues to sink and now it begins to pull the mine down with it, since the mine cable no longer runs freely from the reel. The mine itself, therefore, is drawn from the surface to a depth of seven feet or to such other depth as may have been determined in advance by the length of the plummet cable.

This method of planting mines, and the mine-anchor mechanism that makes it possible to lay them rapidly and in large numbers, have been among the most carefully guarded of the navy secrets. By September, 1918, the Navy Bureau of Ordnance had developed the production of mines to where more than 1,000 complete mines were being turned out daily. An official statement of the Navy Department issued September 9, 1918, stated that "if all the mines produced by the Bureau of Ordnance since America entered the war were planted (the same distance being maintained between the mines as in mining operations at sea) the mine belt would cross the Atlantic eight times."

To obtain these mines in such enormous quantities, as well as to preserve secrecy regarding their characteristics, a radical departure from usual manufacturing methods was adopted. Naval plants did not possess facilities for manufacturing as many as 1,000 mines per month, and such plants were congested with other work. It was impracticable to develop a great plant for the sole purpose of manufacturing mines, since there was not sufficient time for this purpose. The expedient was adopted, therefore, of dividing the mine into many parts and having these manufactured at different commercial plants, all the parts being brought together and assembled, the mine being then loaded at a central mine depot. The work was divided among 140 principal contractors and more than 400 sub-contractors.

In the design of these American mines special care was taken to fulfil all requirements of the Hague Convention. Should a mine break adrift from its anchor it is immediately rendered inactive by internal mechanism placed there for that specific purpose, and it floats on the surface, where it can easily be destroyed. Should a ship strike a floating American mine the firing-mechanism would not function.

XIII

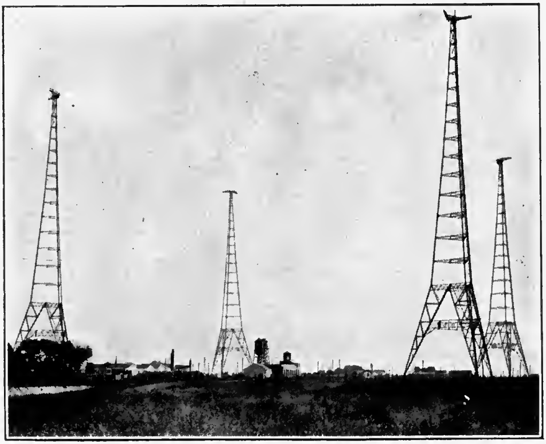
THE WONDERS OF WAR WIRELESS

IN the winter of 1902–03 I had the privilege of visiting William Marconi, the inventor of wireless telegraphy, at his first transatlantic wireless station at Glace Bay, Cape Breton. With the aid of a crude and bulky apparatus signals had just been interchanged for the first time between America and the British Islands. Sometimes the signals were intelligible, sometimes they were totally incomprehensible. Any electrical disturbance in the atmosphere, a thunder-storm, the aurora borealis, made wireless communication impossible. Signals could be transmitted only at night; by day the huge installation was useless.

People laughed at Marconi and his dream of wireless as a practical means of communication. His faith in himself and in the future of his invention was unbounded. One day we stood on the cliff at Table Head and looked out over the Atlantic. Far off on the horizon rose a column of smoke, revealing the presence of a steamship, hull down, just over the curve of the world.

"Some day," said Marconi, "every ship will carry a wireless outfit and will always be in communication with land and other ships. It will make navigation easier and safer, and that will be enough reward for me if I never make any money out of this invention."

It was wonderful to think of. It was incredible that such things could be. The inventor's imagination had projected itself so far beyond the bounds of anything with which the world was familiar that his dream savored of the supernatural. As we passed



THE NAVY WIRELESS STATION AT ARLINGTON

The four six-hundred-and-fifty-foot towers that support the aerials of the most powerful wireless station in the world

through historic Salem on our way back to Boston I outlined briefly to the brilliant young Italian the story of Salem's famous witchcraft trials and executions. Marconi smiled.

"They wouldn't have done a thing to me, would they?" was his comment.

While Marconi was tinkering with his wireless toy on the coast of Nova Scotia a couple of Americans were playing with another toy a thousand miles farther south, on the coast of North Carolina. Down at Kittyhawk the Wright brothers were just finding out how to make a flying-machine fly. They might have laughed at Marconi, as Marconi might have laughed at them, had either of them known what the other was trying to do. Vivid as was the wireless man's imagination, wonderful as were the possibilities of radio communication as he visualized them, the wonders that have been wrought in but a few years have so far surpassed his early dream that the things he alone foresaw then have become commonplace.

Marconi never dreamed, any more than the Wright brothers, of a day when, as the result of the combination of their two discoveries, men flying 150 miles an hour, three, four, five miles up in the air, could talk with other men flying in other machines, or with people on the earth's surface, and hear instructions given by wireless telephone from a distance of twenty, sixty, or even hundreds of miles.

Of all the wonders worked by the miracle-makers in the war the perfection of the wireless telephone is perhaps the most wonderful. In the whole field of radio communication marvelous strides have been made. Communication by wireless telegraphy has been perfected until it is now definitely possible and a matter of every-day practice for messages to be sent from the United States government's great station at Arlington, the largest and most powerful in the world, half-way around the globe.

Weather and atmospheric conditions no longer interfere with successful wireless transmission. By means of tuning-devices, impulses from one station do not interfere with those from another. Means have also

PILOT AND OBSERVER IN A MILITARY AIRPLANE WITH WIRELESS TELEPHONE EQUIPMENT been found for the successful transmission by radio impulses of energy so directed and controlled that vessels may be navigated at a distance, and even aircraft sent aloft, guided and steered and brought in safely without a pilot. But the wireless telephone in its perfection is the most startling and marvelous of all the war-born applications of Marconi's epoch-making discovery, and in its adaptation to communication between aircraft and the earth has found its most spectacular use.

When the United States entered the war there had been developed by the Allies a system of wireless telegraphy between airplanes and the earth, which, however, made it necessary that every observer using it should be an expert telegraph operator. It happened that at the head of the United States Signal Corps was the one man who had probably gone farther than any one else in the field to perfect the wireless telephone, Maj.-Gen. George O. Squier, Chief Signal Officer, U.S.A. General Squier, nearly ten years before, had invented a device which he termed the multiplex telephone, by means of which any number of telephonic communications could be carried on at once over a single wire; the system was in reality a wireless-telephone system, the wire serving merely to direct the wireless waves along a certain path. This system was recently perfected, and is now in commercial use by the American Telegraph and Telephone Company. It was General Squier who first discovered that a tree could be used as a wireless tower by fastening the ground wire to a nail driven into the trunk. He had installed the first wireless system in the Philippines, he had originated other devices and developed the wireless-telegraph system in use by the United States army, and under his direction the development of a radio-telephone system for airplanes was undertaken.

The problems involved were many, the obstacles to be overcome baffling. But before the United States had been a year at war wireless equipment for airplanes, solving every problem and overcoming every difficulty, had been perfected and was being manufactured by thousands of sets, so that within a few months every observation airplane in the service of the United States in France would have been equipped, as a large number of them had been equipped, with an apparatus that would enable the pilot and observer to talk with each other, to talk with wireless-telephone stations behind their own lines, and so convey instantly information of the enemy's movements or report the effect of artillery fire, and to hear messages spoken into telephone receivers on the ground many miles away.

Moreover, the commanding officer of a squadron of airplanes could by telephone direct the movements of the squadron or of particular airplanes. speaking only in an ordinary conversational tone.

And when I say that this apparatus had been perfected I mean precisely that. Details of the mechanism may be further refined, weight may be reduced by such refinement and probably will be in the future, and the range of communication may be, and probably will be, greatly extended by reason of these and other improvements. But airplane radio-telephone apparatus in use to-day, of which the army possesses many thousands of sets, will be perfectly adapted to any service that may be required of it ten or fifteen years from now, just as a high-grade automobile of the 1909 model answers every essential purpose of an automobile to-day. The newer machines may be more attractive in their lines and equipped with more conveniences, but that is all the essential difference.

The first problem to be solved in equipping airplanes with wireless was to overcome the noise of the motor-exhaust and the propeller. Not even the traditional boiler-factory is as noisy as the cockpit of an airplane. Even putting a muffler on the engine, if that could be done without reducing power and causing dangerous backfiring, would not serve to reduce the noise, the worst of which comes from the propeller-blades.

In the Signal Corps laboratory was set up a machine for producing a noise exactly duplicating the noise of a high-powered airplane in flight, and here were tested innumerable devices of ear-pieces intended to exclude all sounds, except those of the telephone receiver, from the aviator's ears. It was discovered that not only must the external ear be protected against sound waves, but that the bones of the head and face all serve as a sounding-board or diaphragm, transmitting sound from the surface to the auditory nerves. So there was finally devised a helmet covering all of the bony surface of the skull, lined with spongy rubber backed up with tin-foil and covered externally with thick leather. With this helmet on the wearer can hear only the sounds formed by the vibration of the telephone diaphragms attached to the inside of the helmet and clamped by it firmly over his ears.

It was not enough, however, to protect the ears of the aviator against the noise of the machine; a transmitter had to be devised that would not gather and transmit the noise of exhaust and propeller, but that would, nevertheless, respond to the aviator's voice without too much effort on his part. This was finally accomplished by inclosing the transmitter, which is attached in such a way that it always is close to the aviator's mouth, in an aluminum-covered, sound-proof case, pierced with three small holes. This permits the receiver to function when one speaks directly

AIR-DRIVEN DYNAMO FOR WIRELESS TELEPHONY

The tiny propeller operates a little magneto when in flight, generating sufficient current to actuate the flyer's wireless-telephone apparatus

into these holes, but sounds coming from an angle or laterally are not transmitted.

Muffled in his sound-proof helmet, a pilot or observer cannot even hear the sound of his own voice. No sound waves can reach him except such as are received through the ear-pieces inside the helmet. Medical observers report a distinct physical and psychological improvement in airmen who wear the helmets. A large part of the nerve strain under which so many fliers have collapsed has been attributed to the incessant noise of the machines, which is thus eliminated. There is also a marked diminution of the tendency to deafness which has affected aviators in the past.

A detailed description of the perfected airplane wireless equipment would involve going into technicalities which even wireless men sometimes find difficult to grasp. It is enough to say that its successful development was based upon novel uses and adaptations of the audion, a little device invented by Dr. Lee De Forest, America's foremost wireless inventor, and which is sometimes termed the "bottle imp" of wireless. The audion, which is a development of the Crookes tube, which in turn is the basis of the X-ray, is the most versatile device known to electric science. It serves as a receiver and as a transmitter, as a detector and an amplifier, for transforming alternating into direct current and *vice versa*, besides being able to perform many other curious and useful tricks.

The whole wireless installation for an army airplane weighs about 125 pounds, and is all stored in a wooden box no bigger than a suit-case. By turning a knob the man in the machine can adjust the instrument to any one of forty-five combinations of tone and wave length, there being nine wave lengths and five tones provided for.

This makes it possible to eliminate interference absolutely; a commander of a flying squadron can use one combination to talk to the men of his squadron, another to talk to the observer in his own machine, another for communication with the headquarters of his squadron on the ground, still another for communication with the artillery whose fire he may be directing, and yet have many other combinations in reserve for use in talking with other stations, and he can switch from one to the other of these instantly by the turning of a knob. At the same time his observer may be receiving messages from one or another of these stations. By means of blinker lights, interference between pilot and observer is prevented, as each sees a visible signal when the other is using the telephone.

The range of wireless telephony, like wireless telegraphy, is limited by the power of the sending station;

WIRELESS TELEPHONE TRANSMITTER AND HEADPIECE

The transmitter is completely inclosed in an aluminum case pierced by three tiny holes, excluding all sounds but words spoken directly into it

the sending range of an airplane is necessarily short. About 15 miles is the maximum for an army machine and around 60 miles for the bigger navy seaplanes, which carry an apparatus weighing about twice as much as that of the army airplane. There is no limit to the distance from which an airplane in the air may receive messages; while it has not been done, there is no reason why an American 'plane flying over Germany should not hear a telephone message directed to it from the Navy Department sending station at

Arlington. It is simply a question of tuning. The 200 feet of copper wire with a weight on the end, which the aviator unreels as he ascends and winds up as he alights, is an antenna sufficient to receive messages from any distance.

For sending wireless impulses the airplane radio outfit generates its own power; storage batteries were tried, but they were too heavy, so a little generator, which is in all essentials, except size, exactly like the big dynamos in electric-light stations, was devised. It is inclosed in a cylindrical case, tapered off at one end until it looks like a shell. At the other end is a tiny propeller. The apparatus is attached to one of the struts of the landing-gear. As the airplane flies the little propeller acts as a windmill, rotating the tiny dynamo; variations in speed are equalized by the versatile audion.

On exactly the same principle wireless telephones are now installed on all naval vessels. In the last months of the war every member of a squadron of destroyers or submarine-chasers was in constant communication with each of the other ships in the squadron by telephone, and each could receive telephone communications from a mother ship or from land stations, although the sending sets on small craft are not capable of extended range. But when President Wilson returned from France on the *George Washington* after settlement of the terms of peace, he was able to talk by wireless telephone from the ship direct to Washington, and to carry on extended conversations, so fully had the wireless telephone been perfected in the four years since the Navy Department began its experiments with the radio telephone. For these communications the navy wireless station at New Brunswick, New Jersey, served as the connecting link between the radio impulses and the land wires of the navy's telephone system, messages between Washington and the ship being transmitted by wire from Washington to New Brunswick, and thence by the radio to the ship, and *vice versa*. These messages were not relayed, but the land telephone lines were so connected with the wireless receiving and sending apparatus as to form one continuous circuit.

The navy's first experiments in transmitting the human voice over great distances by wireless took place on August 27, 1915, in conjunction with engineers of the American Telegraph and Telephone Company, and vocal signals were transmitted from the naval radio station at Arlington to the naval radio station at Darien, on the Isthmus of Panama. Two selections were played on a phonograph placed in front of the telephone transmitter, and these were correctly recognized by the operators at Darien. In addition, words and sentences were spoken into the transmitter by various officials present, and several words and phrases were received. The distance covered was about 2,100 miles.

On September 29, 1915, a test was carried out between the naval radio stations at Arlington, Virginia, and Mare Island, California. The long-distance line from New York was connected to the radio-telephone transmitter, and a telephone line from San Francisco to New York was set up, so that conversation might be carried on in both directions. Speech was successfully transmitted from New York to Washington by telephone, from Washington to San Francisco by radio telephone, and replies were received over the telephone from San Francisco to New York.

Having succeeded in talking over a distance of 2,500 miles, arrangements were made whereby radio-telephone signals transmitted from the naval radio station at Arlington would be received at Paris and at Honolulu simultaneously. On October 23, 1915, the signals transmitted from Arlington were successfully received at both Paris and Honolulu.

All of these tests consisted of one-way conversations only. In May, 1915, a radio-telephone transmitting set was installed on the battle-ship *New Hampshire*, and conversation was satisfactorily conducted in both directions, the Arlington station being used for the shore transmission. The *New Hampshire* was about fifty miles at sea, and observers reported that transmission was even more perfect than with the ordinary telephone. The signals could be received on any radio-telegraphic receiving apparatus, and many operators at shore stations along the Atlantic coast heard the entire test. It is stated that various sounds aboard the ship could be heard very distinctly, such as the sound of an officer's footsteps when walking across the deck to call another officer to the telephone.

The apparatus used in these experiments consisted of several score of vacuum tubes arranged in parallel; it was dismantled soon after the final experiments took place. While the transmission of speech was perfectly satisfactory, the installation was a very expensive one, and the cost of the upkeep of such an outfit would be prohibitive. Messages could be transmitted much more economically and efficiently by radio-telegraphy than by radio-telephony.

A great many advances in the art have been made since that time. At the urgent solicitation of the Navy Department, the engineers of the General Electric Company, the largest electrical concern in the United States, became interested in the matter, and developed apparatus which is entirely different from the original outfit. Instead of utilizing oscillations generated by vacuum tubes, the oscillations are produced by the Alexanderson high-frequency alternator

PERFECTED FORM OF WIRELESS HEADPIECE FOR AVIATORS

Spongy rubber pads press tightly on all the bony parts of the head to muffle the sounds of engine and propellers

installed at the New Brunswick radio station, which has been operated by the Navy Department since we entered the war.

This machine, the invention of Dr. Ernst F. W.

Alexanderson, an engineer of the General Electric Company, may be used not only for radio-telephony, but also without alteration for radio-telegraphy, and, while the initial cost is considerable, the upkeep is comparatively negligible. The machine is very stable and dependable in every respect, and can be produced in any size desired. The resemblance between the Alexanderson machine and the original apparatus installed at Arlington is somewhat similar to the resemblance between a dry battery and a dynamo. The bulbs, like batteries, are expensive and do not last very long, whereas the Alexanderson alternator may be used for years without deterioration.

The principle upon which the machine operates is exceedingly simple. A large metal wheel, the rim of which consists of alternate sections of magnetic and non-magnetic material, rotates at a high speed in a magnetic field, and produces oscillations in the coils in the magnetic field, the frequency of the oscillations being proportional to the speed at which the machine is run. Elaborate attachments are provided to keep the speed of the machine absolutely constant. One of the great advantages of the machine when used for radio-telegraphy is that the wave length transmitted may be varied simply by changing the speed of the machine.

The fields of radio-telegraphy and radio-telephony are separate and distinct. The relation is very much the same as the ordinary telegraph bears to the telephone; for instance, it is usually cheaper and much more accurate to send a message to a distant point by telegraph than by telephone, and it is very much easier to preserve the secrecy of the communication, as a telegram can be sent in code. It is a well-known fact that it is exceedingly difficult to transmit a code message by telephone, as certain letters and words are practically indistinguishable. This has been realized in the navy, where a list of names has been prepared for the various letters and they are always used in transmitting code messages or signals by voice. The following are the names in use:

a—able	j—jig	s—sail
b—boy	k—king	t—tare
c—cast	l—love	u—unit
d—dog	m—Mike	v—vice
e—easy	n—Nan	w—watch
f—fox	o—oboe	x—X-ray
g—George	p—pup	y—yoke
h—have	q—quack	z—Zed
i—item	r—rot	

While the wireless telephone and its applications which I have already outlined is the most widely known application of the principle of energy transmission without the aid of wires, wireless telegraphy in many other forms of development received a tremendous impetus during the war. At the outbreak of the European War the most powerful wireless stations on both sides of the Atlantic were owned by Germany. The big German wireless station at Nauen, in the outskirts of Berlin, had a capacity extending literally around the world. German ships in the Indian Ocean and the South Atlantic were in direct communication with the German Admiralty. And a year before the outbreak of the European War, 1913, the German government built, at Tuckerton, New Jersey, a secluded little village on the shores of Barnegat Bay, the tallest towers in the world. The steel framework of this Tuckerton tower was brought over from Germany all ready to assemble; it was invoiced as "building material," and so little suspicion was aroused that it was possible for the Germans to complete the tower and install the powerful wireless apparatus, using the Goldsmith high-frequency system, before any one in the United States was aware of their purpose. This German wireless tower at Tuckerton and the other German wireless station at Sayville, Long Island, were seized by the United States government long before this country became a belligerent, as there was evidence the Germans were using this means of communication in a way that violated America's neutrality. But before the war was over the United States had constructed at Arlington, Virginia, across the Potomac River from Washington, the most powerful wireless station in the world. This consists of four steel towers, each 650 feet high, supporting the antennæ, which, with the ground system, require 160 miles of wire. This powerful plant was erected and equipped by the navy in ten months. At the signing of the armistice we had under construction at Bordeaux, France, an even more powerful wireless station, and with our naval wireless stations on the Pacific coast, at Pearl Harbor in the Hawaiian Islands and in the Philippines, radio communication between American stations completely encircling the world is assured at all times and any American vessel at sea in any part of the world can be communicated with instantly.

