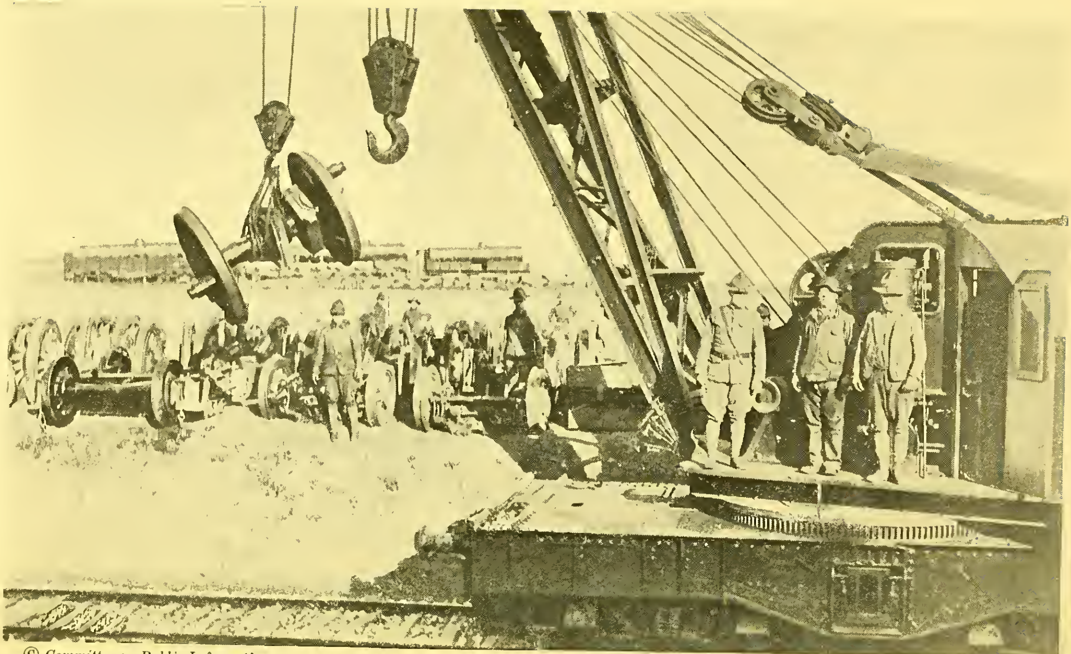
THE FIGHTING ENGINEERS



American engineers on the job

THE FIGHTING ENGINEERS

THE MINUTE MEN OF OUR INDUSTRIAL ARMY

BY

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ILLUSTRATED WITH PHOTOGRAPHS

NEW YORK
THE CENTURY CO.
1918

Published, June, 1918

TO

THE AMERICAN ENGINEERS

AT CAMBRAI

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ILLUSTRATIONS

THE FIGHTING ENGINEERS

THE FIGHTING ENGINEERS

We dug up husky mountains by the roots;
  We spanned the rushing torrent with a bridge;
We laid the rails to guide the steam-charged brutes
  That fed the men and guns at Cambrai Ridge.
We built a road through slush and soupy mud,
  While dodging shells the German "minnies" sent;
We did the Job and saw that it was good—
  And then we heard another call—and went.

The pick and shovel dropped from every hand;
  We didn't even notice where they fell;
We crawled or climbed or ran in No Man's Land
  To bring back tortured souls from worse than Hell.
And then the Germans came—we *had* to fight;
  With something near to joy we grabbed the guns;
For this we'd waited many a day and night
  To send our deadly greeting to the Huns.

With British Tommies we stood face to face
  With Death—and counted it the Chance
Of all—to be with them in that red place,
  To live and fight and maybe die for France.
So shot for shot and ball for ball we gave,
  From trench and shell-hole till the fight was won;
Then we came back, each from his living grave—
  Save those whose living fighting days were done.

So when the story of the war is told,
  Let one small chapter tell our little tale.
Say that we helped the thin first line to hold—
  That when the Big Test came we did not fail.
But do not call us "heroes"—do not give
  For those who died "out there" your futile tears,
But, smiling proudly, let their names still live
  Upon the Roll—the Fighting Engineers!

H. Varley.

Courtesy *New York Times.*

THE FIGHTING ENGINEERS

CHAPTER I

RAILROAD BUILDING "OVER THERE"

ON the declaration of war the call for volunteers for the engineering regiments found America admirably prepared. In organizing its industries to create, rather than to destroy, the country faced familiar problems. The lively dangers of the enterprise served only to arouse enthusiasm. No draft was needed to fill, almost overnight, the ranks of nine regiments of engineers for the period of the war. Drawing upon our boundless resources in skilled workers, the Government has recruited at this writing an army of 115,000 men.

The Great War is preëminently a conflict of engineers. A locomotive may prove more deadly than a battery, while the building of bridges may decide the issue of a campaign.

The fighting engineers often face greater perils than soldiers in other branches of the service. Theirs is in no sense a "bullet-proof job." Their losses frequently exceed those of the artillery regiments, the fatalities in which are, in turn, greater in number than those in the aviation corps. When other troops cross an exposed position, for instance, they usually do so at the double-quick, and seek shelter as soon as possible. The engineers often find themselves under fire at a time when they must stick to their work until it is finished.

The men of the engineering regiments look like those in any other army service. They wear the same uniform and carry the usual arms and equipment. Their best fighting, however, is done with such complicated weapons as engines, batteries, and construction tools. The engineers receive only such military drill as will give them greater mobility and better organization. After a limited period of training in camp they are hurried directly to France, since their real fighting ability, now so sorely needed, has long since been trained to its highest efficiency.

While the drilling of other troops was scarcely under way, America had put in the field complete regiments of railroad men, forestry workers, miners, electricians, bridge builders,—in short, representatives of all departments of constructive engineering. The call for volunteers met with an enthusiastic response in such widely scattered cities as New York, Philadelphia, St. Louis, Chicago, Boston, Pittsburgh, Detroit, Atlanta, and San Francisco. In New York, for instance, there were men enough in line, when the recruiting office opened on the first day, to make up the required quota. Ten applicants offered their services for every one who could be chosen. It is significant that the leading engineering societies of the country display "service flags" plentifully supplied with stars.

No activity of the American engineers has made so profound an impression upon France as the actual work of the regiments of railroad men. The most persistent publicity campaign could not have taught Europe in a generation so much about American railroad methods. The traveled Frenchman or Englishman, especially if he were an engineer, knew something of the progress in railroad building in America, but the general public in the land of our allies was not prepared, and has been taken completely by surprise.

When the first American locomotive reached France a large force of our engineers was on hand to welcome it. Many French railroad men and government engineers watched with lively interest the unloading of the strange importation. As the parts were swung to the dock American workmen quickly assembled them, working with a celerity that amazed the observers. Another force of American railroad workers meanwhile hastily laid a section of track from the dock to the main line. Several days would have been required by the foreign workmen to complete such a task, but in a few hours the Americans had finished both jobs, got up steam, and tooted a farewell.

The American locomotive's trip across

France was in the nature of a triumphal procession. The unusual size and form of the engine naturally attracted great attention, while its American flag served to identify the visitor and assure its welcome. Here, in the midst of the cities and fields of France, was a tangible proof of the arrival of American forces. With its bell and whistle going without interruption, the engine was rushed to the eastern boundary of France.

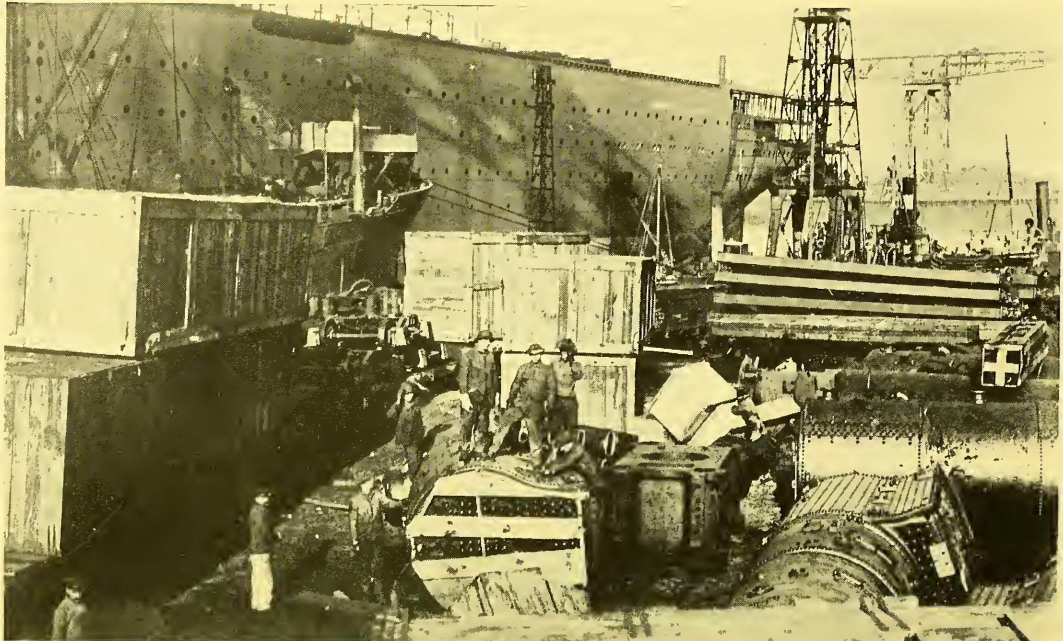
Its destination was a sector occupied by American troops. News of the approach of the locomotive from back home flashed from camp to camp, and when the familiar whistle and bell were heard in the distance the soldiers lined the tracks to welcome an old friend. As the engine came to a standstill the men greeted it with somewhat tremulous cheers, crowding about it and patting its wheels affectionately.

The locomotive had approached very near the front lines, and an unexpected complication followed its noisy greeting. Its American crew had not learned that the ringing of a bell is the signal at the front for a gas-attack. The French troops who heard the clanging bell drew their own conclusions, and lost no time in crawling into their subterranean cellars and shelters. Not a Frenchman was on hand to welcome the new-comer. The bell has been removed, to be put to other uses; but the American locomotive is still in active service.

The American engineers found the French railroads very different from their own. It is a great tribute to their skill that American methods have been so quickly adapted to strange conditions. The French operating system, for one thing, is left-handed; the tracks are not of standard gage, in our sense; the rails are differently adjusted, and a new signal system had to be adopted. Add to these problems the fact that the engineers have to conduct their work by the medium of a foreign language, and the difficulties may be appreciated. Within a few days after their arrival, nevertheless, the Americans had taken hold of this highly complicated system and were operating without mishap.

Large supplies of American locomotives and rolling stock have been carried to

Officers of the Fighting Engineers



Unloading American locomotives at a French port

France, and these have been ingeniously adapted to the new conditions. The difference in the width of the tracks was overcome by adjusting the wheels' carriages so that the railroad-beds would serve.

The method of building tracks in France was a new problem for the American engineer. The French rails are differently supported with wedges to tighten them. Our rails, of course, lie directly on ties or metal tie-plates. The French rail-joints are placed opposite each other, instead of being staggered as at home. In France a railroad curve is built on a scale of meters of radius, while Americans calculate the degrees of curvature.

In taking over the French railroad-projects, the American engineers were first obliged to study the existing French plans and redraw them all to a new scale. The French method of preparing blue-prints of the proposed work differs from our own; besides, such work must be done with the constant aid of interpreters, and here again great difficulty was encountered, since the interpreters were laymen who were not familiar with technical engineering terms. Furthermore, all the French dimensions and quantities, which are measured by the metric system, had to be translated into familiar units of measurement.

The Americans, nevertheless, completed this preliminary work, and carried through immense railroad projects at a rate that astonished the French engineers. Despite all the difficulties they had to contend with, it is interesting to mention the fact that one of the projects entrusted to the Americans has been the construction of main-line tracks long enough to reach from New York to Chicago.

Much of the equipment has had to be standardized to fit new conditions abroad. In laying down standard-gage railroad tracks in France, a special type of eighty-pound American Railway Association rail was rolled for the purpose. The French standard gage is four feet, eight and eleven sixteenths inches, or 114 centimeters, while American track is four feet, eight and one half inches. The narrow track consisted of twenty-five-pound American Society of Civil

Engineers standard rails, laid one foot, eleven and five eighths inches, or sixty centimeters, apart. For both types of rails the American engineers provide standard turnouts, frogs, switches, and cross-overs, made interchangeable left or right. A light, portable type of track is also generally employed, which may be laid very rapidly and bolted into position.

Much of the trackage has been laid down in the immediate vicinity of the great seaport freight-terminals. Practically all the supplies required by our fighters abroad must be ferried across the Atlantic. To handle this immense freight, classification depots and warehouses had to be built and a vast system worked out for routing this material from the ships to the front.

The classification sheds are very long, with a width of fifty feet, and have eight-foot platforms. The most approved mechanical equipment for handling freight had to be designed, built at home, and rushed to France. The railroad construction work in these great regulating freight-yards is said to be the most efficient in France.

The port-docks are great rectangular basins, which presented a peculiar problem to the American engineers. Parallel to the sides and ends of these basins three lines of tracks were laid, and cranes and loading derricks were installed. In planning all this construction, it was found that French timber does not have the same supporting strength as American lumber, and the plans had to be corrected accordingly. Again, the French piles could not be had in lengths greater than forty-five feet.