What may well prove to be the most useful of all applications of radio-telegraphy is the radio compass perfected by the navy electrical experts. The wireless compass operates in precisely the same fashion as a lighthouse, except that its range is unlimited, while that of even the most powerful light is a bare twenty miles; moreover, it is not obscured by fog at night and is equally useful by day. If the shipping routes of the Seven Seas were all marked by rows of lighthouses twenty miles apart, furnishing beacons by night and landmarks by day, navigation would be as simple as walking up Broadway. No captain with his ship under control would have the slightest difficulty in finding his way about or into any port of the world. Of course it will never be feasible, either economically or as a matter of engineering, to mark the paths of navigation by any such means, but the radio compass has provided a perfectly feasible and simple method of accomplishing precisely the same result.

I have said that the principle of the radio compass is the same as that of a lighthouse. The coasts of every civilized country in the world are marked by lights which vary one from another, so that the mariner approaching either a dangerous coast or the entrance to a harbor can tell by the character of the lights visible precisely where he is. Thus, the commander of a ship approaching New York Harbor, seeing a light flashing to starboard at ten-second intervals and knowing that he is somewhere southwest from Nantucket, recognizes it as the Montauk Point light, at the extreme eastern extension of Long Island. A little later on he picks up the Shinnecock Bay light, a group of lights flashing at intervals of 7½ seconds, and that he is steering the right course he determines a few knots farther on when he sees the great white flare of Fire Island flashing once a minute. But if too far out at sea for these and the other coastwise lights to be visible, he must depend at night upon the stars and by day upon the sun to determine his position and in fog he has no guidance.

The radio compass will give him his position on the chart at any time. The visible apparatus required is a coil of wire wound around a wooden frame about six feet square, which is mounted so as to rotate on a vertical axis; the two ends of the wire coil are connected into the ship's regular radio circuit. At fixed and designated wireless stations on shore signals of specified pitch, intensity, and frequency are sent out at regular intervals. Thus, for example, Tuckerton may send signals in groups of three dots and three dashes alternating, with an interval of ten seconds between each group, and this signal may be going out from Tuckerton continuously, day and night, with a wave length of six hundred meters. Brooklyn Navy-Yard may use a different grouping or send single dashes spaced a given number of seconds apart. From Sayville still another compass signal is used, from Arlington another, and so on until every important wireless station in the world is sending through the ether at all times, day or night, compass signals which indicate to every wireless operator who has the published code before him just where the signals come from.

The captain desires to know his position, his latitude and longitude. He asks "Sparks," his wireless operator, to listen in with his wireless compass. The big compass coil is connected up, the operator adjusts his receiving apparatus to the six-hundred-meter wave length of the Tuckerton compass signal, let us say, and instantly he hears the buzz—dot, dash, dot, dash, dot, dash — of Tuckerton. Every five seconds the Tuckerton signal is repeated. He rotates the big coil, the sound grows fainter; he rotates it in the other direction and the sound becomes stronger. In a second or two he has found the position of the coil at which the Tuckerton signal sounds strongest and clearest. The compass shows the coil pointing in a certain direction, and he reports that direction as the bearing of Tuckerton. So accurate and unerring is this device that it tells to the fraction of a degree the exact direction from which the radio signals are being received. Now the operator adjusts his receiving set to the Sayville wave length; instantly he picks up the Sayville compass signal, and, by the same process, gets the compass bearing of Sayville with relation to the ship. It is the work of but a moment to project both bearings on a chart and determine to the fraction of a minute the exact latitude and longitude. This can be done as well when the ship is in mid-Pacific, two thousand miles from the nearest land, as when it is crawling up the coast toward New York.

The practical application of the radio compass was demonstrated by the navy in the closing months of the war, and the extension of the system to cover the entire world was begun early in 1919. The expense is trifling, the cost of the compass coil carried on board ship being very small. While devised as a war-time measure, to make it possible for ships to navigate even when lighthouse lights were extinguished in order to deceive the enemy, it is difficult to imagine anything of greater ultimate usefulness to peaceful commerce. A precisely similar apparatus on a smaller scale has been tried out as an aid to aerial navigation, and by this means aircraft have been enabled to return directly to their home landing field in absolute darkness.

Ships not equipped with the compass coil are also enabled to find their positions. Signals from ship to shore are received at many ports now equipped with similar means of determining the direction from which the impulses come. Thus a captain may get by wireless a cross-bearing from Sayville and New Brunswick, let us say, and quickly ascertain how close he is to New York.

By means of another Yankee development of radio-telegraphy it has been made possible for submarines under water to receive radio signals sent from shore and to transmit signals while submerged. James H. Rogers, a scientist of Hyattsville, Maryland, working in collaboration with Navy Department engineers, demonstrated that radio impulses hurled into the air from a transmitting station and deflected toward the earth do not become dissipated on striking land or water, but continue to flow in straight lines through the earth and through the seas as through the air. By the Rogers system messages were sent from and received in deep holes and caves, and by means of a very simple and crude apparatus clearly intelligible radio signals have been received at a distance of two miles under water. While the Rogers system has not been developed to the point where it seems likely to do away with the high towers for long-distance sending, it definitely eliminates a large part of the cost of installing receiving stations, and by making towers unnecessary for short distances may have a wide application in the development of commercial radio-telegraphy. Moreover, static interference due to disturbing electrical conditions in the atmosphere is entirely eliminated. Because of this advantage, the navy's receiving station at New Orleans, where communication is maintained with ships in Southern waters swept by frequent electrical storms, uses the underground apparatus with marked success.

I have spoken of Marconi's comparison of wireless to witchcraft. Savoring perhaps more of witchcraft than any other single phase of wireless development is the control at a distance of ships, torpedoes, and even aircraft by means of radio impulses. This, too, is a distinctly Yankee trick. John Hays Hammond, Jr., son of the famous mining engineer, had been experimenting in this direction. Some time before the war Mr. Hammond, in the presence of a number of navy officers, had directed from the shore by means of wireless impulses a small boat which he navigated around the harbor of Gloucester, Massachusetts, without the slightest difficulty. So valuable did this appear that Mr. Hammond was asked to carry on his further experiments in collaboration with government experts.

The Joint Army and Navy Board of Inventions reported early in 1919 that Mr. Hammond had demonstrated that it is completely possible to control not only surface craft, but a vessel entirely submerged, except with antennæ projecting above the surface, and the War Department asked Congress for an appropriation of $417,000 for the construction of such a craft. Mr. Hammond's patents have been taken from the Patent Office and placed in the secret files of the government. No other nation possesses this secret, which would make it possible to direct a ship loaded with explosives, a submarine without a crew, or a torpedo, against a hostile ship either from a shore station or a naval vessel.

For peace-time service, however, the wireless telephone and the radio compass are the two triumphs of Yankee ingenuity in radio communication that carry promise of greatest usefulness. It is not difficult to conceive of many important uses of the wireless telephone. An important use of the airplane is expected to be in the Forest Patrol Service. From an airplane the beginning of a forest fire can be detected and the observer can telephone to all the forest patrols in the vicinity of the blaze, giving them the exact location of the fire and thus making it possible to save millions of feet of timber and perhaps thousands of human lives. And a similar extension of the wireless compass system to include not only the approaches to ports, but all the oceans, will make navigation, even under the most adverse conditions, as simple as finding one's way under the electric lights of Broadway.

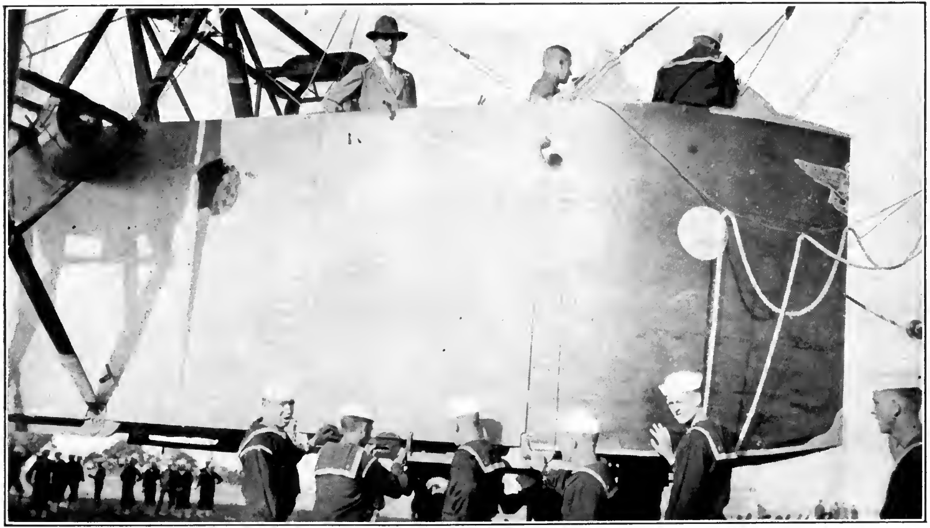
XIV

COTTON BALLOONS AND FIRE-PROOF DIRIGIBLES

BECAUSE so much has been said and written about military and naval airplanes and flying-boats the impression prevails that the dirigible balloon has proved a failure and that lighter-than-air types of aircraft are of no importance. Quite the contrary is true. The so-called "sausage" type of captive balloon is one of the most important elements in the observation service of war on land, as is the kite balloon, which is sent up from the deck of a ship for observation at sea. The dirigible itself is regarded by many competent authorities as holding possibilities for the future of aerial navigation excelling in commercial importance those of the airplane, while it is not to be denied that the German Zeppelins did far more damage and proved a greater menace in the Great War than all the German airplanes.

It is highly significant that among the peace conditions imposed upon Germany by the Treaty of Versailles is the rigid stipulation against the construction or maintenance of Zeppelins or any other type of dirigible. Moreover, it was disclosed, after the termination of hostilities, that the British government had adopted the Zeppelin or rigid type of dirigible balloon and had actually constructed a craft of this sort, a larger and more powerful balloon than anything Germany had ever produced. This craft, the "R-34," made a successful voyage from the British Islands to the United States and back in the summer of 1919. A very important part of our own Navy Department's program for the future consists in material additions to the fleet of dirigible balloons. Up to the end of the war we had not built in this country any dirigibles of the rigid or Zeppelin type, but we had acquired a considerable fleet of non-rigid dirigibles, known on both sides of the ocean by the slangy nickname of "blimps." And it is due to Yankee ingenuity that the dirigible balloon is now the safest of all types of aircraft.

Instead of the dirigible being a failure, the German Zeppelins were in every respect, except that of extreme vulnerability to direct attack, a great success. With two exceptions, every one of the Zeppelins that was brought down by the Allies during the war was destroyed by being set on fire in midair. Nothing could be a worse fire-insurance risk than the Zeppelin, with its huge gas-bag filled with the most inflammable of all gases, hydrogen. But until Yankee resourcefulness discovered a means of producing a gas which would answer the same purpose without being inflammable, hydrogen was the one lighter-than-air substance that was available in large quantities for balloon purposes. And this meant that the dirigible balloon, although capable of navigating in storms in which airplanes could not venture, free from the risk of sudden falls and capable of lifting enormously greater useful loads than any airplane yet devised, was, nevertheless, an extremely perilous craft. In war a single incendiary bullet piercing the envelope of a military balloon ignites the hydrogen and the balloon crashes to earth in flames. Even in peace a single spark from defective electric wiring or a burst



ALL READY TO LET GO

Assistant Secretary of the Navy Roosevelt in the car of one of the big navy dirigibles.

of flame from the engine exhaust might wreck the airship with the loss of all on board.

To obtain a practicable substitute for hydrogen had been regarded as impossible until the problem was solved by American scientists. Toward the end of the nineteenth century Lord Rayleigh and Sir William Ramsay had discovered in atmospheric air a gas previously unknown, to which they gave the name of helium. Helium is only slightly heavier than hydrogen, and it is entirely non-inflammable. It exists in atmospheric air in the proportion of 1 to 250,000 by volume—that is to say, in 250,000 cubic feet of air there is diffused 1 cubic foot of helium. It had also been found in certain rare minerals, but its production had been only in the minutest quantities, at a laboratory cost of about $1,700 per cubic foot. When it is considered that the cubical contents of the new British R-34 are, roughly, about 1,500,000 cubic feet, the cost of the helium gas necessary to fill it would run into the thousands of millions of dollars. Sir William Ramsay, however, early in the war urged upon the British Admiralty that efforts be made to discover new sources of helium gas, and expressed his belief that somewhere a natural source of supply of this useful element could be obtained. In the pursuit of the investigation that followed it was discovered that the natural gas obtained from the Canadian field centering at Petrolia, Ontario, contained one-third of 1 per cent. of helium.

This gave the clue to American investigators. When the United States entered the war the problem of finding an adequate supply of helium and devising methods of isolating it economically was turned over to the United States Bureau of Mines. In co-operation with the Navy Department, chemists, geologists, and mineralogists undertook the examination and testing of natural gas produced from wells in every part of the United States. In northern Texas, near

AN ARMY OBSERVATION BALLOON OF THE "SAUSAGE" TYPE

the Oklahoma line, were found gases which contained a little more than 1 per cent. of the element. A ten-year lease was taken by the government on the gas-wells in this field. Pipe lines were laid to carry the gas to Fort Worth and other plants were constructed alongside of commercial plants which were already extracting oxygen and nitrogen from the natural gas. A third plant was built by the Bureau of Mines at Petrolia, Texas, adjacent to the gas-wells.

After the presence of helium in these Texas gases had been determined the problem of a method of extraction remained to be solved. Under the direction of Dr. Frederick G. Cottrell, the chief metallurgist of the Bureau of Mines, to whose successful development of a method of extracting potash from cement-kiln dust I have already referred, a process was developed, consisting of liquefying the gas at a low temperature and distilling off the other constituents, leaving the stubborn and inert helium behind. To the surprise of every one, it was found that helium could be produced at a cost of not more than ten cents a cubic foot instead of $1,700, which every cubic foot previously produced had cost. This brought the cost of filling a large dirigible down to a few thousand dollars, and for "sausages" and kite balloons the gas cost became almost negligible, in view of the elimination of risk.

Small balloons filled with helium were sent up near Washington and fired at from airplanes with incendiary bullets. These bullets passed completely through them without producing any effect. Just before the signing of the armistice there had been produced 147,000 cubic feet of American helium ready for shipment to France. A small quantity had actually reached Europe, and only the signing of the armistice prevented the carrying out of a plan for sending a fleet of fire-proof dirigibles to drop bombs on Germany from a height of three or four miles.

One important result of the obtaining of a sufficient quantity of low-price helium is the redesigning of

A NAVY KITE BALLOON

By this means observers can be sent aloft from the deck of a ship to a height of a mile, if necessary, and discover enemy ships at a distance of thirty to forty miles, or even more.

dirigibles. Heretofore every aircraft of this type, from Zeppelins down to "blimps," has had its cargo- and passenger-carrying hulls and cabins suspended from the gas-bag; the engines and propellers have also been hung below the gas-bag. This was necessary because of the danger involved in placing the engines too close to the gas. In the new-type rigid dirigibles the quarters of the crew and the engines themselves can be provided for inside the gas-bag; the propeller shaft can run through the main structure and the propellers be attached at the bow or stern of the gas-bag itself instead of below it.

Although the helium discovery was not made in time to be of actual service in war, it will, beyond doubt, prove immensely valuable in the development of peaceful commerce. Other problems involved in the building of the enormous number of observation and kite balloons necessitated by our military and naval program were, however, solved early in our war career by American scientists and technicians.

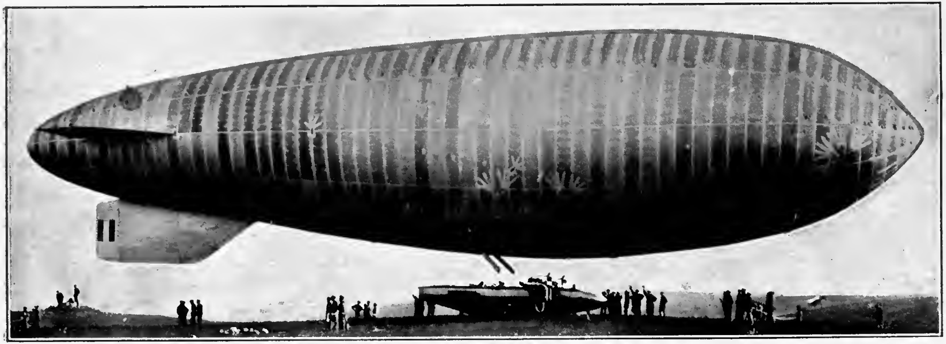
In order to make use of the balloon for war purposes the government had practically to revive a dead industry. The type of observation balloon adopted by our army was that designed by Captain Caquot of the French army, after both Germany and the Allies had had a year or more of experience with observation balloons. Balloon fabric was not manufactured in America, and even the materials with which to make it were not readily available in open market. But just as a method was found of substituting sea island cotton for linen in the manufacture of airplanes, so a fiber was found from which a cloth of the requisite fineness and strength for balloon purposes could be made. This fiber is the long-staple cotton grown in southern Arizona, in a section which, up to a few years ago, was regarded as agriculturally worthless, but which through irrigation and cultivation has developed into the greatest cotton-producing section of the whole world, in the number of pounds per acre, while the very finest grades are readily grown there.

The Goodyear Rubber Company, of Akron, Ohio, which had done more than any other American concern or institution to promote interest in ballooning, established its own cotton plantation in Arizona and,

THE BIGGEST YANKEE DIRIGIBLE

The C-5 started for a voyage across the Atlantic and reached Newfoundland safely in a single flight from Rockaway Beach, Long Island. There being no shelter at Newfoundland the craft was anchored by six two-inch hawsers. A sudden gale parted the moorings and drove the C-5 out to sea, where she was lost. Fortunately, no one was on board when the catastrophe occurred.

in co-operation with army and navy authorities, mills were set to work to spin and weave this wonderful fiber into a cloth so fine and at the same time so strong and so nearly gas-tight as to be comparable only to silk in its texture. Even after being treated with a rubber solution to make it absolutely gas-tight this new American balloon fabric is almost as thin and delicate as a lady's handkerchief. Then, too, the actual construction of the observation balloons, the cutting and sewing of the fabric, required special and intensive training of an army of skilled workers.



NAVY DIRIGIBLE C-I

One of the most important contributions of American ingenuity to military observation is a method devised of running a telephone wire through the center of the steel cable by which the observation balloon is anchored. This cable is attached to a windlass and hauled in to bring the balloon down, or let out if the observer needs to go to a greater elevation. As the observer must be in constant communication with the headquarters of the artillery detachment whose fire he is directing, uninterrupted telephone communication is essential. With the telephone wires separate from the cable, two or more windlasses always required attention; with the wire in the middle of the cable it is not only less likely to be damaged, cutting off communication, but the whole operation of the observation balloon is greatly simplified.

XV

MOTORIZING THE ARMY

UP to the outbreak of the European War in 1914 the speed with which a nation at war could move its army from point to point was limited by the marching speed and endurance of its infantry units. Cavalry could move a little faster than infantry for short spurts, though on long marches men on foot can cover more ground in a given time than horses. Artillery could move at about the same speed as infantry on foot. Only in Germany, where the railroads have been constructed with an eye to their military usefulness as well as their commercial value, was it possible at the beginning of the war to move considerable bodies of troops more than twelve to fifteen miles a day without running a serious risk of separating them from their lines of communication and supplies, and leaving them without adequate artillery support.