In many instances the regular materials could not be found, and any makeshift was employed.

Then, too, when our railroad cars arrived in France it was found that the wheel-trucks would not pass over the French turntables, and an entirely new turntable system had to be designed and built. A thousand unexpected difficulties had to be met, in order that a smooth, steady stream of traffic might flow across France to the front.

The organization of these vast enterprises has been carried out along characteristic American lines. A Director-General of

Transportation has been put at the head of the building and maintenance of roads. The completeness of the organization is indicated by the titles of the various officials, these including a Deputy-Manager of Railroads, a Superintendent of Supplies, a Superintendent of Equipment, a Superintendent of Quarries, a Bridge-Engineer, a Superintendent of Business Affairs, a General-Superintendent of Construction, and many division engineers. Each division is highly specialized.

Shortly after their arrival in France the American railroad men were set to work on the highly complicated problem of double-tracking several of the main lines. Every detail of the work was entrusted to them. Hundreds of miles of land had to be surveyed, the roadbeds and bridges had to be widened, and countless engineering problems had to be solved. Such double-tracked lines have been built from several seaports,—across the entire width of France,—to the front, in order that the carrying capacity of the railroads may be doubled as quickly as possible.

American workers soon became familiar objects in many sections of France. The skill and expedition of these regiments have made as profound an impression upon the French engineers as upon the general public. In the progress of this work a unique record for speed in railroad building has been established in France, if not in the world. A section of standard-gage track, just five eighths of a mile in length,—a French unit of measurement,—was built and made ready for traffic in two hours and ten minutes.

As the fighting men push forward, the task of supplying millions of troops with food and ammunition has become unprecedented. To this end the railroads are always the vital element. The American engineers have been very active of late in the unheard-of-task of transporting a railroad bodily from England to France. Every rail, tie, and spike of this system was taken up, its proper position marked, and the immense bulk of material loaded on steamers. The equipment was complete to the last detail, including the engines, cars, signal-systems, and repair-shops.

After braving the U-boats in the English Channel, the railroad fleet arrivel safely in port, when an even more complicated task had to be faced. Only trained railroad men could be entrusted with the work. The problems involved made a special appeal to the American engineers. Without an amazingly efficient system the work would have fallen into hopeless confusion. With the aid of the newest labor-saving machinery, the track-bed was prepared, the tracks were laid, the repair-shops established and manned, and trains were soon running in a foreign land on their accustomed schedule.

The engineering methods of generations have often been swept aside in an hour. To transport a cargo from London to Paris and beyond has been a complicated procedure. Such a cargo must be handled at least four times in transferring it from train to boat and again to train, with countless delays, due to the conflicting methods of two different countries. To-day a railroad car is loaded with ammunition at a factory in England and unloaded in France at a point convenient to the firing-line. Without the pressure of war, so direct a method might not have been adopted for generations. The American railroad engineer trained to get results in the shortest possible time, is proving indispensable to France and England in the introduction of these radical reforms.

Great technical skill in railroading is required to work out the new problems. The transportation methods of both countries must be thoroughly understood to the last detail before they can be coördinated. The British, French, and American engineers, working together, have mapped out entirely new systems of transportation. Under the crushing burden of the war the French railroads have badly run down. They are in need of men and equipment of every kind. The men who operate them are sorely needed at the front. It is a matter of national pride that our best engineering talent has been quickly recruited for the task of reconstruction.

The gap between the terminus of the regular railroad lines and the trenches is often difficult to bridge. The ground may be continuously under fire from the great siege-guns of the enemy's batteries. Since the battle-line is drawn without a break uphill and down dale for hundreds of miles, it often passes through rough country. The land back of the trenches is frequently broken by deep ravines or valleys, where ordinary railroad construction would be difficult to carry on and to defend. The enemy's aëroplanes are constantly on the lookout for such targets.

A light, narrow-gage track, separated by only twenty-four inches, is commonly used for the railroads immediately back of the trenches. By using light timbers, or almost any makeshift for ties, several miles of such track are often laid overnight. The trains of supply cars are hauled either by steam-engines or by gasoline-motors ingeniously contrived from an automobile. When it is important that the trains be as noiseless as possible, horses and mules are used as motive power.

When very rough country is to be bridged, an ingenious cable railway, which may be thrown across a deep ravine in a few hours, is often employed. A narrow bridge or walk is built of lumber, and light cables are strung at the side. The wheels of the cars are grooved to fit these cables, so that a comparatively heavy load may be moved by hand-power.

When the trench-railroads traverse specially exposed country, tunnels are often dug as a protection against attack. The tracks are arched, covered with branches of trees, ingenious arrangements of boards, or strips of painted cloth for the purpose of deceiving the scouting air men. The most flimsy covering, if the coloring is cleverly arranged, will suffice. The familiar routine of railroading often goes forward in these curious tunnels within sound, perhaps within range, of the firing-lines.

American railroad men have been especially commended by the British officers for their work in the flooded districts near the front in Flanders. Until our men came it had been found impossible to establish railroad connections in the inundated sections. The British troops in this region were compelled to wade through a morass, camping on the slightly higher bits of ground. The railroads were usually covered with water as fast as they were built.

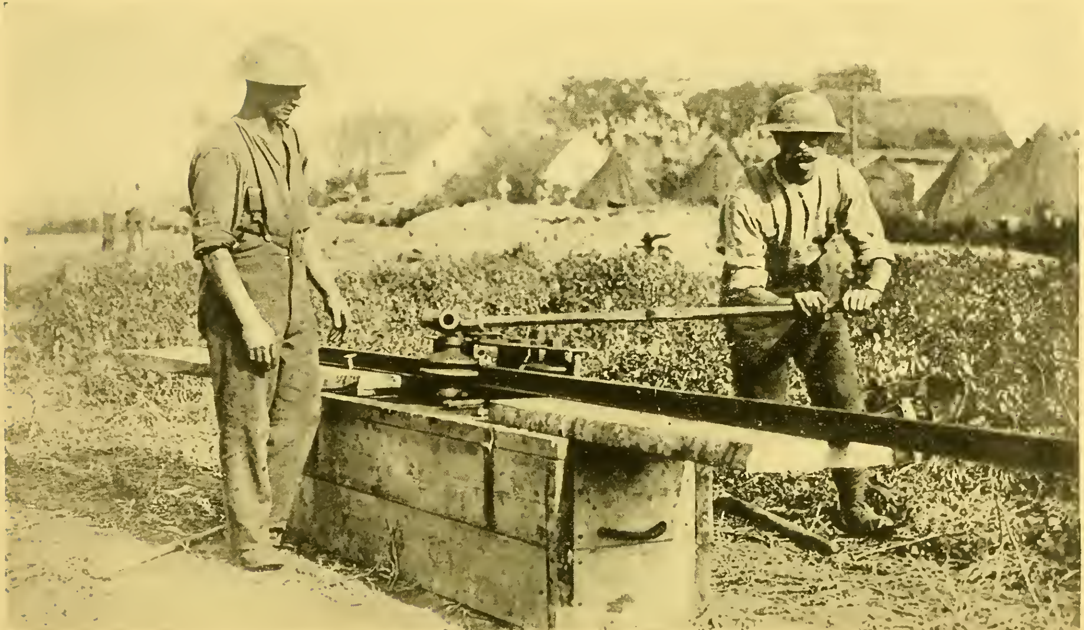
To drain off the land,—hundreds of square miles of it,—was obviously impossible, while filling-in would have required enormous labor. The American engineers solved this problem, and actually "floated a railroad" that keeps the advanced lines in continuous communication with the rear. The censor has not permitted any information in regard to this work to come through,—for such information would be highly valuable to the enemy,—other than the general statement that an ingenious application of hydraulics has been employed.

The fighting railroad engineers at present comprise three regiments for operation, five for constructive work, and one for motive and repair work. The Eleventh Engineers has been recruited largely in New York; the Twelfth Engineers comes from St. Louis; The Fourteenth, which directs operation of railroads, hails from New England; the Nineteenth, composed of railroad shop-men, comes from western Pennsylvania. It is the last regiment which has done such excellent work on the Paris-Orléans system. The Thirty-Fifth was organized at Camp Grant, Rockford, Illinois. Still other regiments have been raised in Chicago, on the Pacific Coast, and in the southwest. Each of these regiments includes 1100 men and 33 officers.

The work of our railroad regiments abroad has been greatly facilitated by unlimited American supplies. Until November, 15, 1917, the orders for railroad equipment exceeded $70,000,000; since that date these figures have been greatly increased. The early orders for supplies included:

100,000 tons of steel.
3000 complete turnouts.
500,000 ties.
12,000 freight-cars.
600 field- and ballast-cars.
600 miles of telephone and telegraph wire.

The work of the Canadian engineers in France has attracted special attention. Little was known abroad of the railroad engineers in Canada. On their arrival, a company of Canadians were assigned to a par-



Track work at the front

A short cut through a deserted French village ticularly difficult piece of railroad construction, and a time far short of ordinary estimates was fixed for completing the work. It was not thought possible that the Canadians could do the work, at least not in anything approaching the time agreed upon. The workmen from oversea were handicapped by an unfamiliar environment. But these men, fresh from a successful struggle with grades in the Canadian Rockies, found the task comparatively simple. The work was completed several days before the expiration of the time allotted them.

Perhaps the most striking feat of the Canadian railroad men has been the transportation of large sections of railroads with their equipment, bodily from Canada to France. The Canadians found that they could spare many of the side-tracks from their railroad systems. To build so much track and equipment would have taken time, and time was a valuable commodity. Miles of track were quickly taken up, carried to the eastern seaports, loaded on shipboard, and carried to France. Within a few days after their arrival the tracks were actually doing invaluable service in putting through troops and ammunition-trains from the seacoast to the front. To borrow a railroad from a neighbor is a unique request, especially when he lives more than three thousand miles over-sea.

All locomotives used near the front are painted a battleship gray, to render them as inconspicuous as possible. The American locomotives now employed in France are not our most powerful type, although far out-classing the European models. A standard locomotive has been selected for this work which weighs 166,400 pounds, or 275,000 pounds with its tender. It is the familiar eight-coupled driver-type, with two-wheeled pony-truck in front, and will haul sixty fully loaded freight-cars.

The biggest order for freight-cars yet received called for 13,000 cars of the flat, gondola, box, and other types. American cars used on French tracks are considerably longer than the French type. The latter has a capacity of twenty tons, while the American car can carry thirty-five tons. They are mounted on two four-wheeled arch-bar trucks, measure thirty-six feet in length, and weigh 32,000 pounds. American engineers have studied the problem carefully and have designed cars for this service that combine the best American and European features. One of the most useful pieces of machinery sent to France is a powerful steam-shovel, mounted on a caterpillar tractor, which is proving invaluable in railroad construction.

The distinguished personnel of the railroad regiments is a guarantee of their high efficiency. America is lending her best talent to the service of France. The organization and development of the railroad regiments is in charge of Mr. Samuel Felton, president of the Chicago Great Western Railroad. In 1916 Mr. Felton was selected to advise the United States Army in the Mexican campaign. American railroad operations in France are in charge of Brigadier-General W. W. Atterbury, one of the operating vice-presidents of the Pennsylvania Railroad system. Prominent in the work are such well-known railroad men as Brigadier-General McKistry and Colonel G. M. Hoffman.

When the history of the American engineering regiments in France comes to be written, one of their achievements, which has hitherto passed uncited, will doubtless take a high place. During the Allied advance at Cambrai, American engineers quickly extended their tracks far behind the enemy's trenches. In the forward rush they suddenly came upon a German railroad that had been left untouched in the panic of retreat. The challenge was instantly accepted by the Americans, who connected their own line with the German system, so that trains could pass from the Allied line to the former German railroad without interruption. Our engineers laid altogether eight miles of track on the heels of the advancing column. By British officers this work has been commended as the most daring piece of construction in the war.

The American railroad men have the credit, therefore, of building the first connecting link in the service between Paris and Berlin since the outbreak of the war, although the schedule of trains remains to be adjusted.

CHAPTER II

DESTRUCTIVE ENGINEERING

IN no other war have such scientific engineering methods been employed in purely destructive work. New standards for ruthlessness have been established. The enemy's engineers have brought technical training and wide experience to the task, and have applied the most ingenious efficiency to the work of devastation. It has been commonly supposed that the methods of the Romans in destroying Carthage had set a perpetual standard; but their work now appears primitive and unscientific.

The destruction of a railroad is an especially difficult problem for the engineers of an invading army. In a familiar picture of the Civil War troops are shown prying rails from the ties, heating and bending them into grotesque shapes. The fighting engineers of a modern army, with the latest tools and experience at their command, could repair such damage in a few hours. To destroy miles of track so that they could not be again utilized would involve enormous labor.

During General Hindenberg's operations in Galicia hundreds of miles of track were destroyed by an entirely new method. Soldiers attached dynamite-cartridges to the fish-plates of the tracks, hundreds of men doing the work at top speed. When the dynamite was exploded, every plate and rail was either shattered or badly bent, thus putting the system entirely out of commission.

When the same engineers had more time to work, their program was varied. The Russian railroads are built with a much wider gage than those in Germany, and the engineers with the armies invading Galicia were quick to profit by it. The ties were taken up and sawed, so that they would barely serve for the German gage of tracks. The roadbed could thus be utilized by the Germans, and on their retreat would be found useless for the purposes of the Russian railroads. The Germans make a practice of destroying all railroad buildings, such as repair-shops, round-houses, train-sheds, and stations.