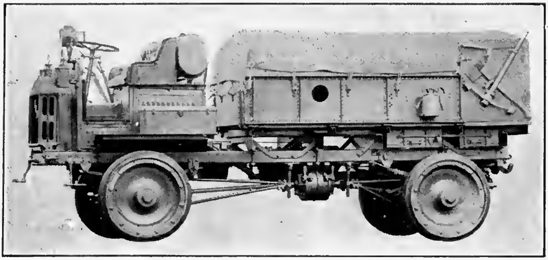
While the motor-propelled road vehicles had been in common use for ten years and more prior to the opening of hostilities, their application to military purposes had been so completely neglected that none of the Allied countries, when the war began, had either motor-trucks for the transport of troops and supplies, motor-vehicles for the use of officers, or motor-tractors for its artillery. The first hundred thousand troops of the British regular army, "The Old Contemptibles," were rushed across Belgium in motor buses, so

ONE OF THE 14-INCH AMERICAN RAILWAY-MOUNTED NAVY GUNS IN ACTION ON THE WESTERN FRONT recently diverted from their peaceful traffic in the streets of London that they carried with them to the battle-fields of Flanders such signs as "Piccadilly Circus," "Trafalgar Square," and "Use Pears' Soap." France sent its artillerymen out in Paris taxicabs to

THE "LIBERTY" TRUCK, DESIGNED BY ARMY ENGINEERS

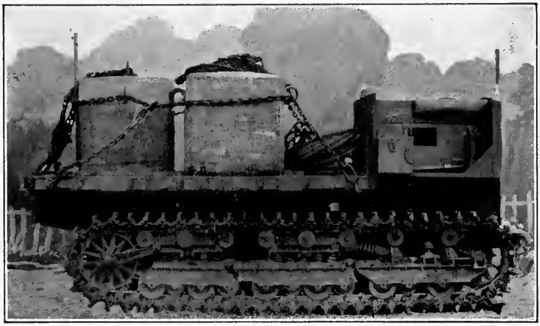
turn the flank of the advancing Huns at the first battle of the Marne. One of the very biggest of all the unsolved war problems, it was demonstrated at the very beginning of hostilities, was that of providing swifter means of transportation for men, guns, ammunition, and supplies.

In the solving of this problem both for the Allies and for our own army, Yankee ingenuity played an important part. While no army had been completely motorized at the signing of the armistice—more horses



THE FAMOUS "F. W. D.," OR FOUR-WHEEL-DRIVE TRUCK

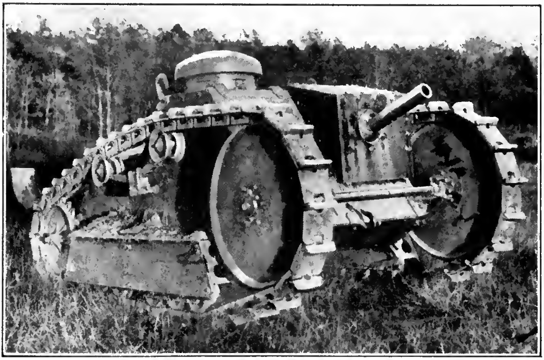
Devised by army engineers and built in huge numbers. It can go where ordinary trucks are hopelessly stalled, and carry a three-ton load over almost insurmountable obstacles.



TEN-TON CATERPILLAR TRUCK

and mules were used in this war than probably in all previous wars put together—the army which the United States was preparing to throw into the balance and the very threat of which turned the scale against Germany would have been unquestionably the most mobile military force that had ever taken the field in war, and this in spite of the fact that up to the entrance of the United States into the war in the spring of 1917 we had made practically no advance since the Civil War in the matter of army transport. General Pershing's Mexican expedition in 1916 still relied upon horses and mules for transport; the forces on the Mexican border had a few passenger-cars for officers' use and a few commercial motor-trucks of different types, but in the army motor-vehicles were still regarded as unreliable and experimental and it was not until we found ourselves plunged into the European conflict that we even began to prepare a program of motorization for the army. So rapidly did the development of motor-transport proceed, however, that in August, 1918, when the country had been sixteen months at war, there was established the Motor Transport Corps, a new and independent branch of army activities, charged with the control of the entire field of mechanical transport which, by this time, had become recognized as equally important with the other staff corps of the army.

Under the control of the Motor Transport Corps, at the termination of hostilities, were some 50,000 motor-vehicles, while with the application of mechanical motive power the artillery had been developed to a point where, in the expected spring and summer campaign of 1919, no unit, no matter how swiftly it might travel in motor-vehicles, could move faster than the guns could keep up with it.



THE FORD "BABY TANK"

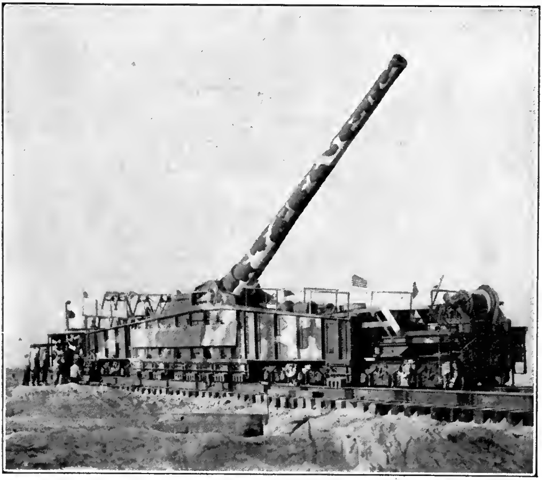
THE AMERICAN-BUILT RENAULT TANK

In the whole program of military motorization the most sensational development of the entire war, although first practically applied by the British, was distinctly a product of Yankee ingenuity. This was the "tank," which was, in fact, a small, mobile fort mounted on caterpillar tracks. The caterpillar is the one distinctively American contribution to land transport. Every other type of vehicle, from the wheelbarrow to the automobile, had its origin elsewhere. It was an American inventor who conceived the idea of mounting a traction engine on parallel, flexible, endless tracks, so that it could move over plowed fields or grades impassable to a wheeled vehicle. The caterpillar tractor for farm purposes had been in successful use in America for a number of years prior to the war. Colonel Swinton of the British army conceived the idea of building completely inclosed, tanklike bodies which, when supplied with caterpillar traction, could traverse the shell-torn areas of the battle-field, climb across trenches and up and down embankments, and bring artillerymen and machine-gunners, themselves protected behind steel walls, into close range with the enemy's infantry.

At the beginning of America's participation in the war one of the first steps undertaken was to provide an adequate supply of tanks for the use of our army. Since the British army by this time had in operation enormous factory facilities for the manufacture of tanks, a contract was made between the United States and Great Britain by which we were to manufacture the motors and provide ordnance for a large number of tanks; the structures and their mechanism were to be manufactured in England. With the successful development of the Liberty motor, however, experiments were begun with tanks adapted to the use of

SEVEN-INCH GUN ON RAILWAY MOUNT

This mount was built for use against submarines in the raids along our coast.



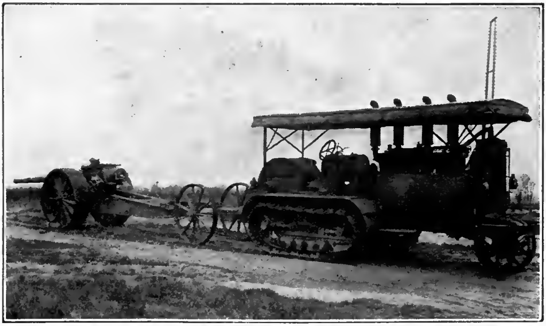
TWELVE-INCH 50-CALIBER LONG-RANGE GUN ON SLIDING RAILWAY MOUNT

The power and range of this mount are not exceeded by any railway mount in the world. Its range is in excess of twenty-eight miles.

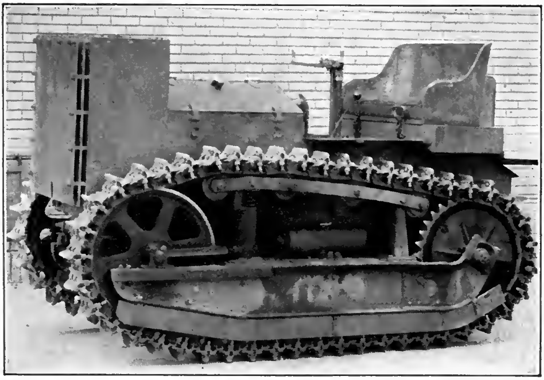
this engine. The huge 35-ton tank "America" was the most successful of these, and by the end of the war we had just begun to manufacture a quantity of these large tanks. America also adopted the French Renault tank, building a quantity of these on the French model, and later adapted this model to American methods of manufacture for the production of a faster and lighter type of tank mounting two machine-guns instead of one.

America's most ingenious contribution in the way of tanks, however, was the Ford baby tank. The idea of a light-weight, speedy, miniature fort, small enough almost to follow a squirrel track through the woods, appealed strongly to Henry Ford, who began the experimental development of this device in 1917. In June, 1918, I had the opportunity to see the tests of the first completed Ford tank of the type finally decided upon. "Nimble" is the word that best describes this miniature engine of war. It has been said of the Ford car that it will climb anything—even the side of a house. The tank literally did exactly that! It climbed a sloping structure at an angle of less than 45 degrees from the vertical without the slightest difficulty. It went down embankments that were almost straight up and down, stood on its nose in ditches four and five feet deep and backed out again without injury, scooted at twenty miles an hour over rough, plowed ground, stopped and turned instantly in its own length, and from a little distance irresistibly reminded one of a playful animal disporting itself—an animal combining, as it were, the qualities of the mud-turtle and the rabbit.

Inside the Ford tank are two men and one machine-gun. The machinery consists of two ordinary Ford engines, one for each side of the caterpillar mechanism.



CATERPILLAR TRACTOR DRAWING A 6-INCH GUN



LIGHT CATERPILLAR TRACTOR FOR HAULING 3-INCH GUN

By running one engine forward and reversing the other the baby tank can be made to spin like a top. The machine-gun is so mounted that the gunner is perfectly protected against anything short of artillery fire, while himself able to pump lead in any direction.

It was in the application of the caterpillar principle to other tractive transportation purposes that Yankee ingenuity scored even more heavily than in the matter of tanks. With good roads, or even passably good roads, the motor-truck mounted on ordinary wheels is adequate for all practical purposes. With bad roads, or no roads at all—and there is never a guaranty that an army in movement is going to find roads exactly where it wants them—the advantages of the caterpillar are obvious, since it lays its own road as it goes along. The handicap of the caterpillar, as previously developed, had been its low speed; four miles an hour was fast enough for agricultural tractor purposes and nobody had tried to build caterpillars that would move any faster. It was merely a matter of mechanical ingenuity and design, and before we had been a year at war our engineers had speeded up the caterpillar to twenty miles an hour. In the autumn of 1918 I rode across the Aberdeen proving-ground near Baltimore in a caterpillar motor-truck, running a race with the Assistant Secretary of War, Benedict Crowell, who was riding on a caterpillar gun-caisson. Our speedometers registered above sixteen miles an hour over very rough ground; the jolting and jarring were very much less than would have been the case with wheeled vehicles on the same sort of terrain.

Perhaps the ingenious idea of mounting heavy artillery on caterpillar carriages ranks first among the artillery innovations introduced into warfare by America. An 8-inch howitzer is a terrific weapon.

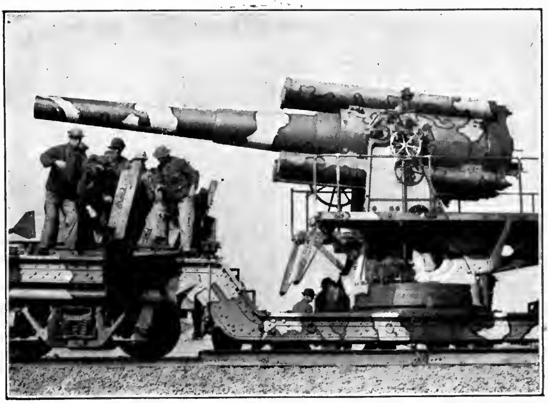
SQUADRON OF AMERICAN RENAULT TANKS GOING INTO ACTION

AMERICAN TANK IN ACTION

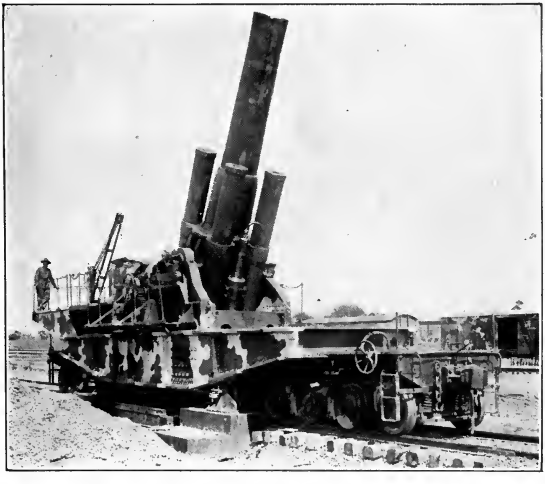
Twenty horses are ordinarily used to pull one, and by such means it can be moved very slowly indeed. Mounted on a caterpillar carriage, it can go anywhere as fast as an army can move, even faster, and it can make its own road, not only through underbrush, but through thick woods. I saw this caterpillar-mounted howitzer move through a patch of woods at Aberdeen, bearing down big trees by its own weight and the force of its impact. One tree measured seventeen inches through at the butt; many of them were more than ten inches in diameter. The gun moved through the woods as easily as an elephant through a bamboo jungle.

Caterpillar tractors, speeded up for hauling guns of all sizes and for ammunition caissons, were developed. Out of the experience obtained in the application of the caterpillar principle to all sorts of purposes it is obvious that many new applications of this distinctively American type of vehicle will be made in peacetime commerce. In rough or sparsely settled country, where the amount of traffic does not justify the expense of building and maintaining good roads, the speeded-up caterpillar provides means of transportation peculiarly adapted to such pioneer service. In rough and mountainous country, where ordinary motor-trucks cannot be used, the caterpillar trucks can be utilized for hauling ore from isolated mines and for similar purposes.

America's chief contribution to the problem of the motor-truck in war, apart from the caterpillar development, was the four-wheel-drive truck. This type of vehicle, in which the motive power is applied equally to all wheels instead of only to the two rear wheels, thoroughly demonstrated its war usefulness. In addition to the better distribution of tractive power, it



EIGHT-INCH GUN ON RAILWAY MOUNT



SIXTEEN-INCH HOWITZER RAILWAY MOUNT SHOWN IN FIRING POSITION AT MAXIMUM ANGLE OF ELEVATION

This is one of the most powerful howitzers in the world.

has the advantage of being able to move in either direction with equal ease and speed, a consideration often of the greatest usefulness on narrow roadways where there is no room to turn.

More emphatically than in any previous war the importance of artillery was emphasized in this one. All artillery development, except that of guns permanently mounted in fortifications or on floating gun-platforms, such as battle-ships, had been limited, as I have said, by the speed and power of the horse. The horse can pull continuously about 650 pounds on level ground. It took a team of six horses to pull a 3-inch gun before this war, and indeed almost up to the end of the war this size of gun was the largest that could be regarded as mobile artillery, in the sense of being able to fire a few shots and then change its position quickly before the enemy could get its range. The caterpillar not only made the 3-inch gun more mobile, but made guns up to 8-inch caliber mobile artillery.

Yankee ingenuity went even farther than that. When the armistice was signed we had on the European front 14-inch rifles with a range of nearly thirty miles that were almost as completely mobile as the 3-inch guns of five years before; we had even heavier weapons than these, 16-inch howitzers, lacking but an inch of the bore of the "Big Berthas," the 42-centimeter Skoda howitzers with which the Hun battered down the supposedly impregnable fortifications of Liège at the outset of the war. We had 12-inch guns 50 feet long, capable of throwing 2,000-pound shells twenty miles, and so completely mobile that one of them could be advanced to firing position, fired half a dozen times, and removed to a point of safety or another fighting position several miles away within

THIS IS ONE OF THE SURPRISES WE HAD IN STORE FOR FRITZ, AN EIGHT-INCH HOWITZER ON A CATERPILLAR MOUNT

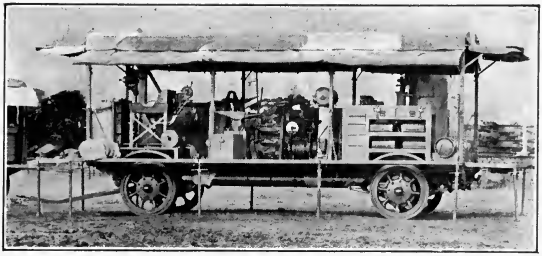
TWELVE-INCH MORTAR ON RAILWAY MOUNT

This picture shows the heavy mortar on railway mount at maximum elevation in position for firing against ammunition dumps and dugouts.

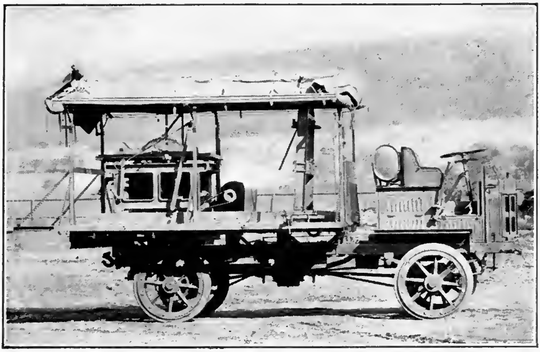
the space of an hour. We had larger numbers still of great 7-inch guns and of 12-inch mortars, all equally mobile.

These were the guns, howitzers, and mortars on railway mounts. By the time America entered the war it had become obvious that one of the most pressing needs of the Allies was more heavy artillery. Our army canvassed the supply and found 464 heavy guns, ranging in size from the 7-inch navy guns to 16-inch howitzers. There were 6 12-inch naval guns that had been manufactured in this country for the Chilean government; there were 96 8-inch, 129 10-inch, and 49 12-inch seacoast-defense guns, and 150 12-inch mortars. All of these that could be spared were taken and the manufacture of other guns was pressed, while railway mounts were constructed for these different types of weapons. The problem that had to be solved was first to build a railway carriage sufficiently strong to carry the mounted guns, then to adapt this carriage to either standard-gage or narrow-gage tracks, and then to provide means for absorbing the tremendous recoil pressure at the moment of firing.

This latter problem was solved in two ways. Some of the guns were so mounted that, by an ingenious arrangement of jacks, the gun crew, once the carriage had reached the point from which the gun was to be fired, could in a minute literally lift the carriage off the tracks, leaving it supported by the jacks, each of which had a sliding contact with the rails. By this means, when the gun was fired, instead of the carriage rolling thirty or forty feet along the tracks and requiring a recalculation of the aim and trajectory, it slid but a few inches, not enough in most cases to disturb the predetermined aim. For the smaller railway

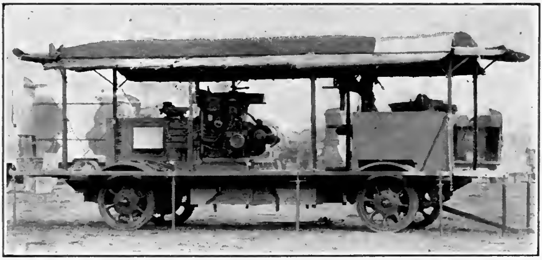


A BLACKSMITH - SHOP, FORGE, ANVIL, AND ALL, AND AN ELECTRIC WELDING OUTFIT EQUIP THIS UNIT OF THE ROLLING MACHINE-SHOP



A PORTABLE SAWMILL CONSTITUTES ONE UNIT OF THE MACHINE-SHOP ON WHEELS mounted guns braces were provided for the carriages so that the whole apparatus was firmly held in a fixed position. This method, however, involved a great deal more time and labor in getting the gun ready to fire.