The destruction of bridges has also become a scientific problem. In the early days of the war bridges were mutilated by the simple expedient of breaking them in the middle. The central span would be dynamited, leaving a gap in the structure, when the work was considered complete. As the invaders retreated, the engineers found little difficulty, however, in patching up these structures, sometimes in a few hours. They would build up a pier,—often with light scaffolding,—and mend the gap so that troops, or even trains, would soon be passing over them. Profiting by these mistakes, the engineers of the invading army thereafter made a much more thorough job of bridges by tearing the frames apart until restoration was impossible.

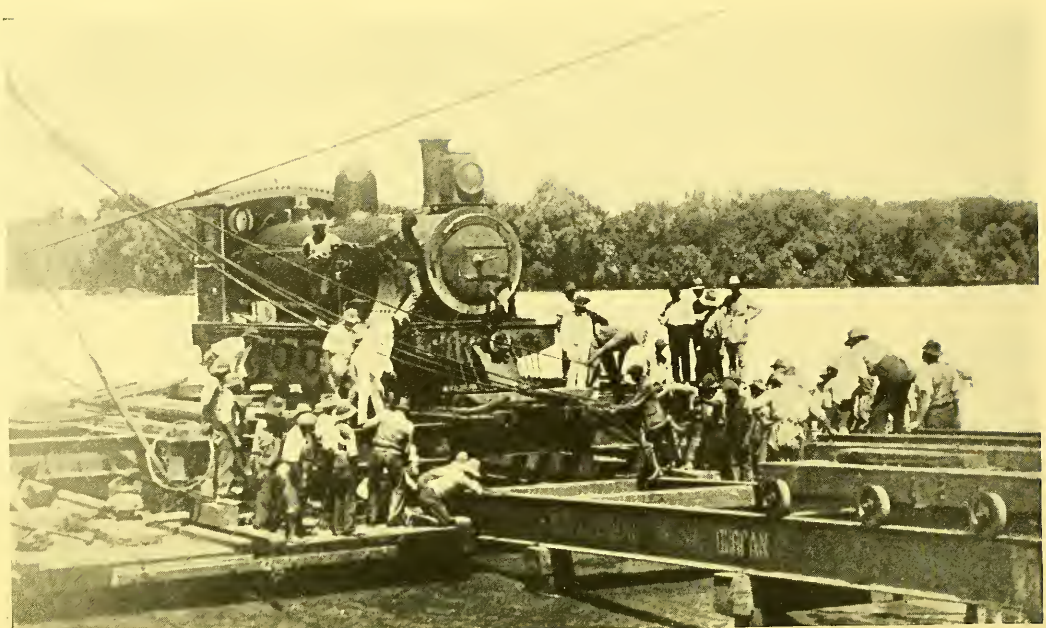
The long tunnels, hewn often from solid rock, offered still another problem to the engineers of destruction. New methods had to be devised. In previous wars armies that have occupied land containing tunnels have respected these works which represent so much labor and which play so important a part in industrial life. In former times the lust for destruction was not so highly developed as at present. German engineers, however, do not content themselves with destroying the tracks or roadbeds of tunnels, but drill deep into the rock and blast away the entrance, until the passages are completely blocked and can only be cleared at great cost of labor and time.

The German engineers have also applied characteristic methods of efficiency in cutting down the forests of Belgium and Northern France and in transporting them to Germany. The most modern type of sawmills and machinery for cutting and hauling logs have been brought from Germany. The logs are stripped of their bark, which is utilized, so that no byproduct shall go to waste. When lumber is needed in any section near the forests, sawmills have been established, in order that the finished products can be prepared without loss of time.

To "spike a gun" has long been an accepted synonym for crippling it. Histories of battles abound in stories of daring men

Narrow gauge construction

Placing a turntable on a narrow gauge railroad



Marine engineering

who have rushed upon an enemy's gun, forced a bayonet into the bore, and thus destroyed its usefulness, perhaps at the cost of their own lives. The great modern pieces of ordnance are proof against such attacks. The old-fashioned cannon of cast-iron or bronze might be reduced to junk by blows of a sledge-hammer or a charge of powder. The strength of a modern gun, however, is proof against such attacks. But the mechanism for loading modern guns and moving them into position is delicate, and the complicated machinery may be put out of commission by a few blows directed with scientific certainty.

The technical methods employed in modern range-finding have been made an excuse for immense destruction. Many great buildings, even whole towns that would have been spared in past wars, have been attacked, because they aided the enemy in directing artillery fire. The success of a shot from one of the great modern cannon is not due so much to the man behind the gun as to the man behind the telescopic sight. By destroying towers, or positions from which such observations may be made, the effectiveness of artillery may often be greatly reduced. A problem new to international law has thus been raised in the present conflict.

It is frequently found necessary to sacrifice valuable property, belonging to loyal citizens, in order to facilitate artillery fire or to gain some purely technical advantage. During the early days of the war, when the German advance through Belgium menaced Paris, a considerable section of the city was marked for destruction, in order to give free range for the great batteries brought up for its defense. Besides, in the event of the enemy's advance to this point, the buildings would afford valuable shelter. Here was a problem for the technical engineer. A large force of men was engaged in this work, and rows of buildings were scientifically demolished. Explosions of the blasts used to reduce them were distinctly heard on the inner boulevards of Paris.

A special tribute should be paid to the Frenchman who cheerfully sacrificed his château in Northern France, so as to assist the artillery fire of a French battery. The ancient building, surrounded by gardens, was shown to be in the way. The owner at once agreed to make the sacrifice; and he calmly watched the French guns reduce his ancestral home to ruins.

A striking parallel might be drawn between the methods employed by the Romans in devastating Carthage and those employed by the invaders of modern France. The scientific destruction of this rich, fertile country has been complete in every detail. When the enemy's forces retreat, nothing is left that the returning population may utilize in restoring their land to normal conditions. The homes in villages, for example, are reduced to piles of debris. Trained engineers first inspect the ground and determine how dynamite may be exploded to reduce the walls with the least possible waste of energy. Bridges are damaged beyond hope of repair by men skilled in bridge construction; roadways are ploughed up; shell-fire has pitted much of this country with craters, while the intricate systems of trenches have chopped up the once fertile fields.

Engineers who have visited these scientifically devastated regions differ widely as to the length of time necessary to bring this land back to its original condition. Some have thought that a generation would be required, while others have been more hopeful. Meanwhile the problem of restoration has been attacked with an engineering skill and efficiency equal to that of the invaders. Portable cottages are built wholesale. They are then taken apart, to be set up with all possible despatch when the opportunity comes to reoccupy the relinquished territory. An army of workers has been recruited for this work for which much of the service is volunteered.

In Northern France many of the roads that were the pride of the country have been found hopelessly mutilated by the enemy's engineers. The work has evidently been done by experts in road engineering, so that it would be easier to build a road in a new land than to attempt to mend these old roadways. To work such destruction by hand would require an immense expenditure of time and labor; so, with characteristic efficiency, massive power-machines have been employed by the enemy, machines that tear up the roadbed and scatter it, while keeping up a slow but steady pace.

The work of directing the water-courses and flooding the country whenever possible has evidently been carried out by expert hydraulic engineers. A dam is thrown across a stream, and, when necessary, the water is even siphoned to a new level. Great tracts of land are thus placed under water, and these tracts have to be drained at great expense before the territory can be reclaimed. These engineers often show great ingenuity in diverting the streams in such a way that sand will be washed over the fertile soil, thus rendering it useless to the farmers for a long period to come.

Since France is covered with an intricate network of canals, the enemy's engineers have found an unusual opportunity for scientific destruction. In time of peace a great fleet of canal-boats can navigate from one end of France to the other. The destruction of these waterways will cripple the interior commerce of France for years to come. A favorite method of the invaders is to construct dams across the canals and so flood the surrounding country. In other places great sections of the banks are torn away by exploding mines, so that when the country is reoccupied by the French the waterways cannot be used without rebuilding them.

One of the most wanton tricks of the retreating Germans is to leave a watch hanging in plain view in a deserted home. The watch is electrically connected with a mine, so that the first person who touches it is probably instantly killed in the explosion that follows. No possible military advantage is gained by this practice.

The condition of these reoccupied cities has been vividly pictured by a member of the 11th Engineers in a recent letter from the front. He writes:

> Visited a large French city the other day, which the Germans occupied, but which was later recaptured by the French. No human being could imagine the destruction that has been wrought there. Among the thousands of houses, there is not a single one that could be lived in. Most of them are beaten to dust, churches and everything else.

CHAPTER III

THE ROAD AND QUARRY REGIMENTS

FRANCE, in proportion to its area, has an immense mileage of roads, which naturally play a vital part in military operations. In many sections of that country there is an average of one mile of road to every one and a half square miles of land. Enormous labor is involved in keeping these roads open for war traffic, and American engineers have tackled this problem with characteristic vigor.

The Road Building and Quarry Regiment, which was organized especially for such work, contains engineers experienced in road building under a great variety of conditions. The regiment carried to France a large constructive plant, with much labor-saving machinery, new to Europe, to facilitate the work.

These American engineers first made an

exhaustive study of the resources of the French quarries. Two men were selected to investigate. One was formerly prominent in the quarry business on the Pacific Coast, and the other was formerly the representative of a large machinery manufacturing company. In their tour of inspection they covered nine hundred miles by automobile, visiting the principal quarries of France. The data thus gathered made it possible to accurately gage the resources of the quarries and at the same time to suggest what machinery would be required.

It was found that the French method of quarrying calls for little use of the modern mechanical equipment common in America. According to American standards of efficiency there is an immense loss, due to the general use of hand-labor. It is impossible at present to find the proper mechanical equipment in France, and such machinery will have to be imported from America.

To begin with, most of the drilling in the French quarries is done laboriously by hand. The rate of drilling is said to be only from one to one and a half meters per man a day.

The drill-holes are usually about eight feet in depth. As a rule, the rock encountered is a soft limestone, with layers of clay. When the American steam-driven jackhammer-drills get to work, the output will doubtless be enormously increased.

After a blast the rock is usually broken by hand. The hammer used for this work is small, and the handle has been compared by Americans to a light cane. The stone-crushers used in some quarries are small and ineffective, compared with the American machines. Great improvement is also possible in the use of power in driving these machines. The cars used for carrying stone are usually loaded by hand. The plans of the engineers of the Quarry Regiment include the general use of modern American stone-drilling and stone-crushing machinery, new methods of handling and storing the stone, and greater efficiency in loading the cars.

One of the first problems in such construction is to build roads as free as possible from dust, since the dust-clouds quickly attract the enemy's fire. The slow, laborious work of road-construction must often be carried on very close to the front, and the casualty rate is high. The problem is rendered extremely difficult by the unprecedented burdens the modern military road must support. It is often impossible, moreover, to get the best materials for road-building, and ingenious shifts must be employed. Again, ordinary road-building machinery cannot be employed near the front. A puff of smoke from a steam-roller, or the steam from its exhaust, is likely to attract a devastating fire from some German battery.

It was soon found that the limestone used in France for road-making was so soft that it clogged the American stone-crushers; but this was obviated by designing a special jaw for crushing it. American engineers have learned to like the soft limestone, since it compacts easily and thus facilitates the work. The familiar macadam road is found to stand up best under the enormous strain of war traffic, but even the best roadbed requires constant mending. It has been difficult to find the trap-rock commonly used in America, but in the vicinity of the industrial centers there is abundance of slag. The road-builders are constantly experimenting with new materials and new constructive methods, and this war experience is proving invaluable.

A large force of American engineers and workmen has set to work to widen the French roads. These men find the main roads sufficiently wide, but many of the roadways are only eighteen feet in width, and these are to be increased to thirty-four feet. An immense amount of labor is, of course, involved in this work.

The existing drainage-system must be readjusted, bridges must be widened, and scores of such problems solved, without interrupting traffic for an hour. The main military roads must be constructed with all the skill known to such engineering. A weight of thirty tons is commonly carried on a four-foot wheel-base, while eighteen tons of artillery are often supported by a single axle. The tanks are kept off the roads as much as possible, and when they have to be used a road-mending crew always follows to repair the resulting damage. The weight of the tanks also worries the builders of wooden bridges.

The regulation of road-traffic on crowded thoroughfares is always difficult; but the problem is immensely complicated near the front. A greater number of motors often pass a given point near the front than are to be seen on Broadway or Fifth Avenue during the rush hours. Accidents are common, but the road must be kept clear at all costs. This dense stream of traffic must also be hurried forward at night, without slackening its pace and practically without lights, lest they attract the enemy's attention.

War traffic is regulated by military "traffic cops," stationed at regular intervals. By day the traffic men signal with three flags,—red, green, and white,—and by night they use small lanterns of the same colors. The white signal, day or night, means "all clear," the green signal is to slow down traffic, and the red is to bring all traffic to a stop. When artillery or infantry wishes to pass, the road is completely cleared for them without a moment's delay.

It is so important that all lights be con-

The highway regiment at work

French Official Photograph

Ruthless destruction of shade trees

cealed at night that the immense traffic is compelled to find its way in the dark. To keep this traffic on the straight way a series of whitewashed pickets are driven at intervals of ten feet along the roadside. One of the favorite diversions of the German airmen is to locate a crowded military roadway and, flying low, to rake the line of ammunition-trucks with their machine-guns, in the hope of causing an explosion.