All of the guns mounted by the army on railway mounts were so fixed that they could be fired in almost



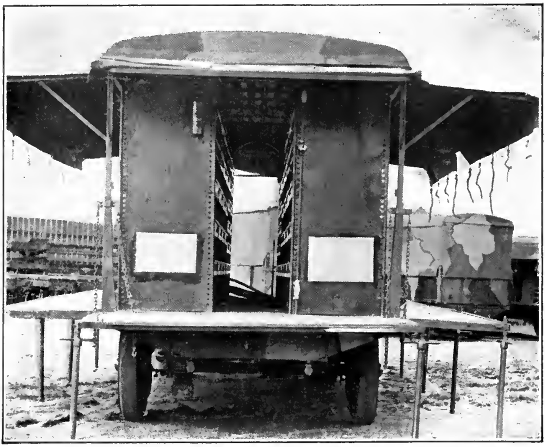
ONE OF THE UNITS OF THE MACHINE-SHOP ON WHEELS; THIS TRAILER TRUCK CARRIES A DRILL-PRESS AND A POWER SHAPER

any direction; the 7-inch navy rifles were mounted on pedestals set on the gun-car in such a way that they could be fired in any direction around a complete circle. These guns could likewise be depressed so as to fire from an elevation at a submarine offshore, it being the purpose to use them for coast-defense work particularly.

The largest American guns that actually reached the front were five of the 14-inch navy guns, mounted and operated by the navy. These guns were placed on a specially designed type of railway mount and rendered effective service in the last few weeks before the signing of the armistice.

THE GENERATOR MOUNTED ON A TRAILER TRUCK

The generator has its own direct-coupled gasolene-engine and furnishes electric current to operate all the other machines that make up the machine-shop on wheels.



NO MACHINE-SHOP IS COMPLETE WITHOUT A STOCK-ROOM FOR MATERIALS AND SPARE PARTS; THE MACHINE-SHOP ON WHEELS HAS THIS UNIT, TOO.

Like the rest of American war preparations, the gigantic plan for mobile artillery of every size and caliber was cut short just as its important elements were approaching the peak of production. When it is considered that in this work, as in many other lines of military preparation, absolutely new ground had to be broken, plants equipped, workmen trained, and everything done as though nothing of the sort had ever been attempted before, the success actually achieved appears as a triumph of American manufacturing resourcefulness.

Just as the war ended we had finally perfected a method by which a machine-shop, equipped to repair anything from heavy artillery to a mule's halter, could travel with the army and keep pace with even the speediest of its motorized units. This traveling machine-shop consisted of three motor-tractor trucks, each hauling three trailers. On each vehicle, tractor and trailer alike, was mounted some part of a complete machine-shop unit. There were lathes, drill-presses, planers, and other power-driven machine-tools, each having its own electric motor; on one truck was mounted an electric generator, direct-connected to a gasolene-engine. This furnished electric power for the whole plant and current for searchlights to enable even the most delicate machine operations to be done at night. Air-compressors for certain classes of work were mounted on another truck; one carried a complete blacksmith-shop, another a harness-shop with a power sewing-machine. On another was a carpenter's complete equipment, while a most important part of the outfit was the traveling stock-room, a truck fitted with innumerable drawers, bins, racks, and cupboards for carrying every sort of material that might be required for repairs in the field.

The platforms of all the vehicles in the unit were of equal height, and all had sides and ends hinged so they could be lowered to a horizontal position, and supported by props, making extension platforms affording ample working space around each group of machines.

XVI

YANKEE WEAPONS

THE backbone of an army is its infantrymen, and the weapon of the infantryman is his rifle. I do not think the most captious critic will dispute the statement that the American infantryman, taking him by and large, is the best marksman in the world, and it would be unsafe, in the presence of an American doughboy, to dispute the assertion that the American infantry rifle, the Springfield, model 1903, is the best rifle ever made, with the Springfield, model 1917, the modified Enfield, the only other infantry weapon that even approaches our standard arm for all-around military use.

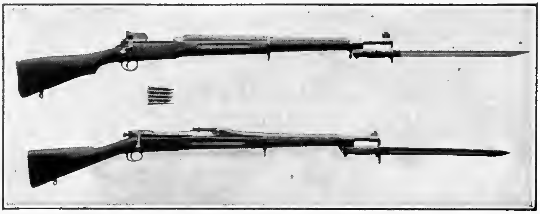
Just as the pioneer life of our forefathers compelled the development of skill with the rifle and established an American tradition of marksmanship which has not been permitted to die out, so American inventors have been responsible for every important improvement in small-arms for more than a century. Even the automatic pistol, credit for which was claimed originally by Germany, was a deliberate theft of a Yankee idea, as any one who cares to inspect the models in the Patent Office at Washington may prove to his own satisfaction. The first improvement over the old-fashioned flint-lock, the percussion cap, was a Yankee invention. So was the breech-loading rifle, and likewise the repeating rifle; the revolver was

FIRING THE TWIN GUN

This "Yankee trick" made it possible to fire six-inch shells at U-boats as fast as the little rapid-fire guns can shoot their one-pounders, both barrels being aimed at one time and firing alternately.

an American invention, and so, too, was the machine-gun.

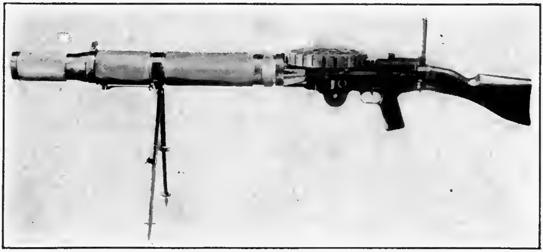
At the beginning of the war in Europe the demand for rifles for the British, French, and Russian armies was so far greater than their manufacturers were able to supply that they called upon America for help; so when this country entered the war we had a number of well-equipped factories that had been for over a



Top—SPRINGFIELD, MODEL 1917 (MODIFIED ENFIELD); ROLLED BAYONET, MODEL 1917
Bottom—SPRINGFIELD, MODEL 1903; BAYONET, MODEL 1905

year producing rifles in enormous quantities for these foreign governments. We had on hand about 600,000 of the model 1903 Springfield, with manufacturing capacity at our government arsenals of only about 700 a day. To adopt the British weapon would have involved changing our ammunition. The problem was solved by making certain modifications in the British Enfield rifle so that it took the same ammunition and the same sights as the old Springfield. This modified Enfield became the Springfield, model 1917, and with it we armed nearly three million soldiers.

Yankee ingenuity had even a better opportunity than this to play its part in the equipment of our infantrymen. In this war as never before the machine-gun was one of the most important weapons used by all the armies in the field. Two distinctly American types of machine-guns ranked among the most important American triumphs of the war. These are the Lewis and the Browning guns. Another American machine-gun, the Marlin, became the standard arm for airplane pilots. The original ma-



LEWIS MACHINE-GUN, MODEL 1917

chine-gun, the invention of Dr. Richard J. Gatling, was brought out in 1861, and was really a revolving rifle consisting of a number of barrels rotating around the central axis and firing in turn. It was another American inventor, who later became a British subject, Sir Hiram Maxim, who developed the single-barrel machine-gun, operating automatically by its own recoil. But when the war in Europe began there had been developed two machine-guns which had all the advantages of the rapid-firing mechanism of these and similar weapons, and besides were light enough so one man could carry them. These were the French Bénet-Merciér and the American Lewis guns. The Lewis gun, although the invention of Col. Isaac N. Lewis, of the United States army, had been rejected by the American military authorities, but adopted by the British, and large numbers of these guns were made in America for the British army in the early years of the war. The Lewis gun is different from all other machine-guns in that the cartridges, instead of being fed into the chamber from a web or strip, are fed from a magazine which revolves horizontally around a vertical axis. As developed for the use of American aircraft, the Lewis gun magazine carries ninety-six cartridges and can be fired at the rate of more than 300 shots a minute.

The Lewis gun weighs only twenty-five pounds, this being one of its principal advantages over earlier types of machine-guns, which were water-cooled—that is, the barrel was surrounded by a water-jacket to keep it from overheating when fired continuously. For aircraft use, where the firing is not continuous, but in short "bursts," so called, the cooling problem is not a serious one, and the Lewis gun proved admirably adapted for this purpose. It may really be called the first successful air-cooled machine-gun; many previous attempts at an air-cooled machine-gun had been made by American and foreign inventors; all of these overheated when fired continuously for any length of time, some of them becoming so hot that the barrels became soft and bent out of shape.

When the United States entered the war, then, we had the Lewis gun, which had not been officially adopted by the army, but which was being manufactured in limited quantities in this country for the British government by the Savage Arms Corporation, of Utica, New York. There was also being manufactured for the Russian government the old-fashioned type of Colt machine-gun, being made by the Marlin, Rockwell Corporation, at Syracuse, New York. The

THE COLT DOUBLE-ACTION .45 -CALIBER REVOLVER

The Yankee "six-shooter" that has been the standard side-arm of the American army for more than half a century.

THE COLT .45-CALIBER AUTOMATIC PISTOL

The standard army weapon of this type carrying seven cartridges in the hollow butt. Another Yankee invention.

facilities available for machine-gun production, however, were extremely limited. Such as they were, they were taken over by the government, but the importance of the machine-gun as an infantry arm had by this time become so evident that it was necessary to focus all possible efforts on the development of some type of gun that would answer all the purposes of modern warfare and at the same time be capable of production in huge quantities.

In this emergency there came forward a man unknown to the general public, but known to manufacturers of weapons throughout the world as a genius of rare order, whose inventive talents were responsible for almost every important improvement in small-arms for more than forty years—John M. Browning. His identity buried for more than four decades under the names of the great manufacturing corporations whose chief output was the product of his fertile brain, this square-jawed Yankee mechanical genius brought to the War Department early in May, 1917, three new types of machine-guns, each designed for a particular and specific, separate use, and each of them so far in advance of anything that had previously been developed that it took less than a month of tests to determine their superiority and insure their adoption by the United States army as its standard machine-gun equipment. John M. Browning, who thus suddenly leaped into fame through the controversies in Congress and in the newspapers over the respective merits of his weapon and the Lewis gun, is the inventor of nearly every one of the Winchester rifles, from the model of 1873 to that of 1906. He invented the auto-loading shot-gun and the auto-loading rifle, known throughout the world by the name of the Remington Arms Company. He was responsible for the perfection of the Stevens 12-gage repeating shot-gun. It was John M. Browning who invented the Colt automatic machine-gun, which had been our standard army weapon up to 1917. He had designed all the Colt automatic pistols; he was the

SMITH & WESSON DOUBLE-ACTION REVOLVER, CALIBER .45, MODEL 1917

patentee of the .45-caliber automatic pistol, which was the standard side-arm of the United States army. None of his inventions was known in this country by his name, but in Belgium, where the manufacture of small-arms had been perfected long before the war to a higher degree than in any other country in the world, the name of Browning was synonymous with high-grade repeating rifles, shot-guns, and pistols, and in 1914 the manufacture of the one-millionth Browning pistol in the Belgian National Armory at Liège had been celebrated by the bestowal upon the Yankee inventor of the Belgian Royal Order of King Leopold.

The three types of Browning machine-gun are the "heavy" or water-cooled gun, the "light" air-cooled gun or automatic rifle, and the Browning airplane-gun. The water-cooled Browning gun weighs only twenty-five pounds, the lightest weight of any water-cooled machine-gun. The old Colt machine-gun, also Browning's invention, depended for its automatic action upon the pressure of explosion gases operating against a piston. The new Browning gun uses the force of the recoil to operate the mechanism which automatically ejects the shell of the cartridge just fired, resets the firing mechanism, and feeds in a fresh cartridge. The only heavy machine-guns that had previously utilized the recoil for this purpose were the Maxim and the British Vickers. It is the ideal principle for rapid firing; the gun automatically continues to fire as fast as cartridges can be fed into it from the web belt which carries the cartridges in loops. It will not stop firing until the cartridges are exhausted or the release of the trigger automatically blocks the firing mechanism. The old Maxim gun, regarded as perhaps the best of the water-cooled machine-guns, gave off puffs of steam as the water in the cooling jacket became heated; in the Boer War these puffs of steam enabled the sharp-sighted Boers to locate the British Maxim gunners and to pick them off with their deadly long-range rifles. The Browning gun has a completely inclosed water-circulating apparatus, so that no steam escapes into the air to betray the gunners' position. With its water-jacket filled the Browning heavy gun weighs only 36¾ pounds, making it easily transportable by infantry.

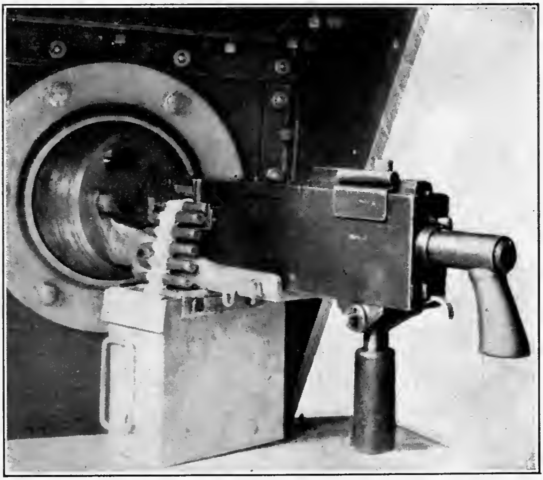
Simultaneously with the water-cooled gun, John M. Browning offered a light machine-gun or, more properly speaking, an automatic rifle, weighing only fifteen pounds. This is a gun that can be fired from the shoulder and which will continue to fire automatically so long as the marksman keeps his finger on the trigger and the supply of cartridges is kept up. The cartridges for the Browning automatic rifle are fed in in clips of twenty at a time; the twenty shots are fired in a quarter that number of seconds. It takes less

HEAVY BROWNING MACHINE-GUN

than a second to slip a new set into place. There had been automatic rifles before, but none that equaled the Browning in simplicity of construction and operation or that compared with it in weight. The 15-pound gun, although nearly twice as heavy as the standard military rifle, is not too heavy for a strong man to fire efficiently from the shoulder. Many old-fashioned duck guns, as well as the elephant rifles used by African hunters, weigh more than this.

The Browning aircraft rifle is in all essentials the Browning heavy machine-gun with water-jacket removed. As I have pointed out, an air-cooled machine-gun can be used in aerial fighting, and this gun has the advantage for this purpose over the automatic rifle in that the cartridge supply from a continuous belt or web requires little or no attention from the aerial operator of the gun. For aircraft purposes the firing mechanism of the Browning gun was so altered as to double the rate of fire, and devices for synchronizing this gun for firing between the propeller blades were also perfected. The Browning airplane-gun, however, had not got into production sufficiently to equip our aerial forces by the time the armistice was signed. The Lewis gun became the standard arm for aerial warfare, with the Marlin machine-gun, a development of the old Colt gun, for use in fixed position in front of the pilot and synchronized with the propeller as I have described in a previous chapter.

As in the case of every other important item of military equipment, America's problem had only just begun when the type and design of the Browning gun had been determined upon and accepted by the army. To manufacture these guns, as to manufacture any other device requiring a multiplicity of precisely sized and carefully fitted parts, meant, first, an enormous work of preparation of drawings, machines, and tools, the provision of a continuous supply of raw materials, and the enlistment of a veritable army of skilled workmen to operate the machines and assemble the finished parts. It was May, 1918, before the first Browning automatic rifles were turned out by the Winchester Company, the first Browning heavy machine-gun by the Westinghouse and Remington companies, and June before the Colt Company had begun to produce these. By the end of July, 1918, however, 10,000 heavy Brownings had been made,



BROWNING TANK-GUN MOUNTED IN TANK

and at the signing of the armistice there had been delivered to the government 42,000 of the heavy Browning guns and 52,238 light Browning automatic rifles.

When, in the spring of 1918, it became evident that a special machine-gun would be required for use in tanks, the development of a Browning tank machine-gun was begun. This was the heavy Browning water-cooled gun with the water-jacket eliminated and an air-cooled barrel of heavy construction substituted; hand grips and sights were added and an ingenious ball-and-socket method of mounting the gun in the armor of the tank was devised. The barrel of the Browning tank-gun is fixed in a solid ball of steel, which fits into a spherical socket in the wall of the tank in such a way that the gun can be rotated and aimed in any direction, the only opening through which an enemy bullet or fragment of shell might enter being the tiny aperture through which the gunner inside the tank aims his weapon. So mounted, the Browning machine-gun is as flexible and easy to handle as the ordinary infantry rifle, but with infinitely greater killing power because of the tremendous velocity of its continuous stream of bullets.

While on the subject of guns, we must refer to two most ingenious devices developed for and by the navy. One of these, the Davis airplane-gun, proved the most successful effort yet made to adapt rifles larger in caliber than the ordinary infantry rifle to airplane use.

The problem to be solved was that of abolishing the recoil. In the Browning, Lewis, and Marlin machine-guns the force of the recoil after each shot is expended in operating the mechanism that slips the next cartridge into the chamber and pulls the trigger. Thus all the jar of the explosion—the "kick"—is neutralized or absorbed.

Guns of larger calibers have to be provided with elaborate and necessarily heavy mechanism for absorbing the recoil, unfitting them for use in the air. Yet the 30-caliber machine-gun was not powerful enough or of sufficient range to make a seaplane effective against a submarine. The Davis gun solves the problem by literally shooting both ways at once!

The device consists of two barrels, pointing in opposite directions; the appearance is that of a long-barreled gun having an equally long rearward extension that goes back over the gunner's shoulder. One end of this end-to-end double-barreled gun is bored and rifled for the standard navy one-pound shell; the other end is smooth-bored and carries a charge of fine bird-shot of the same weight and with

THE DAVIS GUN THAT SHOOTS BOTH WAYS
At the same time that a one-pound shell is discharged toward a submarine a pound of bird-shot goes into the air over the gunner's shoulder, absorbing the recoil

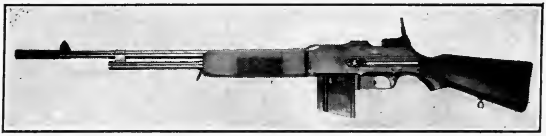
the same powder-charge behind it. When the trigger is pulled both cartridges are fired simultaneously. The recoil in each direction exactly counterbalances that in the other, the bird-shot falls harmlessly to the earth or the sea and there is no jar or strain on the structure of the seaplane.

Another ingenious navy experiment in double-barreled weapons was the twin gun. This was two 3-inch navy rifles mounted parallel on a single mount. The purpose was to achieve rapidity of fire when attacking a submarine, but the device had only reached the experimental stage when the armistice was signed.

American inventive genius manifested itself in many other types of arms. We improved the bayonet—a weapon which had become almost obsolete and much neglected by military authorities prior to the European War, but which came back into its own in the hand-to-hand fighting incident to the storming of the enemy's trenches. We devised a way of manufacturing bayonets by rolling them out of steel instead of hand-forging them, as had been the universal practice.

One application of Yankee ingenuity to small-arms evoked a protest from the German government, which declared that we were conducting warfare in an inhuman and barbarous manner by using shot-guns in the trenches! The Germans claimed that this was in violation of the Geneva Convention, which prohibited the use of weapons calculated to cause unnecessary pain and suffering. The main charge was true—we *were* using shot-guns. The efficacy of the sawed-off shot-gun or "riot-gun" had been demonstrated by many Western sheriffs. We supplied our troops with both Winchester and Remington repeating shot-guns with shortened barrels, primarily for the purpose of arming the guards placed over German prisoners, but many of them were actually used in the trenches. Each shell contained nine buckshot the size of a pea; for close fighting there is no firearm so deadly.

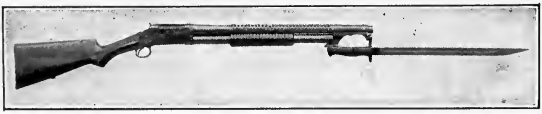
How our manufacturers of arms speeded up the production of the Colt automatic pistol and the Smith & Wesson 45-caliber revolvers, how new and ingenious methods were adopted to speed up production of cartridges for rifles and machine-guns, are stories rivaling in interest in their recital of desperate efforts against unforeseen odds any story of actual fighting itself; I shall not stop to tell them here.



BROWNING AUTOMATIC RIFLE

This weapon, which fires twenty shots in five seconds, weighs fifteen pounds and can be handled by one man

We had a new problem to solve in manufacturing tracer bullets and incendiary bullets for aerial warfare. In loading cartridge-belts for aircraft machine-guns a tracer bullet is substituted for the ordinary bullet, made of lead with a cupro-nickel jacket at stated intervals. The tracer bullet gives off a bright light as it passes through the air, a light so brilliant as to be plainly visible in the brightest sunlight. This enables the gunner to know at all times whether his



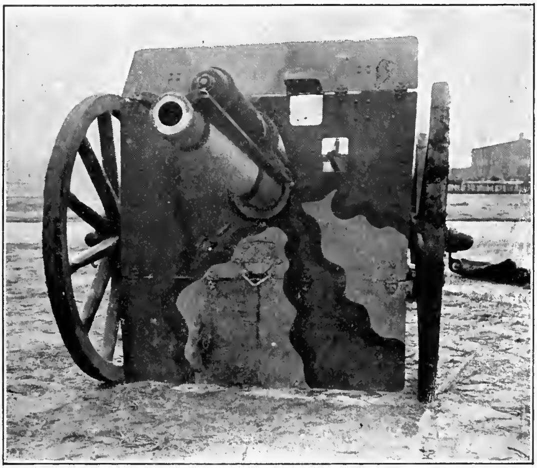
WINCHESTER 12-GAGE RIOT-GUN

bullets are reaching their mark, as he can actually see the tracers, which may be every fifth bullet, for at least 500 yards of their flight. The tracer bullet, as developed in America, consists of a cupro-nickel shell, the nose of which contains a leaden core to balance the bullet properly. The rear chamber of the bullet holds a cup containing a mixture of barium peroxide and magnesium. The rear of the bullet is left open, so that the chemical mixture is ignited by the flame of the powder at the moment of discharge.

THE LIVENS PROJECTOR

One of the most carefully guarded war secrets, which the Germans were never able to solve, was this electrically fixed device for sending shells into the enemy lines.

The purpose of the incendiary bullet in aerial warfare is to set fire to the gas-tank of the enemy machine. In the incendiary bullet phosphorus is contained in a chamber in the nose of the bullet. Behind the phosphorus is a block of lead coming flush with the base of the bullet and soldered to it, and in one side of the bullet is a hole drilled through the hard casing and filled with a special kind of solder. The heat caused by the friction as the bullet passes through the gun-barrel melts the solder out of this hole and fuses the phosphorus in the nose of the bullet. The centrifugal force of the revolving bullet whirls the phos-



"THE WEAPON THAT WON THE WAR"

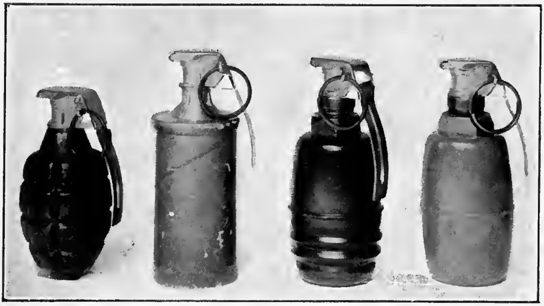
The French *Soixante-quinze*, or 75-millimeter field-gun, was the most effective weapon the Allies had. This is the American three-inch gun, built on the French model with Yankee improvements.

phorus out through the hole. The incendiary bullet gives off a spiral of blue smoke as it passes through the air, and at a range up to 350 yards such a bullet striking the gas-tank of an observation balloon or a Zeppelin, or any inflammable part of an airplane or its gas-tank, starts a conflagration.

The armor-piercing bullet is not a solid chunk of steel; such a missile might make a dent in thin armor-plate, but it would not penetrate it. As every one who has tried to drill a hole in steel realizes, a lubricant for the drill is necessary. In the case of the armor-piercing bullet this lubricant is melted lead. The outer casing of the armor-piercing rifle bullet is of cupro-nickel; this is lined with a thin coating of lead somewhat thicker at the ends. Inside of this is a sharp-pointed block or pin of hard steel. When the bullet is fired against armor plate the cupro-nickel jacket shatters into pieces, the lead melts under the heat of the impact and the steel block passes through the armor, lubricated by the molten lead!

The conditions of trench warfare brought new problems in weapons to be solved by Yankee ingenuity. The hand-grenade, an ancient weapon long before discarded, the name of which lived only in the title of that handsome body of foot-soldiers, the British Grenadier Guards, came back into use in warfare in the early days of the trench fighting in Europe. At first the only grenades used were of the defensive or fragmentation type, consisting of a container made of stout metal that would fly into fragments when the interior charge exploded. Six other distinct types of grenades were developed during the war. America's own contribution was the offensive grenade made of paper!

The use of paper for the manufacture of missiles of warfare surely deserves to rank among the most ingenious of all products of Yankee ingenuity in the war. Instead of relying for its killing power upon fragmentation, like a shell, its deadly effect was produced by the flame and concussion of the explosion itself. The fragmentation grenade, thrown by hand, could be safely used only from behind an embankment or from the trenches. When it exploded its fragments were as likely to fly back and kill the man who had thrown it as they were to kill the enemy, unless he were sheltered. The offensive grenade, made of paper, however, while it was sure to kill any man within three yards of the point where it exploded,



FOUR TYPES OF HAND-GRENADES

From left to right: Fragmentation hand-grenade; offensive hand-grenade made of paper; gas hand-grenade; phosphorus hand-grenade.

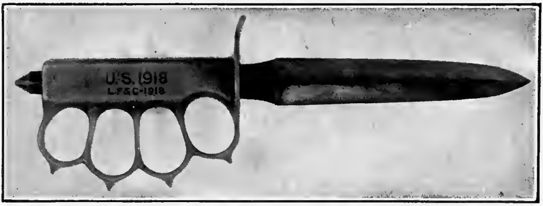
could be used in open surface warfare without danger to the troops using it. Before describing the paper grenade let me point out that the hand-grenade was a type of weapon to which American soldiers, with their practically universal experience in baseball, were much better adapted than the troops of any other country engaged in the war.

The American offensive grenade is made of laminated paper spirally wound and waterproofed by being dipped in paraffin. The top of this body is a die casting into which the firing mechanism is fastened. By the time the armistice was signed these grenades were being produced at the rate of 60,000 a day, and more than 6,000,000 of them had been delivered to the government.

The gas grenade, the phosphorus grenade, the combination hand and rifle grenade, the incendiary grenade, and the thermit grenade were the other developments of this type of weapon; all of these were adapted from European experience in the earlier years of the war, America's problem with regard to them being mainly that of obtaining manufacturing facilities and production.

One of the most closely guarded war secrets was that of the Livens projector, a device for throwing gas-bombs or drums into the enemy's ranks. Although used in the latter part of the war by British, French, and Americans, the Germans were never able to discover the nature of this device or to produce anything similar to it. The secret was guarded most carefully. In the government office at Washington where the designs for its production were worked out and in the plants where it was made armed guards were always on the watch for suspicious characters, and no one was permitted to enter who was not personally known, not merely to be a good American but to be able to keep his mouth shut. The Livens projector consists of a long steel tube or barrel planted in the earth and braced against a pressed-steel base-plate. It has a range of about 1,500 yards—nearly a mile. In warfare these projectors are usually fired in groups of twenty-five or multiples of twenty-five by electricity, so that the touching of a button or the throwing of a switch, perhaps several miles behind the front, would send a rain of gas-shells into the enemy's ranks.

The use of the knife as a weapon of war was also a revival of ancient fighting methods forced upon the contending armies by the conditions of close hand-to-hand fighting. Every European army used trench knives of one type or another. The trench knife developed for the use of American soldiers was a combination of the best points found in all the others. It is a vicious-looking little tool. It has a flat steel



THE YANKEE TRENCH KNIFE

The handle is of solid bronze, making it effective as "brass knuckles" if the nine-inch blade is broken off.

blade nine inches long and a cast-bronze handle with four holes into which the user's fingers fit, the outer edge being provided with projections which make the hilt resemble the outlawed fighting device known as brass knuckles. At the butt of the hand piece is a sharp-pointed nut, serving both to hold the blade firmly in the guard and also to inflict serious damage in case the blade should be broken off.

We cannot dismiss the subject of weapons without reference to the most important improvement in field artillery devised by Americans—the "split trail" for the 3-inch or 75-millimeter gun. This French weapon, conceded by all military men to be ultimate perfection in field artillery, had one defect which Yankee ingenuity remedied. It was so mounted that it could not be elevated, or pointed upward, sufficiently to be

A TRIUMPH OF YANKEE INGENUITY

This was the perfection of this short-range cannon—the 37-millimeter gun for trench use.

THE MOST IMPORTANT YANKEE IMPROVEMENT ON THE FRENCH "SEVENTY-FIVE" OR 3-INCH FIELD-GUN WAS THE "SPLIT TRAIL," PERMITTING ITS ELEVATION TO FIRE AT AIRCRAFT used against low-flying aircraft, or to send a shell over a high near-by hill. American army engineers remedied this by dividing the "trail," the part of the gun-carriage that rests on the ground when the gun is in action and that is attached to the caisson when in motion, into two parts, hinged so they could be spread apart. This made a V-shaped opening that permitted the depression of the breech and the elevation of the muzzle, so that the gun could be fired almost directly upward.

Still another Yankee contribution was the little 37-millimeter (1½-inch) rifled gun or trench field-piece. This miniature cannon was being produced in large volume when hostilities ceased. Small and light enough to be carried easily by a corporal's guard, it was proving a most effective weapon at the front.

XVII

CAMOUFLAGE AND COUNTER-CAMOUFLAGE

CAMOUFLAGE, a word taken from French theatrical slang and meaning nothing more nor less than "make-up," came to designate in the Great War every sort of device for deceiving the enemy as to the true nature of ships, guns, munition-dumps, or other objects which it was desired to conceal. The use of camouflage by both sides was general before the United States became a belligerent. American ingenuity, however, made one of the most important contributions to the art—it can hardly be called a science, although many of its scientific principles were ultimately developed—of camouflage. This Yankee contribution was in the camouflaging of ships.

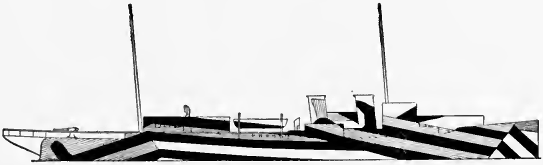
One day in the spring of 1918 a photographer who had been doing some work for the United States government was told to take his camera to a little island near the western end of Long Island Sound and photograph eight newly camouflaged ships which would go out to sea by that route that afternoon. The navy authorities wanted a pictorial record of the appearance of these craft in their new paint. The photographer set forth in his motor-boat and took up his post at the island, a mile or so off the main ship channel. Late in the afternoon he caught his first glimpse of one of the camouflaged ships. He ran

CAMOUFLAGED YANKEE SHIPS AT THE BASSENS DOCKS, BORDEAUX alongside in his motor-boat and made a photograph. Then he hailed the officer on the bridge.

"Where are the others?" he asked.

"Why, they all went through ahead of us!" was the reply.

Seven ships had passea this experienced marine photographer at a distance of less than two miles and he had not seen one of them, so completely had

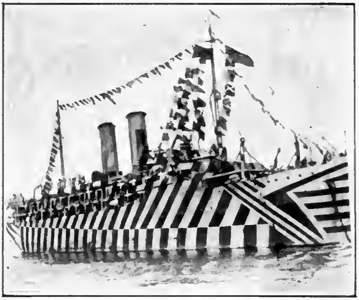


THE LAST WORD IN MARINE CAMOUFLAGE

This freakish-looking craft, painted by the "dazzle" system, eluded searchlights and keen-eyed coast-artillery men nearby.

their camouflage deceived him. He had seen something, but he had taken the craft he saw for a tow of barges, a Sound freighter, or some of the innumerable small motor-craft always present in the Sound!

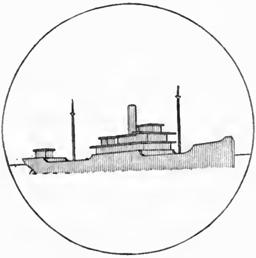
The camouflage method that fooled the photographer was the first result of the researches of the Submarine Defense Association, and their application. This association was formed in 1917, with Lindon W. Bates, an American engineer, as its chairman. A group of American artists, headed by William Andrew Mackay, Maximilian Toch, Gerome Brush, E. L. Warner, and Louis Herzog, had been working out camouflage methods, basing their work on their experience in the study of nature's colors and in painting pictures of natural objects. The purpose of the association was to systematize and standardize their work and to develop the best possible means of making our transports and cargo-ships invisible, or at least baffling to the Hun U-boats. Their efforts, combined with the effective system of naval convoy and the other measures taken against the submarine, were so successful that only one troop transport was sunk by a torpedo and less than twenty cargo-ships carrying supplies to our army through the submarine zone.



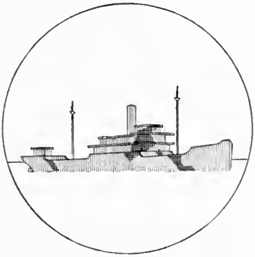
A CAMOUFLAGED SHIP

At a distance of two miles no one could tell what sort of a craft this was.

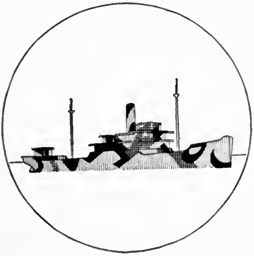
At first the ship-camouflage problem appeared to be merely one of visibility. When the ships of the American navy were first painted the color now everywhere known as "battleship gray," at the time of the Spanish War, that was in a true sense camouflage, as this color provides what navy men term low visibility; a gray ship is much less easy to distinguish at a distance than one painted white or black. The experience of the British and French on land, however, had shown that the breaking up of any surface by a variety of colors made it much less easily seen than a solid surface of any color. Applied to ships, it was found that the observer looking through a periscope actually could not see a ship at a distance of three miles or more if it were painted in judiciously arranged blotches of sky-blue, white, brown, and black. He might see something, just as the photographer did, but the white would look like foamy wave-crests, the



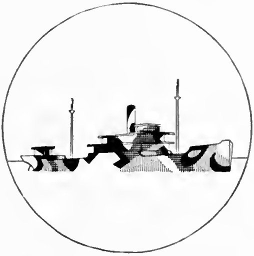
The ordinary cargo ship, uncamouflaged, looks like this; a mere collection of angles. The hull is plain gray.



The first step is to conceal the angles and give an effect of angles elsewhere, by masses of dark blue.



Patches of black destroy more of the visible angles and break up horizontal and vertical lines.

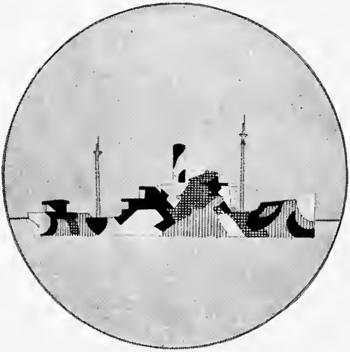


A final application of white, in patches of sizes and shapes carefully worked out, reduces visibility to a minimum.

SUCCESSIVE STAGES OF SHIP CAMOUFLAGING

blue like patches of sky, the brown and reds and black might be seabirds or bits of wreckage or just the reflection of the sun on the water.

There is evidence that scores of ships painted by the low-visibility system of camouflage passed within three or four miles of lurking U-boats alert for their prey, without being discovered. But after some ships so camouflaged had been discovered and sunk by U-boats that happened to come up for a look at closer range, it became evident that low visibility alone was not sufficient protection. Some way must be found to baffle the U-boat up to the very moment of firing the torpedo.



WHAT THE U-BOAT CAPTAIN SAW

A "periscope view" of a ship painted in the combined dazzle and low visibility system of camouflage

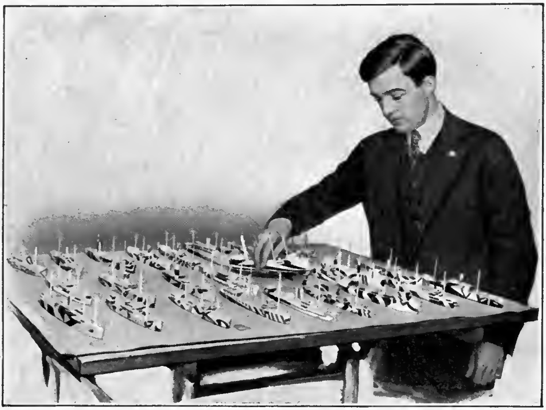
The Submarine Defense Association concentrated upon this problem. George Eastman personally became interested and placed the resources of the Kodak laboratories at the disposal of the association's engineers and artists, and Lloyd Jones, of the Kodak organization, invented a visibility meter which, used in connection with a portable periscope, made it possible to tell from the examination of a painted model ship just what combination of colors gave the most protection at a distance and what arrangements of stripes, zigzags, and blotches would make it most difficult for the U-boat commander to tell the size of the ship and whether it was moving east or west, even when seen at close range.

As a result of hundreds of experiments there was evolved a method of camouflage known as the "dazzle" system, the purpose being to make it impossible, even at close torpedo range, for an attacking U-boat to aim correctly at the target. Certain arrangements

PAINTING THE CAMOUFLAGE ON THE MODEL BOAT

of stripes, it was found, give the impression that a ship is larger or smaller than it really is, or that it is moving in one direction when it is actually moving the other way; the principles of physics and optics involved are too complicated to explain here, but they are the same that lie back of many popular illusions, such as arrangements of diagonal lines in a design that appears to be curved when it is really straight, or in patterns of equal length that appear different in size. Something of the same principle that makes the wheel of an automobile seen in a motion picture appear to turn backward at times is also involved.

A ship protected by the dazzle system offers the most baffling sort of target to the man behind the periscope. He is just as likely to aim his torpedo



A GROUP OF CAMOUFLAGED BOATS READY FOR "SERVICE"
These are models of the large transports and ships which carried our troops and supplies to France.

astern of the ship, under the impression that he is sending it to intercept her, as not. He may aim at the engine-room, or what he thinks is the engine-room, and merely puncture the forward hold; more often he will miss the ship entirely, so confusing are the different "dazzle" methods adopted. The dazzle system is the reverse of the low-visibility system, as its full effect cannot be gained without the greatest possible visbility. And since it is, of course, most desirable that the ship should not be seen at all, the camouflage system finally adopted and applied to all American ships of every sort so long as the war lasted was a compromise between the two methods.

America's contributions to the art of camouflage on land were mainly in the adoption and development of systems that had been tried out and found most useful by the French and the British. Every gun, every piece of equipment of any sort that was expected to be used anywhere near the front, was camouflaged in standardized patterns and colors before it left the factory in America. Yankee ingenuity found application in the devising of methods of putting on the camouflage with the utmost speed and efficiency. In the gun-carriage plant of the American Car and Foundry Company, for instance, I watched the girls in khaki overalls spraying the camouflage on the finished caissons and wheels one afternoon. The paints of different colors, in huge tanks, were deposited by means of a gigantic reproduction of the air-brush, used by artists everywhere. A stencil pattern covered all of the caisson except that which was to be painted yellow, for example; the camoufleuse wielded a hose as big as that of a vacuum cleaner, and in a few seconds all the exposed parts of the apparatus were covered with yellow. Then the blue, brown, and black were sprayed on by the same means.