As the road-builders approach the front, their work becomes increasingly difficult. The ground is often a succession of shell-craters, where no ordinary road could be built without an immense amount of grading; and neither time or money can be spared for such work. In such cases they build a very serviceable plank road. The timbers for this road are prepared of a standard size, measuring five by nine inches, with a length of nine feet. The lumber is adjusted to the irregularities of the land, the planks are spiked firmly together. This plank road is quickly laid and serves very well for one-way traffic.

The Road-Building Regiment has also

performed invaluable service in constructing miles of foot-bridges throughout the devastated regions of Northern France and Belgium. Great tracts of country have been so cut up by shell-craters or abandoned trenches as to be practically impassable.

The Americans have introduced a type of foot-bridge familiar in marshy tracts in the United States, by driving stakes into the ground and constructing a narrow board-walk a foot or more above the ground or water, as the case may be. Its construction is simple and inexpensive, and it clears the way for the passage of light wheelbarrows, small wagons, and foot-traffic.

Volumes might be filled with descriptions of the engagements of the road-builders. For instance, it is the boast of the men of the Road-Building Regiment that when they had been enlisted but seven months they had seen four months' service at the front.

The following quotation from a letter from one of the officers gives an excellent picture of their work. He writes:

The day after Thanksgiving we left camp at six o'clock. We were running parallel with the front line and about one mile and one half from it.

There was very heavy shelling,—in fact, quite a barrage was breaking just over the hill between us and the front line; but, as we had been more or less under shell-fire during the past weeks, we did not think it was anything unusual. We had just set nicely to work, spread along nearly a half-mile, when the barrage lifted over the hill. We had to get out then as quickly as we could, although we had not yet any idea that the Boche was coming over.

Lieutenant Holstrom had to go through the barrage to reach his detail. Lieutenant Cone went in one direction and I went in the other, to get all the men away. In fact, we did get every man away who was in sight; but a number of men had jumped into dugouts for shelter from the shell-fire, and we could not see them.

When I had brought every man away from my vicinity, I started across a field, hurrying the men ahead of me to a sunken road several hundred yards away. Cone was one hundred yards to my left and slightly in the rear, hurrying along the men he had gone for. We were all just ahead of the barrage.

When I reached the sunken road I got the men into dugouts there, and looked back over the edge of the road. There was Cone coming along, with his head, face, neck,—everything,—covered with blood. He had been caught by a shell-burst ahead of the main barrage, and the shell-bursts of the barrage were now getting thick about him and over the sunken road. I hurried out and helped him in, with two of his men who had come in with him. The shell-fragment had gone in one side of his steel hat and out the other, giving him a bad scalp-wound on top of his head, but not injuring the skull.

He said that Sergeant Haley was out there, and that he had been hit at the same time. I went out and found Haley, with Sergeant Donald McIsaac and two British Tommies, in the midst of the barrage. We picked him up and carried him to the sunken road. McIsaac and I then returned for a Tommy, who we had been told was wounded out there in the barrage. We could not find him, and as the Boche was then coming over the hill, we returned to the sunken road and got the men out of the dugouts and started them back to safety.

As the shell-fire stopped, it seemed as if hundreds of Hun aëroplanes filled the air and turned their machine-guns on us while we were crossing the field or were on the roads. They were flying so low that we could see every detail. If we had only had our arms—! Never again!

The shortest man in the regiment is a little Second Lieutenant (one of those who has been promoted) who was struck in the head with a bullet that went clean through both sides of his steel helmet and chipped the upper edge of his forehead on the way. If he had been one quarter of an inch taller, it would have finished him. A story has reached us through the Tommies that one of our men was found dead in the field from bayonet-wounds; but he had three Germans in front of him, killed by the railroad pick he had wielded valiantly.

CHAPTER IV

FOREST AND FARM REGIMENTS

IN recruiting the Forestry Regiment only men having technical training or actual experience in forestry work were chosen. The foresters are in charge of two regular army officers, and this body includes fifteen foresters selected from the United States Forestry Service, two from the Forestry Branch of British Columbia, one lumberman from the Indian Forestry Service, and thirteen foresters, or skilled lumbermen, taken from civil life. One thousand skilled woodsmen complete the regiment, which is divided into six companies of 164 each. No more vigorous and fearless body of fighting engineers could be found than this regiment of brawny lumberjacks, seasoned by exposure in many winter camps.

The foresters were among the first Americans to enter war service. As early as June, 1917, a sawmill unit, composed of 360 men, was recruited in New England, completely equipped with portable sawmills, and hurried abroad. The machinery and supplies were sufficient to make the unit self-sustaining for one year. The unit has since been at work cutting lumber in Scotland for use in France. Timber-land on Andrew Carnegie's estate at Skibo Castle, or in the vicinity, contains about 15,000,000 feet of lumber.

The lumbermen assigned to France were first assigned to two training camps,—at Washington and at Fort Leavenworth, Kansas,—where they were uniformed and armed like other units of the United States Army. The camp experience was intended to train these independent types of workmen in military discipline and accustom them to teamwork. In this way a mobile body of workers has been formed to carry on the work of logging and milling in France and to solve many problems in intensive forestry.

Never, perhaps, has a more difficult problem confronted America's woodsmen; for the forests in many parts of France have been destroyed with malicious, scientific skill.

The American Forestry Regiment fights with weapons of characteristic power and ingenuity. Their equipment includes five complete, large, mobile, steam-driven sawmills, which have been transported across the Atlantic and hurried to the devastated sections of Northern France. Each of these sawmills can turn out 20,000 board feet of lumber every ten hours. By working the mills in two shifts, each of these mills has turned out 40,000 feet of lumber a day, while the total daily output of the combined units is 200,000 feet.

This regiment also carried to France five smaller and more portable sawmills which might be drawn by either a motor or four horses, thus saving much valuable time. The smaller mills, have an output of from 8000 to 10,000 feet of lumber, or a combined output of 50,000 feet every ten hours. A number of horses were carried along to be used in logging work, so that the Forestry Regiment suppled both the machinery and the power required.

The problem of transportation was anticipated by carrying to France twenty-five miles of light steel rails for the construction of a railroad to carry lumber and finished products from the forests to the front. The scientific ruthlessness of the Germans is thus matched against an unexpected unit of efficiency from overseas.

The hum of these American sawmills has sounded a new and welcome note in the forests of France. Once safely landed on the Continent, our men and machinery were quickly transported to the forest lands. With a skill born of long experience in American forests, the trees were felled and transformed into the finished products so anxiously awaited.