But even though our contributions to the camouflaging of guns were only in the line of quantity production, Yankee ingenuity did contribute, and very importantly, to means of counteracting the effect of the enemy's camouflage; for the Germans early in the war became themselves extremely adept in methods of concealing their gun emplacements and other facts which they wanted to hide. As I have already pointed out, the most important function of the airplane in war is to spy out the enemy's positions, and particularly to locate his guns. When aerial defense had been perfected by the Germans to the point where no airman could fly low enough or slow enough to see their gun positions with the naked eye, resort

THE BOAT AS SIGHTED THROUGH A PERISCOPE

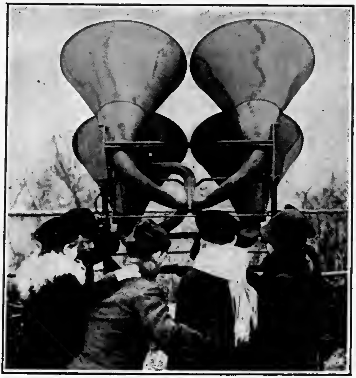
The lenses are adjusted to make the "vessel" appear two miles distant; this test is made to make sure that the camouflage is perfect.

was had to photography; eventually the German camouflage baffled even the camera lens, in many instances. The problem that had to be solved, then, was to find a method of locating enemy guns that did not depend upon actual observation of the gun itself.

This problem was so important that it justified any possible expenditure in money and lives for its solution, for the most important essential in war is to discover and destroy the enemy's artillery. The solution was found in a system of electric listening and sound-recording devices that made it possible to locate a gun with the utmost precision by comparing the time between the three distinct sounds that followed its discharge. This was done by placing microphone receiving stations at various known and recorded points within the zone of shell-fire, connecting them by wires with central recording stations and by means of triangulation finding out exactly where the gun that fired a given shot fired it from. A system of sound-ranging was in use by the British and French before 1917. This method was based upon the fact that there are three distinct sounds heard at what might be termed the "receiving end" of artillery fire.

The first sound is that of the shell itself passing overhead, since the projectile fired by a high-power rifled cannon travels faster than the speed of sound, which is normally 1,086 feet a second, varying, however, with wind velocity and direction and the temperature and density of the air. The next sound recorded is the "boom" of the gun, and then comes the sound of the exploding shell. As each of these three sounds was reported to the central station by different microphones, the exact location of each of which was known, the distances between the receiving stations formed a base line on a map, the time between the different reports furnishing a clue to the distance of the gun and the velocity of the shell, and a complicated system of calculations "placed" the gun at a point on the map to which artillery fire was then directed. It was a crude and imperfect method, but by means of it sixty-three German guns were discovered in a single day, and destroyed aerial photographs of their positions showed them so close on the map to the points determined by sound-ranging that a single pin-prick covered the results of both observations!

Immediately upon the entrance of America into the war our scientists of the Bureau of Standards were put to work to devise an improved, more accurate, less delicate, and complicated method of locating enemy guns by sound. They began by eliminating two of the three sounds used in the earlier method, and worked out a plan that required only a record of the sound of the gun's discharge and the exact fractional part of a second of time when it was received at each of a number of microphone stations. So thoroughly was this done that in the last few months of the war, according to an official statement by the Assistant Secretary of War, more German guns were located by this means than by any other. In one day a single American sound-ranging instrument, with its attached microphones, spotted 117 German gun positions.



THE AIRPLANE-DETECTOR

A Yankee soldier showing some French youngsters how it warns of the approach of a hostile 'plane at night.

The American sound-ranging device consists of a central station located several miles behind the lines and six microphones which are placed at intervals of about a mile along the front, usually in a trench. When the armistice was signed the American forces had twelve sets of sound-ranging apparatus in operation, covering a sixty-mile front. These microphones required for their construction a degree of electrical and mechanical skill seldom applied to anything but laboratory instruments. They had to be so delicately adjusted that they would pick up only a certain type of sound and at the same time so rugged that they would withstand the jar and shock of continuous bombardment.

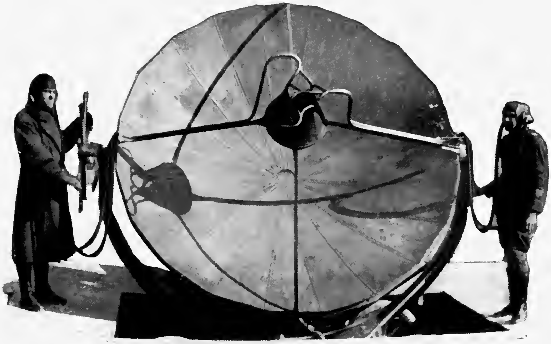
As each microphone picked up the sound of a gun behind the enemy's lines the impulse was transmitted to the central station, where a strip of photo-sensitive paper tape was slowly unwinding behind an electromagnetic needle. The impulse from the microphone moved the needle, the path of which along the tape was marked by a continuous line, broken only when the impulse was received. For each microphone a separate parallel line was made on the moving tape, which was itself calibrated to fifths of a second, so that the exact time of the reception of the impulse from each of the six microphones was automatically recorded. To triangulate from the six known positions and so locate the gun whose explosion had set up each of the six impulses was a very simple matter. In the last month of the war the Bureau of Standards still further improved this light and portable apparatus by substituting for the photographic tape a strip smoked by an acetylene flame; the needle traced a white line as it scraped through the smoked surface.

The application of the microphone to the location of guns was a development of its earliest use in the Great War, for detecting subterranean mining operations by the enemy. For this purpose it was first used by the French. Inclosed in a box and placed in an underground gallery or on a solid rock, it gave warning of any disturbance of the earth within seventy-five yards or so. American scientists developed a geophone with a much greater range, and devised the method of connecting a number of them with a central station. These devices, hidden under trash or earth in No Man's Land, not only recorded any subterranean activities of the enemy, but at night picked up the vibrations caused by the footsteps of enemy raiding-parties and even conversations carried on in low tones, exactly as the dictagraph does.

When hostilities ceased Yankee engineers and scientists had developed a device even more marvelous than any of these—a shell-detector which by picking up the vibrations transmitted through the earth when an enemy gun was fired gave warning in time to enable troops within range to get under cover. This could be used only where the exact position and range of the gun were known, but frequently the American forces knew the exact location of some hundreds of enemy guns, detected by sound-ranging; the practice was to wait until the hour of attack before silencing the guns so detected, and then concentrating artillery fire on all of them at once as the troops moved forward. So the usefulness of an instrument that would tell when a shell from one of these guns was coming toward our positions is obvious. The physical fact that earth vibrations travel many times as fast as air vibrations is the basis of this apparatus. The experiments that had been concluded just as the war ended showed that at a range of 4.1 miles this mechanism gave warning of the approaching shell nineteen seconds before it was due to arrive, thus giving ample time for every one to get under cover.

Another application of the principle of sound-ranging, developed by our army with the co-operation of scientists, was the apparatus developed for detecting and locating hostile airplanes at night. The principle here was the same as in the submarine-detector, which I have described elsewhere. Four great horns are mounted on a standard in such a way that they can be turned in any direction. One pair is used to determine the particular point of the compass from which comes the sound of the propeller and engine of a hostile bombing-'plane, which can be heard from one to three miles away; the other pair is used to discover the altitude of the 'plane, by fixing the angle from the horizon at which the sound is heard. When these two directions have been ascertained, the work of but a second or two, the searchlights can pick out the raider with no difficulty and convert him into a perfect target for anti-aircraft guns or our own fighting-'planes. In operation the listener moves the horns horizontally, "in azimuth" as this movement is termed, until the sound received in his ear-pieces through the tubes attached to each horn is of exactly the same intensity in both ears. Then the other horns are swung vertically until they reach an elevation at which the sound in both ears is the same. A simple scale indicates both angles and the instrument is precise enough to locate a 'plane within one degree of arc.

The French invented an improvement on this method, using a device called a parabloid sound-reflector, which was portable, while the horn device was cumbersome to carry about. The parabloid is a hemispherical basin, built of wood curved into a true parabola. Just as a searchlight or an automobile headlight, by means of its parabolic mirror, gathers the light rays from the lamp and projects them in parallel lines, so the parabloid sound-reflector gathers sound waves from a single direction only and reflects them to a point in the focal center of the parabolic curve. At this point a microphone picks up the sound. Since the only sound waves thus gathered are those that must come from a point lying exactly



THE PARABLOID AS PERFECTED BY AMERICAN INGENUITY

This device gives the location of a hostile airplane at night. All sounds are reflected from every part of the curved surface to the microphone receiver set at the focus of the parabola; by turning the apparatus from side to side and up and down until the sound registers at its greatest intensity the direction and angle of height of the approaching 'plane are discovered.

in line with the axis of the parabloid, the moment they are heard the azimuth and elevation of the 'plane making the sound are known and indicated. While not so accurate as the quadruple horn method, this device had the advantage of portability. American engineers, however, improved the French parabloid by reducing the weight from 3,000 to 1,300 pounds, reducing the cost 60 per cent. and so constructing it that it could be set up in one-sixth the time required for the French machine.

At first glance there does not seem to be any industrial or commercial salvage from the devices and methods which I have just described. It is not improbable, however, that the experiences of our scientists and manufacturers in devising and making sound-recording instruments of a delicacy and durability never before achieved, and in figuring out new and ingenious applications of the principles of the science of acoustics, may be turned to account in such decidedly useful and peaceful arts as bridge-building. Engineers have never agreed on a satisfactory method of measuring the stresses and strains of bridge structures, in which may be included the steel skeletons of tall buildings and the steel frames of ships. The effort has always been to provide a "factor of safety" sufficient to take care of all wind strains and possible overload, which has doubtless in innumerable instances led to the use of much more material than was necessary, with consequent unnecessary expense; while, on the other hand, even the most careful calculations go astray at times, as the disastrous wreck of the great Quebec bridge across the St. Lawrence River proves.

The armistice had hardly been signed before the technicians of the Bureau of Standards, whose chief function is that of testing materials and mechanisms of all kinds, were at work on plans for the application of the microphone and sound-recording devices to the testing of bridges, to ascertain by the sounds and vibrations under varying loads and different conditions of temperature just where and in what degree such structures are affected—in other words, where the strains come and how great they are. Out of this may well be evolved principles that will govern steel construction of the future.

XVIII

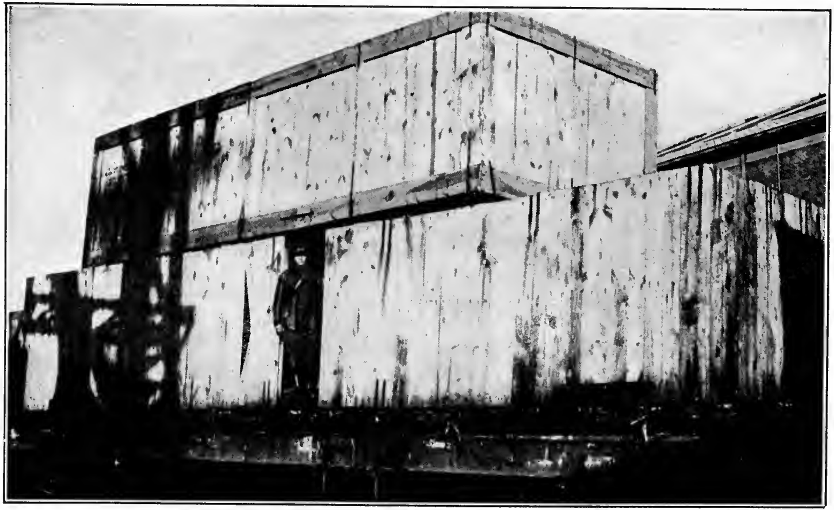
DOLLAR-SAVING DISCOVERIES AND DEVICES

THE principal difference between the operations of a government, whether in war or in peace, and the operations of a private business enterprise, is not one of size or the extent of the operations of either; many national governments spend less money annually, deal with a much smaller area of the earth's surface, and affect the destinies of fewer persons than any one of a dozen big American business corporations. The essential difference is solely that government operates, in theory at least, to get things done well, efficiently, promptly, and to the best advantage of the greatest number of people, while these purposes are only incidental to the operation of a private business, the sole test of which, as to its success or failure, is whether or not it makes money for its owners. If it can make more money by doing things well, efficiently, promptly, and to the advantage of the greatest number of people—as many big corporations, and small concerns as well, have found to be the case—well and good; these things are not the reasons for which the business is conducted, however.

Most of the criticisms of governmental operations arise from the failure to recognize the essential difference between them and ordinary business operations. Government bureaus are criticized because they are not self-supporting, whereas there is no obligation for them to be self-supporting; heads of government bureaus, fearing this sort of criticism or failing to recognize the fallacy of the premises upon which it is based, try to make their bureaus self-supporting and fail to do the things which they have been intrusted with doing in the way they should be done. From many experiences of this sort has arisen the prevailing impression that whatever the government does is done badly and extravagantly and that this inefficiency and extravagance are inherent in governmental operations. There are many thousands of business men in America to-day, however, whose experiences in dealing with the government during the war have given them a new impression of governmental methods and purposes, and who are applying in their private business principles and processes worked out by scientists under governmental direction, applied to war production by governmental authority, which no private enterprise ever before had the initiative to discover or the vision to adopt until they were forced upon them.

One subject in which the educational value of methods devised by and for the government during the war can hardly be overestimated is the commonplace one of packing goods for shipment.

For half a century or more America has been exporting locomotives and railway cars to the four corners of the earth, and throughout that period these commodities have been shipped "knocked down," each part or a number of parts being packed in a wooden packing-case. American engineers built 937 miles of standard-gage track in France and laid down several times as many miles of narrow gage, to connect the ports of St.-Nazaire, Brest, and Bordeaux with the A. E. F.'s supply-depots and all with the front. We



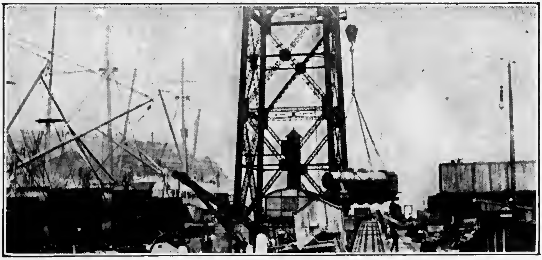
LOCOMOTIVES IN BOXES

Three of the nineteen packages formerly needed to hold one "knocked-down" locomotive.

had to ship locomotives and cars in great numbers, and they were sent at first in the old-fashioned way, a locomotive in nineteen packages and a freight-car in twenty-six different boxes and bundles. As early as October, 1917, General Atterbury pointed out the economies in time, money, and man-power that would accrue if locomotives could be shipped to France "all standing," ready to take out of the ship's hold and put on the rails. The manufacturers of locomotives ridiculed the suggestion; so, too, did the officials charged with the shipment of freight for the A. E. F.

War Department officials, however, became convinced that the project was feasible; the question was where to get ships that could carry complete locomotives. The huge car ferries that ply between Key West and Havana, and across the St. Lawrence at Quebec, might do it, but they were unavailable, and there was a question whether they could carry deck-loads of locomotives across the Atlantic in stormy weather. The big ore and grain ships of the Great Lakes had hatchways big enough to admit a locomotive to the hold, but to get these vessels to the ocean involved tremendous expense and delay; only the smaller Lake ships could by any means be made available for ocean service. The most careful search for suitable ships finally turned up four such craft, the *Feltore*, *Firmore*, *Cubore*, and *Santore*, built by a steel company for bringing iron ore from its Cuban mines, and provided with the huge hatches necessary for the use of modern unloading machines. On May 18, 1918, the *Feltore* sailed for France with thirty-three locomotives in its hold, on their own wheels, carefully packed in with baled hay. How successful was the venture is told in General Pershing's cable, which I quote:

Shipment of erected locomotives transmitted on the *Feltore* very satisfactory. Boat completely discharged of locomotives and cargo in 13 days, with saving of fifteen ship's days in unloading the 33 locomotives erected, as compared with same number of locomotives not erected and further saving of 14 days of erecting forces. Observations of Captain Byron, who came with these locomotives, show that by loading locomotives in double tiers, placing cab parts and tools, now in separate packages, within tender space and fire boxes, 40 to 45 locomotives can be loaded.



UNLOADING LOCOMOTIVES ALL READY TO RUN

For the first time, we shipped Baldwin "Moguls" across the Atlantic on their own wheels. Note the huge hatches of the *Firmore*, the ship that took thirty-six of them in this shipment.

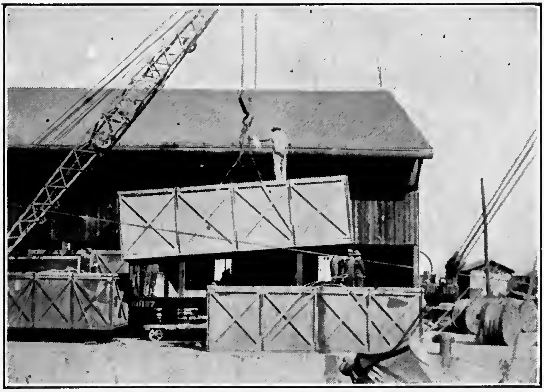
Five hundred and thirty-three locomotives were shipped in this manner. In addition to the immense saving of time, there was a money saving of $775 per locomotive that would have been spent for "knocking down" and packing, and of $800 each, the former cost of erecting them on the other side.

While Lake steamers big enough to admit locomotives could not be brought to the seaboard, many of the smaller type of Lake ships were loaded at Lake ports and sent directly through to France with cargoes. The narrow-gage railroad tracks used in the combat areas close to the front-line trenches were manufactured at Cleveland. They consisted of steel rails bolted to steel cross-ties, making short sections of track all ready to lay down. These were loaded on ships at the Cleveland piers and sent through the Welland Canal and across to France. For many years direct freight service from Lake ports to Europe has been a dream of shipping men; its realization as a measure of war economy brings it nearer as a commercial possibility.

Locomotives were more economically shipped all standing than knocked down; airplanes, on the other hand, must be boxed. The first airplanes we shipped overseas occupied immense areas of valuable cargo space. A number of officers detailed to work out more economical methods of packing airplanes spent weeks in experiments, with the result that a standard package for knocked-down airplanes was evolved, which saved, at the lowest estimate, more than $13,000,000 in tonnage space that otherwise would not have been available for other cargo.

In solving this problem and many others relating to the packing and shipment of war-supplies the army availed itself of one of the most efficient and least known of the government's scientific bureaus, the Forest Products Laboratory of the United States Forest Service. I have referred to the part this institution played in the production of aircraft, through the development of the Tiemann dry kiln and its tests of glue and of airplane woods and parts. The 350 scientific experts of the Forest Products Laboratory are concerned with every use of wood, and the study of packing-boxes was not the least important phase of their work. When the need for the safe shipment of millions of tons of munitions and supplies to France became the most pressing problem for the army to solve, the Forest Products Laboratory was called in, and specifications prepared by its staff were adopted by the army General Staff for the entire War Department, for all packing of shipments.

Tackling the problem with a background of thorough scientific knowledge of every kind of wood, its



UNLOADING CRATED AIRPLANES IN FRANCE

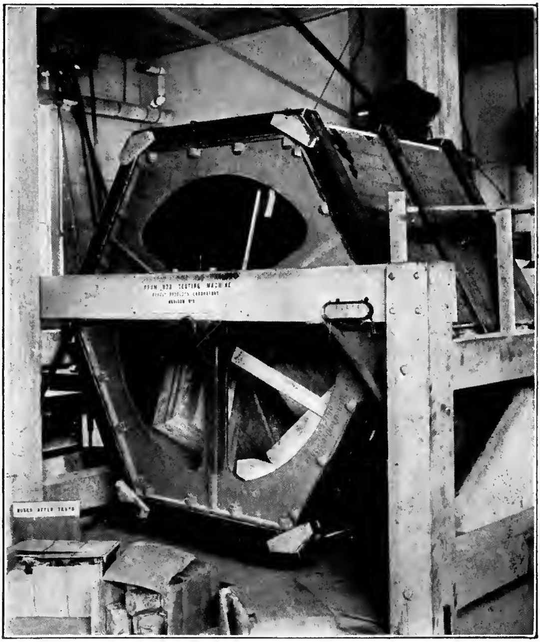
More than $13,000,000 in cargo space was saved by packing 'planes in boxes.

qualities, its availability, and the best uses to which it can be put, the Forest Service added the results of its tests of packing-boxes, made by means of an ingenious six-sided revolving-cage, or "tumbler," which subjects any package in a few minutes to all the bumps, knocks, and strains to which it would be subjected in many thousands of miles of travel by rail and water and the most careless handling by railroad freight men and stevedores.

More than twenty types of packing-boxes were re-designed for the army by the Forest Service. The boxes permitted under these specifications were cheaper, to begin with; where the old army specifications had called for clear white pine, for example, the new permitted the use of many cheaper woods. Fewer nails in some types of boxes, more nails in others, screws for some classes of shipments instead of nails, wire or metal straps for others, all were determined by scientific tests. Not only were the redesigned boxes savers of cargo space, but the excessively high percentage of broken packages reaching France was immediately reduced, the figures after July 1, 1918, showing damaged boxes amounting to only 15 per cent. of the former proportionate number.

Millions of boxes were shipped to France containing ordnance equipment of different sorts; by using any of thirty different species of wood instead of white pine, and using also thinner material, cargo space of inestimable value was saved. Grenade boxes were redesigned to save space. A box originally designed to carry 30 one-pound cans of saddle soap was redesigned with a saving of 43 per cent. of the space formerly occupied. The boxes carrying 140 pounds each of cannon powder were reshaped so as to save 14 per cent. of space. A box designed to carry two Browning automatic rifles with equipment was redesigned, with a saving of 28 per cent. both in cargo space and in material. In the boxes in which the infantry rifles were shipped, ten in a case, there was a saving, through redesigning, of 33 per cent. of space. More than two cubic feet were saved in the space occupied by each harness box.

If their war contracts had done nothing more than to direct the attention of manufacturers and business men all over the country to the commercial value of the scientific researches of the Forest Products Lab-



TESTING PACKING-BOXES

By the use of this machine the Forest Service saved the government millions in cargo space and in damage to munitions in transit.

oratory it would still be possible to contend that something of real importance and peace-time usefulness had been learned. Many thousands, however, came for the first time into contact with another of the government's scientific departments, the Bureau of Standards of the Department of Commerce, whose function is primarily to make tests of materials and machines. Here, too, lessons of lasting value were learned.

More than two hundred military and naval problems were put up to the Bureau of Standards for solution. All were solved and almost all of the solutions have definite industrial and commercial applicability. For example, we were woefully short of infantry rifles when the United States entered the war. American manufacturers had taken contracts for the manufacture of large numbers of rifles for the British and Russian governments, and had installed and equipped expensive plants for their manufacture. It had taken them many months longer than they had anticipated to begin production, and some of them were still away behind on their foreign contracts when America's demand for weapons was added to that which they were already attempting to supply. One of the largest companies, in fact, had actually paid to the British government a $5,000,000 penalty for failure to deliver rifles on the dates called for in its contract.

The United States had to rely on these same manufacturers for the equipment of its army. It was obvious that the manufacture of rifles involved some difficulty which was not easily overcome; when the problem was analyzed it was found that the chief delay was due to the absence of any method of determining in advance the quality of the steel of which the rifle-barrels were made. A single bar the size of a rifle-barrel might be hard in some parts and soft in others; this lack of uniformity caused the drill used for boring out the hole through the center of the bar to diverge. The drill would hit a hidden hard spot and be thrown out of its true course, with complete loss of all the time and labor spent on the barrel to that point.

A FIVE-TON MOTOR-TRUCK KNOCKED DOWN FOR SHIPMENT TO FRANCE IN A SINGLE BOX

"Is there any way," the War Department asked the Bureau of Standards, "to find out if a piece of steel is of uniform texture and hardness without drilling into it?"

There wasn't any way then available, but the bureau found a way. The magnetic properties of steel vary with the hardness or softness of the metal. A device was constructed, composed of electric coils, through which the magnetized undrilled rifle-barrel is passed. The exact degree of magnetization of each successive inch of the rod was thus determined, and if it were unequal or irregular the rod was thrown out and no time wasted in trying to make it into a rifle-barrel.

Industry had long been looking for a method of determining quickly and cheaply the presence or absence of hidden flaws in steel rails. In railway practice alone the process devised by the Bureau of Standards is of immense value, since flaws in the rails are the cause of a majority of all railway accidents. In steel construction of all kinds, the possibility of detecting flaws with certainty is of the greatest utility.

One of the most important and ingenious contributions to the art of war by the Bureau of Standards did not get an opportunity for use under actual war conditions; it was one of the long list of Yankee inventions and devices which would have helped in the complete annihilation of the Hun had the Germans not quit when they did. This is an electrical method of machine-gun control for firing "through the propeller" of an airplane. I have described in a previous chapter the hydraulic device with which our military 'planes were equipped, by which a fixed machine-gun under the control of the pilot is fired at intervals corresponding with the propeller revolutions, the bullets passing between the blades of the propeller itself. The best of these devices was not always accurate; a small amount of wear, unless immediately compensated for by new adjustments, made the gun fire at the wrong time, and in numerous instances the propeller itself was punctured or shot away.

Just before the armistice was signed the Bureau of

Standards had perfected a device which substitutes electric control for any sort of mechanical control. An electric magnet on the side of the gun holds the hammer back, after the gun has been automatically recocked by the recoil of the previous shot, until the instant when the space in front of the gun is clear of both propeller blades. The electric connection with the propeller axis is positive; the circuit actuating the magnet which holds the hammer back cannot be broken until the propellers are in a safe position. This electric control, moreover, has another advantage over the mechanical methods previously in use in that the pilot does not have to press a trigger with his hand or his foot, but merely to touch an electric button, which starts the gun firing; this button or any other means of making an electric contact can be placed anywhere in the cockpit.

This made it possible to construct a rubber mouthpiece which the pilot can hold between his teeth and containing a simple device for making and breaking the electric gun-control circuit. With both hands busy, he can fire his machine-gun by merely pressing his teeth together!

The largest single job given to the Bureau of Standards was that of making master gages for the calibration of every part of every item in the whole vast munitions program. Until 1918 Sweden had a monopoly of high-grade gages for precision work. The gages made under the direction of the Bureau of Standards excel the best ever produced abroad in both precision and quality of workmanship; many of them are accurate to within one-millionth of an inch.

XIX

MEDICAL AND SURGICAL ACHIEVEMENTS

WHEN the history of the Great War comes to be written from the perspective of twenty years hence the conscientious historian will point to the marvelous advances in preventive medicine, in curative medicine, in surgical principles and technic, in sanitation, and in personal hygiene as perhaps the most important group of scientific achievements brought about by the war and the pressure of military necessity. In point of lasting and cumulative benefits to the people of the whole world the new knowledge acquired of means for the prevention and cure of disease and the healing of injuries, together with the application on the largest scale in history of the accumulated scientific knowledge of the whole subject of individual and community health, may well rank first, whether it be measured in terms of dollars and cents or in terms of personal happiness, in its collective value to mankind.

Whether the discovery of new medical and surgical measures and the instruction of twenty thousand and more young physicians in their use is of greater importance than the training of more than three million young men in the care of their own bodies and the elementary principles of community sanitation is too fine a point to be decided. The physicians who have served in the Medical Corps of the army and navy

ROENTGENOGRAPHS OR X-RAY NEGATIVES OF INJURED BONES and the men who have been subjected to their intensive hygiene training have come back into civil life as missionaries of health; their experience and new-found knowledge will prove the greatest possible stimulus to the introduction of wise measures for the general elevation of the health of all the people, and will make for a higher average of good health in the coming generation.

Nothing could better illustrate the progress that has been made in the science of preventive medicine since the Civil War than to contrast the proportion of deaths from disease and those from injuries in battle in that war and in the Great War just ended. In the Civil War 97,000 Northern soldiers were killed or died of wounds, while 184,000 died of disease. The casualty list of the War Department to June 1, 1919, showed that in the war 44,763 American soldiers were killed or died of wounds, and only 19,887 died of disease! Compared with the mortality among men of the same average ages in civil life, there was a slightly larger proportion of deaths from disease in the army. This was due entirely to the transmission of the highly communicable diseases, measles, scarlet fever, meningitis, and pneumonia. These took their heaviest toll among soldiers from rural districts who had never been exposed to these infections, and their prevalence was the natural result of bringing them into close contact with men from every section of the country. With the exception of the four classes of infection named, there was a smaller proportion of deaths from disease in the army than in the same number of men of the same age in civil life.

Typhoid, the scourge of all former wars, was almost totally absent. This disease, which killed thousands in the Spanish War, is so completely guarded against

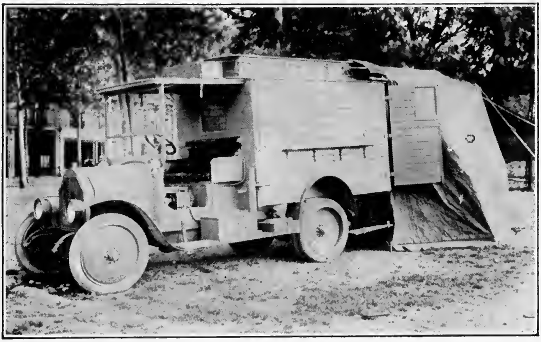
IN AN AMERICAN ARMY BASE HOSPITAL

Every device that Yankee ingenuity could devise for the comfort as well as the rapid recovery of wounded men was adopted; these mechanical aids to convalescence were a constant source of amazement to foreign observers.

that it now barely figures in army health reports. And before the United States had been in the war a year there had been developed a vaccine or serum against pneumonia which holds every promise of accomplishing in the prevention of this disease what the anti-typhoid vaccine has done in its field.

It is to the researches of the scientific staff of the Rockfeller Institute for Medical Research that this new prophylactic is due, as well as many of the other remarkable medical and surgical discoveries made during the war. Ten weeks before the Seventy-seventh Division was sent overseas from Camp Upton about half the men were inoculated with this new serum. Not a single case of pneumonia developed among the men so inoculated, while among those not inoculated the prevalence of the disease was greater than before. The extension of this method of preventing pneumonia to civilians as well as to the rest of the army is only a matter of obtaining a sufficient supply of serum. Eventually it will be as readily obtainable everywhere as is the diphtheria antitoxin. Serums which have proved effective against meningitis, dysentery, and gas gangrene were also developed by the Rockefeller Institute for the United States army.

One of the most important of all medical discoveries due to the war is the identification of the "cootie," or body louse, as a carrier of disease, and the development of means of combating his activities. To the "cootie" have been traced the germs of typhus and of several other diseases. Typhus from time immemorial has been the scourge of armies the world over. It is indeed known in some parts of the world as "army fever." In some countries it is called "prison fever." Wherever there are people living in crowded quarters, with more or less physical contact and under unclean and unsanitary conditions, typhus is a certain menace. It broke out in Serbia among the non-combatant population early in the war, and tens of thousands of Serbians died from it. Many



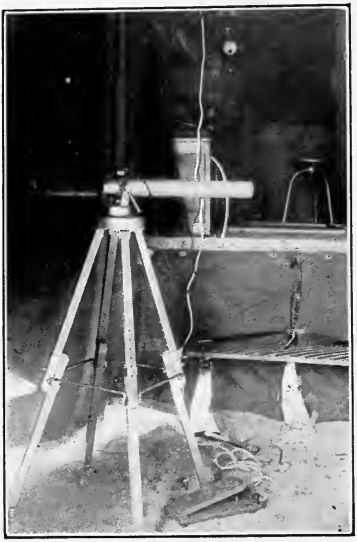
A FIELD OPERATING-ROOM

members of the American "typhus commission" sent to Serbia by the Red Cross also caught the fever and died. At that time it was only suspected that the body louse might be the principal carrier of this "spotted fever." Now the guilt has been definitely placed and another of the world's chief causes of misery and death has come under the control of man.

Far more spectacular than these and many other important advances in medicine are the achievements in surgery whereby it is now possible to bring back wounded men from the very brink of the grave; to heal and restore to usefulness men who, similarly injured in any previous war, would inevitably have perished; to save limbs that formerly would have been amputated; to patch up and rebuild maimed and shattered bodies and features into marvelous semblances of their former selves, and to enable the man who has lost arms or legs to become a skilful, competent workman in spite of his dismemberment. Surgery cannot yet restore sight to the blind nor hearing to those whose ear-drums have been broken by the concussion of great guns, but short of these there is hardly a miracle imaginable that cannot to-day be performed upon the unfortunate victims of war. While the value to a world at peace of the prevention and cure of disease is naturally greater than the value of even the most marvelous possibilities of reconstructive surgery, these latter are, nevertheless, a distinct added asset to the world's wealth, in view of the wide variety of industrial and other accidents which may call them into play.

Perhaps America's most important surgical contribution to the world's heritage of health from the war is the discovery of a new and more positive and powerful antiseptic than was known before and of a scientifically exact method of applying it, so that, provided the prescribed technic is properly carried out, it cannot fail to heal even the most seriously infected wounds. Much has been said about the Carrel-Dakin method of treating infected and other wounds. How marvelous it actually is in the precision with which it achieves its end is not generally understood. It reduces the most difficult of all surgical problems to the same mathematical precision with which the simplest operation is performed.

The Carrel-Dakin treatment is another production of the Rockefeller Institute's research, having been devised by Drs. Charles Dakin and Alexis Carrel, two of the most distinguished members of the institute's staff. To Doctor Dakin belongs the credit of discovering a new antiseptic, hypochlorite of sodium. Chlorin, the same deadly gas that, as I have pointed out in a previous chapter, gives the killing power to phosgen, mustard gas, and the rest of the deadly array of war chemicals, is the germ-killing basis of this new antiseptic. To combine it with other elements in a proportion that would prevent it from injuring raw tissues, while permitting it still to exercise all of its powerful germicidal effect, was the problem Doctor Dakin solved. Doctor Carrel, the Americanized Frenchman whose surgical technic is the marvel of the medical world, the man who has performed and devised methods of performing more new and radical operations than any other surgeon of modern times, worked out the system of the application of the



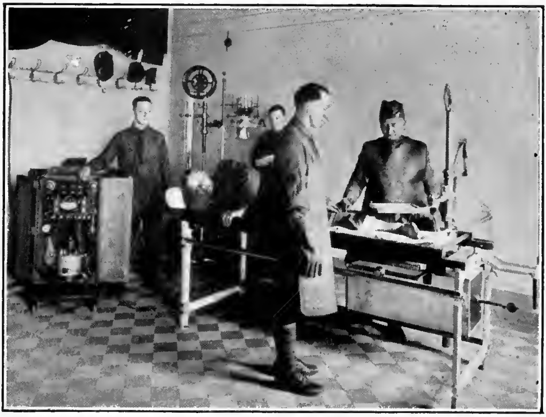
PORTABLE ELECTRO-MAGNET

Used in extracting steel particles from the eye and to aid in locating them under the skin.

Dakin solution to the deepest and most inaccessible wounds, and reduced his method to such an exact mathematical formula that any surgeon, once skilled in the method, can operate it with perfect results.

The underlying principle of the Carrel-Dakin method of wound treatment is that nature will heal any injury if given a free chance. First the wound must be cleaned out with the knife, every particle of infected tissue cut away, no matter how deep the operator has to go. Then the Dakin fluid is applied, by means of an irrigating device invented by Doctor Carrel, which leads the fluid through a number of tiny hollow rubber "fingers" into every farthest recess of the wound. The exact number of "fingers" to be used and the exact amount of fluid to be applied are carefully calculated in advance proportionate to the area of exposed surface. The application is precisely timed as to duration and frequency; the temperature of the wound, taken by a thermometer inserted under the dressings, is the gage that determines whether the instructions have been followed. Given a wound of a certain depth and extent, if the prescribed method be followed, it can be predicted in advance, almost to an hour, when the outer lips of the wound can be closed and the patient removed. Nothing so precise, nothing so mathematically exact, has ever been known to surgical science. More than a thousand army surgeons were given special two-week courses of training in the Carrel-Dakin method at the Rockefeller Institute before being sent overseas; thousands of wounds that under old methods would have meant death or amputation were healed with the least possible reminders remaining to the victims.

Under the direction of officers of the Medical Corps of the army remarkable advances have been made in the use of the X-ray for the detection and exact location of foreign bodies. Not only does the perfected X-ray apparatus show by photography the position of a bullet or a piece of shell, but by ingenious methods the exact depth below the surface is also determined. At the same time the Roentgen photograph is being



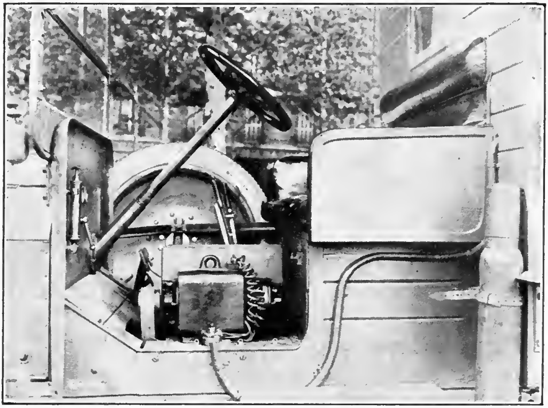
PORTABLE FIELD X-RAY EQUIPMENT

taken a powerful electromagnet is brought over the patient's body. The surgeon places his hand as nearly as possible over the spot beneath which the piece of steel is embedded. When the current is turned on the "pull" of the magnet on the embedded steel sets up a vibration which the surgeon's hand readily detects. The force of this vibration gives the clue to the depth of the steel below the surface. To use this method requires training and experience and it is supplemented by other devices.

Formerly the taking of an X-ray photograph was a matter of fifteen minutes or more; the perfected army apparatus does the work in a few seconds. Moreover, there has been devised a portable X-ray apparatus that can be sent up to the front-line hospitals, the generator being mounted in a motor-truck, so that wounded men in the last months of the war did not have to wait until they could be sent back to the base hospitals before their cases could be thoroughly diagnosed and frequently the bits of shell removed.

It would be easy to write many pages of description of surgical innovations devised and introduced by Americans in the war. The surgical work of our men in the Medical Corps, both of the regular army and of the reserves, was the marvel of the Allies, even as our hospitals, their equipment, and their nurses and nursing methods far excelled anything previously seen in Europe. Among the most valuable of these achievements is the discovery by Dr. William Townsend Porter, of the Rockefeller Institute, of the cause of the formerly fatal condition known as "surgical shock," and of a cure for it "Shock" is a term used by surgeons in several different connections. Broadly it means mental and physical collapse. "Shell-shock" is a nervous condition susceptible of cure. The form of shock arising from dread of the knife and the pain of an operation is purely mental in its origin and is effectually prevented by the discovery by Doctor Crile, of Cleveland, of a way of blocking off communication through the nerves between the seat of operation and the brain. But surgical shock is a condition following severe injuries, amputations, or compound fractures that is distinctly physical and not at all mental or nervous in its origin.

Doctor Porter discovered that surgical shock, which is frequently the cause of death after industrial accident as well as on the battle-field, is caused by the entrance into the blood-vessels of tiny globules of fat, either from the fatty layers just below the skin or



GENERATOR FOR PORTABLE X-RAY EQUIPMENT

from the marrow of broken bones. These fat globules choke the tiny capillaries and keep the blood from flowing to the brain and the extremities; meanwhile, the heart keeps on pumping, but the blood collects in the large veins of the abdomen and the patient literally bleeds to death in his own veins. After making this discovery, Doctor Porter worked out a method of stimulating the action of the lungs so as to draw the blood into the chest cavity and by thus forcing the circulation keep the victim alive until the fat particles could be absorbed. This is accomplished by forcing the patient to breathe a mixture of air and carbon dioxid, administered through a cleverly devised apparatus. It is simple, portable, and instantly effective. Another triumph for American surgical science!

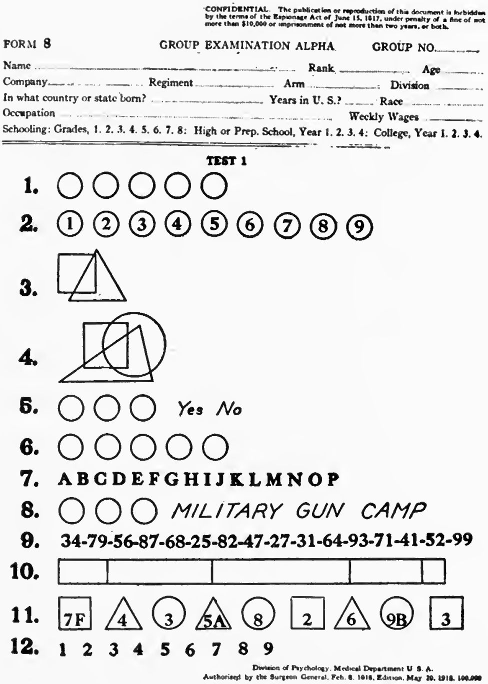
Equally valuable as a permanent contribution to surgery is the new "ambrine" anesthetic, the merciful invention of Dr. Gordon Edwards. Sprayed on a burn or an open wound, it instantly relieves pain; with its aid dressings can be changed and wounds treated without the slightest sensation on the part of the patient.

The French and Italians have carried farther than have American surgeons the plastic surgery that literally gives the man who has been wounded in the face a new set of features. Some wonderful things in this line have been done, however, by Americans. A new nose has been made of bone from the patient's own shin and flesh and skin from his forearm; shattered jaws have been replaced by silver "bones," so adjusted that there is hardly an outward indication of an operation. And in the field of artificial arms and legs and their perfect adaptation to the necessities of the dismembered American methods have superseded almost all others. Artificial arms and hands with which the soldier who has lost both arms can write, handle knife and fork, lift a glass of water, and perform many other simple operations have been fitted; artificial legs and feet that enable their wearer even to dance have been brought to perfection by the staff of expert surgeons and limb-makers working at the Army Medical College and the Walter Reed Hospital at Washington. All of these inventions, devices, and discoveries are that much distinct gain, adapted as they are to the needs of a world in which disease and accident will still continue to take toll of human life and limb.

When the United States entered the war the entire supply of surgical instruments on hand in the United States was adequate for only a fraction of the probable need. Surgical instruments had been chiefly made in Germany; almost every dealer in surgical instruments in America was an agent or a branch of a German house. The peace-time supply of some classes of instruments had been coming from England for the first two years of the war in Europe, but that source was shut off by England's own needs.

One of the most vital and difficult tasks the Surgeon-General's office undertook was the establishment in America of a surgical-instrument industry. The makers of ordinary needles could not make surgical needles. By adopting six standard sizes and shapes and placing contracts for ten million needles with the big sewing-machine companies the army was equipped as early as these were needed. Tested at the Bureau of Standards, they were found to be superior to the best German needles, and America is now independent of Germany. Manufacturers of knives were induced by big contracts to undertake the manufacture of surgical knives. Here, too, the German product was improved upon. For artery forceps recourse was had to the manufacturers of scissors; now we make all we need in America. So with many other kinds of surgical appliances and instruments, until America in every respect became independent, now and for all time, of Germany or any other country.

No survey of the work of the Army Medical Corps would be complete without at least a reference to that triumph of Yankee ingenuity, the mental analysis of three million soldiers and their classification by



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FORM 8 GROUP EXAMINATION ALPHA GROUP NO. ....

Name .... Rank .... Age ....

Company .... Regiment .... Arm .... Division ....

In what country or state born? .... Years in U. S.? .... Race ....

Occupation .... Weekly Wages ....

Schooling: Grades, 1. 2. 3. 4. 5. 6. 7. 8: High or Prep. School, Year 1. 2. 3. 4: College, Year 1. 2. 3. 4.

TEST 1

1.

2. 1 2 3 4 5 6 7 8 9

3.

4.

5. *Yes No*

6.

7. A B C D E F G H I J K L M N O P

8. *MILITARY GUN CAMP*

9. 34-79-56-87-68-25-82-47-27-31-64-93-71-41-52-99

10.

11. 7F 4 3 5A 8 2 6 9B 3

12. 1 2 3 4 5 6 7 8 9

Division of Psychology, Medical Department U. S. A.
Authorised by the Surgeon General, Feb. 8, 1918, Edition, May 20, 1918, 100,000

FIRST PAGE OF THE "ALPHA" TEST

It looks like a game, but it records human intelligence unerringly when properly applied.

5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54

Form No. CCP-1-1000M-9-17

QUALIFICATION RECORD

To be sent at once to the Division Personnel Officer

Name DOE, JOHN, W.
(Last name) (First name) (Middle name)

Occupation? Blacksmith

How many years have you worked at it? 5

Name of last employer J.R. Williams

Business " Horshoeing

Address " Highland, Va

Your weekly wage in this position $ 25.00 Age 28

Describe the jobs or enterprises in which you exercised the greatest authority or leadership; such as foreman, manager, captain, etc. None

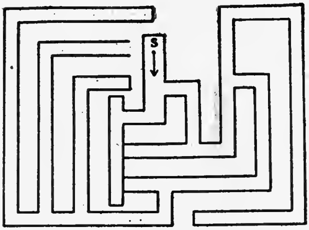
50

In the columns to the right draw one line under those occupations at which you have worked; draw two lines under those at which you are expert. After each underlined occupation write also the number of years (i. e., 1, 5, 9,) of experience you have had in that occupation.

	Years		Years		Years
1. Factory worker		22. Auto driver		37. Accountant	
2. Farmer		23. Motor-truck driver		38. Bookkeeper	
3. Laborer		24. Auto-repairman		38. Clerk	
4. Lawyer		24. Gas engine repair man		38. Shipper	
5. Teacher		25. Horseshoer	5	38. Stock-keeper	
6. Machinist		26. Mule-packer		39. Stenographer	
7. Blacksmith	1	27. Care and handling of horses		39. Typewriter	
7. Wheelwright		28. Veterinary		40. Baker	
8. Carpenter		28. Farrier		40. Cook	
9. Concrete foreman		29. Draftsman		41. Butcher	
10. Electrician		30. Surveyor		42. Grocer	
10. Dynamo expert		31. Telegrapher		43. Chiropodist	
11. Gunsmith		31. Wireless operator		43. Dentist	
11. Locksmith		32. Lineman		43. Druggist	
12. Miner		32. Phone repairman		43. Medical student	
13. Painter		33. Phone operator		43. Nurse	
14. Pipe-fitter		34. Photographer		43. Physician	
15. Railroad operating man		35. Moving picture expert		44. Brass wind instrument	
16. Section-hand		36. Navigator		44. Other band instrument	
17. Railroad fireman		36. Seafaring man		45. Barber	
17. Steam engineer				46 Canvas worker	
18. Rigger				47. Harness maker	
19. Sheet metal worker				47. Shoemaker	
20. Foundryman				48. Tailor	
21. Engineer graduate				49. Watch-maker	

If you are an expert in any occupation not mentioned in these columns, write it here.

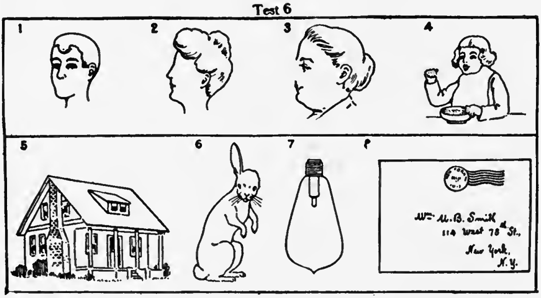
scientific psychological methods that rated their relative intelligence fairly and accurately and made it possible to pick out and place where they could render most effective service the men who were capable of leadership, those who could be made into officers, those best adapted for the work of each of the other arms of the service, and those of low mental caliber who were fit only for the Service of Supply or for work around the home camps.



PART OF THE "BETA" TEST
Illiterates demonstrate their mental power by tracing through mazes like this.

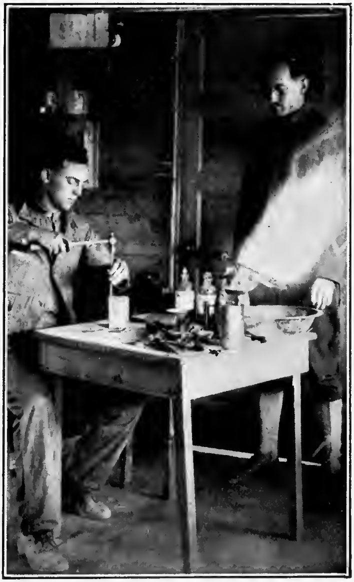
Washington looked forward to not less than three more years of war on that April day in 1917 when the President and Congress finally agreed that the patience of the American people had been stretched to the breaking-point. If we were to win the war in that time, we must find a quicker way than the army knew, than the civilian world knew, of fitting the square pegs into the square holes, and finding a round peg for every round hole, or our army of two or three or five or ten million men would be nothing but a mob of two or three or five or ten million men. It would not be an army at all, and it would not win the war.

We won the war in eighteen months—half the time that we expected to take. And among all the contributing causes that enabled us to train nearly four million average Americans into soldiers, provide them with sufficiently competent officers, and send more than half of them overseas, there is none that more strikingly illustrates Yankee resourcefulness and ingenuity in the application of science to practical every-day affairs than the methods devised and applied by American psychologists for a determination of the mental qualifications and the special abilities of officers and men alike.



PART OF THE "BETA" TEST IS TO TELL WHAT IS WRONG WITH PICTURES LIKE THESE

"Psychology" is a word used so loosely in ordinary conversation and that has been so misused for purposes of commercial exploitation by individuals who have no possible claim to be regarded as scientists that the offer of the American Psychological Association to co-operate with the War Department and the army General Staff was received with considerable skepticism as to any possible usefulness. So completely did the application of psychological science justify itself that it is a safe assertion to say that no officer or enlisted man will ever again be taken into either the army or the navy of the United States except on the basis of his fitness as disclosed by the methods devised and applied in the Great War, and that the rating, classification, and detail of the army personnel will always in a large measure be governed by these or similar tests applied to each individual soldier. That as a result of this complete and successful demonstration of the practical utility of applied psychology government civilian employees before long may be rated and classified in the same fashion is not improbable.



TEST FOR RADIATOR REPAIR-MAN

Under the direction of Dr. Robert M. Yerkes, president of the American Psychological Association, who was commissioned a Major in the Medical Corps, there was brought into the service a staff of trained psychologists who devised and applied a simple, efficient series of mental tests, the results of which were amazing, even to the psychologists themselves, in the accuracy and speed with which the intelligence of the men examined by this means was ascertained.

The practical application of the psychological tests covered a very wide range indeed. The highest intelligence among enlisted men is required in the field artillery, machine-gun battalions, and Signal Corps. Men of the lowest grade of intelligence may serve adequately as laborers, teamsters, and other non-combatant service, while men below the average can perform duties of an infantryman satisfactorily.

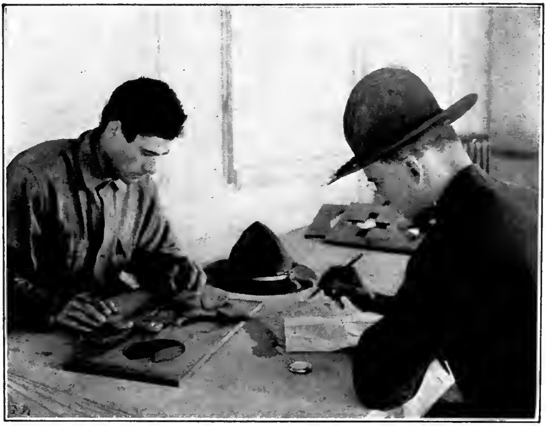
SHEET-METAL WORKER DEMONSTRATING SKILL ON SIMPLE WORK IN HIS TRADE BY MAKING A TIN CUP

By the application of the mental tests it was found possible to bring up the average of particular companies, regiments, and detachments by exchanging men of high mentality from one regiment for an equal number of men of the lower grades from another regiment in which the average of mental ability was low. It obviously was an immense saving of time and energy to be able to determine that a particular soldier, on the strength of his psychological score, was qualified to be turned into a good artilleryman, machine-gunner, Signal Corps man, or what not; by preventing the loading up of a competent division with men who could qualify only for the service of supply, the work of the psychologists saved incalculable delay in getting our overseas contingent ready to fight.

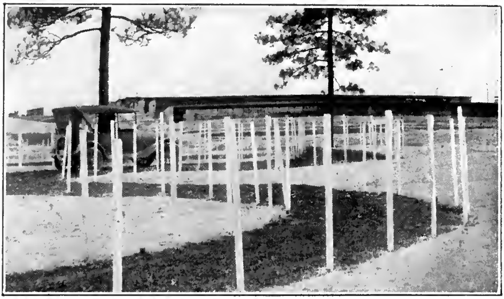
And while one group of psychologists, working under the direction of the Surgeon-General's office, was classifying the army personnel as to the mental capacity of its units, the Personnel Branch of the Operations Division of the General Staff was undertaking the task of determining the special technical and vocational ability of every one of the millions of men drawn into the army through the medium of the selective draft, and placing each of them where he could contribute most to the strength of the nation's military force.

These trade tests were as carefully devised and worked out by scientifically trainedp sychologists as were the mental tests which I have already described. For example, who can tell offhand what a first-class plumber ought to know? Half a dozen plumbers may have half a dozen opinions. Their employers may regard certain knowledge as essential which the men themselves do not so regard. In Newark the practice may be for plumbers to do certain things which are not done in Cleveland or in St. Louis; so for every trade and occupation listed in this huge dictionary of occupations exact information as to what sort of questions should be asked of men professing to know each trade was obtained from employers, from officials of labor unions, from recognized skilled workers actually at the trade, in five different cities,

A GROUP OF CANDIDATES FOR COMMISSIONS TAKING THE ALPHA TEST



THE "BINET" TEST FOR THE MEN OF LOWEST MENTAL CALIBER



AUTO-DRIVER TEST COURSE

The stakes are knocked down by the poor driver and that counts against his total score in the test.

RUNNING THROUGH AN ARTIFICIAL SAND-PIT AS PART OF THE MOTOR CYCLE TEST covering every part of the country in which the particular trade is extensively practised.

From the consensus of information thus obtained there was devised for every trade in the occupational index a list of questions and their proper answers. In many cases the questions were supplemented by pictures of tools, apparatus, or processes. A man who professed to be a blacksmith was asked questions the answers to which revealed at once his familiarity, or lack of it, with the blacksmithing art; he was shown pictures of tools used by blacksmiths, and if he could not name them properly his claim to being a blacksmith vanished. If, however, he passed this first oral test, then he was immediately given an opportunity with anvil, forge, and sledge to demonstrate his manual skill in applying the knowledge which his answers had indicated. These men were classified, not only as blacksmiths, but as experts, journeymen, or apprentices.

This system of trade tests was under installation in all training and receiving camps and cantonments at the signing of the armistice. It was in full operation in only a few of the camps, although the first preliminary classification was complete for the entire army personnel. So there was at every camp or division headquarters a card index, one card for every man in the division or camp, so classified by means of punch marks and marginal numbers and different colored metal tags that a telegram from Washington to each division headquarters would bring back at once a precise census of the number of qualified cobblers, mule-drivers, or what not available in the entire army. It was then a simple matter to send the necessary men from one camp to another and instantly meet the need of the moment.

MANY GROWN MEN WERE FOUND WITHOUT ENOUGH INTELLIGENCE TO PUT THE ARMS AND LEGS ON A WOODEN DOLL

MAKING THE TRADE TESTS

As I have taken pains to point out, the importance of this successful demonstration on a huge scale of applied psychology in the selection, rating, and placement of men doesn't end with the ending of the war. The work done in the army has pointed the way for the determination in civil affairs of the relative value of men in every walk of life, from those requiring the highest intellectual activity to those occupations in which the sole requirement is physical stamina. It has pointed the way, too, for the standardization of occupational requirements so that the employer of artisans of any sort can determine, without the ruinous waste of time and materials that has always been necessary to pick out the skilled workman from the mass of incompetents, whether a particular man is qualified for a particular job without having to hire him first in order to find out.

Nobody in or out of the army would claim that the system or any part of it has achieved ultimate perfection; as a long step in the direction of the solution of such economic problems as can be solved by keeping the square pegs out of the round holes, the war work of American psychologists is a distinct and valuable contribution to the peaceful progress of the world.

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CONCLUSION

THE old adage, "Necessity is the mother of invention," is literally true. Human progress in the arts and sciences has from the beginning of time been dictated by humanity's economic necessities. The most marvelous invention ever made is of no value unless, in some way, it ministers to a social need. But given the need, the invention will surely be made.

The record of Yankee ingenuity in the war, of which I have in this book touched only the high spots, is a perfect demonstration, on the largest scale in all history, of this economic truth. Our needs were great and imperative, but they had only to be expressed to be filled. Should another similar crisis occur in our national career, who can doubt that even more and greater marvels would result from the application of our traditional resourcefulness and skill in applied science?

What was true in war is equally true in peace. Our scientists and inventors who gave the lie to the croakers who said "It can't be done" stand ready to repeat the performance whenever the pressure of social necessity requires it. All the stimulus that is needed is the existence of a need and the general recognition of its existence.

Invention moves no faster than demand. It may be and often is the case that the inventor is the first to recognize the need which his particular application is designed to fill; that society did not realize that it wanted his invention until he had offered it to them. The world is full of disappointed inventors, men and women who have fancied a social need that did not exist, or that had not yet become recognized as such by society. The great inventions that have benefited mankind are those which have most completely satisfied wide-spread social needs that existed at the time of their introduction. And, as I have said, no recognized need ever waits long for the means to satisfy it.

Compared with the ceaseless struggle between mankind and the forces of Nature, the Great War itself was but a trifling bit of by-play in the stupendous drama that has the whole earth for its stage and on which the curtain may be said to have hardly risen as yet. We have only begun to find ways of harnessing the lightning and the floods, of turning to the use of humanity the hidden energies the keys to whose hiding-places we are only just beginning to discover.

From a flat plane of two dimensions the stage of this human drama has suddenly become a three-dimensioned space, within which man moves as freely in all directions as the very air itself. The imagination hesitates before the picture of a conquered sphere, every square mile of which contributes its share to the satisfaction of new and as yet undreamed-of human needs; yet the exhibition in the war of human resourcefulness and of power already acquired over the forces that shall one day make this earth of ours all that the prophets of the millennium have pictured compels the belief that the pressure of our common need will one day see this achieved. Our children's children may yet see to the conquest of space added the annihilation of time and an approach to that fourth-dimensional state that is as yet but a figment of the mathematician's fancy, that state in which the words of promise shall be fulfilled, "There is nothing hidden that shall not be revealed."

We who are alive to-day are spectators for whom the curtain has not yet fallen on the first act. The actors are the men of science who are giving themselves to the service of humanity and the millions of young men, inured to hardship by war, fired with the spirit of adventure, who are even now, as this is written, advancing over earth, sea, and air toward every remote and unconquered region of the world, to set up new outposts of civilization and bring their forests, their rivers, their mines, and their fertile fields into the service of mankind.

They come from every country, of every race, these young veterans of the Great War—French and German, English and Austrian, American and Bulgarian, Japanese and Turk, Australian and Russian. From the headwaters of the Amazon to the steppes of Tartary, in steaming African jungle and in the ice-bound Yukon you shall find them, side by side, working out the destiny of their children and ours in the great world-drama.

And in this war of man with nature, as in the war of nations, who can doubt that no small share of the victory will be due to Yankee ingenuity?

THE END