It is estimated that about 25,000,000 feet of lumber is needed monthly to supply the armies and carry on the war. For this supply the Allies must depend mainly on the forests of France. American forestry experts report that the French forests consist of pine, fir, oak, beech, and other hard woods. The timber is smaller than the American lumberjacks are accustomed to, and the forests resemble the wood-lots of southern New England. The logs are sawed into boards and dimension material; the smaller trees are hewn into ties, poles, etc. Nothing is wasted. One of the most valuable products of the forests is charcoal. The soldiers in the trenches warm themselves by burning charcoal in small braziers, since the smoke from wood-fires would attract the attention of the enemy. Timber is selected and cut with the greatest care, so that the forests may be left in good condition for further production.

In following the fortunes of our forestry workers in France, it should be kept in mind that the men are serving in two regiments, known as the Tenth Engineers and the Twentieth Engineers. The former regiment, comprising about 3000 men, has been serving in France for several months at this writing. The latter regiment, whose full strength will be 7740 men, is now being recruited and trained for immediate service. It includes ten battalions, each commanded by a major, with the usual number of captains and lieutenants. Of these officers, fifty per cent. are men who have had practical forestry experience, while twenty-five per cent. have had regular military training. The forestry regiments are representative, having been recruited from fourteen districts in widely separated sections of the country. A good idea of the versatility of the forestry regiments may be gained from the list of workmen. This includes skilled axmen, wood-sawyers, crosscut-saw-filers, tie-hewers, skidders, teamsters, wheelwrights, blacksmiths, mill-sawyers, circular-saw-filers, expert mill-hands, carpenters, machinists, and charcoal-burners. All the men are enlisted for the period of the war.

The vital need of lumber to construct railroads was soon relieved by an output of millions of railroad ties. Several of these mills have been worked overtime at full speed, especially in the winter months, to supply cordwood for fires to warm the troops in camp. The trenches have drawn freely upon this supply.

In rebuilding cities and villages throughout Northern France our American sawed lumber has proved invaluable. Entire villages have been rebuilt with such material within a few days after their evacuation by the Germans. Much of this work has been standardized. Roofs have been constructed by the thousand, and these may be quickly placed on the walls of houses that have been left standing. Houses are built wholesale, taken apart, and transported to the devastated districts, to be set up in an incredibly short time. The advance of this American regiment into the forests of France will be remembered as one of the great achievements of the war.

In building barracks and hospitals by the acre for our soldiers in France an unsurmountable difficulty seemed to face American engineers. France was already badly in need of lumber, and the extensive barracks required for the shelter of a million or more men made a serious demand upon her resources. The American Forestry Regiment was turned loose on the work. The French Government assigned to their use extensive forest lands in France, and the regiment, with their battery of sawmills, advanced on the double-quick. By working these perambulating sawmills double-time, hundreds of thousands of feet of lumber of the desired

The invaders despoiling a French front

Amputation after a gunshot wound

shape and size were turned out daily, and the great barracks rose as if by magic.

The experience and energy of American foresters have in the same way worked marvels in restoring the mutilated forests of France. A tree that has been badly damaged by gun-fire, for instance, may often be nursed back to life. The modern tree-surgeon works astounding cures. His skill in saving trees damaged by wind-storms or in prolonging the life of historic trees is well known at home. The shattered limbs are pruned with a skilful hand, or parts are removed and the cavities filled with the cement. Serious wounds are thus healed, while old trees are rejuvenated and their lives prolonged indefinitely. By the application of these modern methods of intensive forestry, thousands of trees have already been restored in France.

In the regions seemingly devastated beyond hope by the invaders the work of reforestry was quickly begun. The method is familiar in many sections of the United States. Trees are grown from seeds sown in hotbeds; and these seeds sprout like grass.

The tiny sprouts are separated and transplanted, and on reaching a height of a few inches, are set out in specially prepared soil throughout the regions to be reforested. A bed of small trees a few feet in extent will some day spread out to cover great areas of land. To save time, small trees are imported, and a small package may contain trees that will some day reclothe mountains and valleys. The Forestry Regiment has not waited for the end of the war, but pushes forward as quickly as the Germans retreat.

One of the most cruel outrages visited upon the invaded country by its plunderers has been the destruction of fruit-trees. The practice is forbidden by international law, and even in Biblical times and during the Roman conquests invaders spared such trees. Great orchards in Northern France have been ruthlessly and senselessly cut down, being left, so it was supposed, to die on the ground.

Among the first to reach this devastated land have been the tree-surgeons. These men represent a branch of technical engineering that the Germans had overlooked.

By these specialists the cross-sections of the trees are treated and joined, and the trunks are bandaged and fastened together by means of splints. A convalescent period follows, when the soil is renewed and the withered branches are pruned away. The French soil responds quickly to the touch of a friendly hand, and many thousands of these trees have blossomed again.

No plan in the complicated problem of restoring these devastated areas has been neglected. The regiments of American engineers have included a number of agricultural experts, who have made minute surveys of the farm-lands. On the retreat of the enemy, these once fertile fields are often found in an appalling condition. For instance, it is impossible to imagine more hopeless fields than the region known as "no-man's-land." There the earth has literally been torn to pieces by the explosion of the most deadly shells ever devised. The crater-holes are sometimes twenty feet deep, with an even greater diameter. The heat from these countless explosions and the poisonous gases have seared the ground, killing vegetation.

Besides, thousands of the shells have buried themselves in the earth without exploding, and the farmers are in constant fear that a chance blow from a plough or rake will set them off.

Our engineers have collected various types of such shells and made careful tests. They have found that a shell whose detonator has not gone off after traveling five or ten miles through the air is practically harmless. Tests, made by striking them with bars of iron, showed that the farmer's danger is extremely slight. It was found, on taking such shells apart and analysing their mechanism and chemical contents, that after they have been buried in damp earth for a few months it was practcially impossible to explode them. Therefore the farmer may safely pick up these old shells as if they were so many stones and throw them to one side, or plough them under. The examinations of the American experts have done much to reassure the French farmers.

It was feared that the terrific force of repeated explosions had destroyed the rich topsoil and would render this once fertile land barren for a generation to come. To the eye of the layman the appearance of this land is appalling. An American expert on the chemical qualities of various soils, who has studied these regions, has made a fortunate discovery. He finds that, while the non-humus-bearing, or lower, soil has been thrown up in great quantity by the explosions, the effect is likely to have a beneficial result. The explosions have served to loosen this lower strata, similar to the result accomplished in America when farmers dynamite the hard-pan, so that roots may reach the lower strata with its heavier moisture. This expert points out that, for every pound of this subsoil that has been disturbed, a much larger quantity of the topsoil, which is rich in vegetable matter, has been widely scattered over the surface. Earth disturbed by a shell-explosion takes the form of an inverted cone, and it is the base or frustrum of this cone that is sifted about.

After this amazing upheaval the surface soil is believed to be far richer than it was before, and thus will yield better crops for many years to come. American observers have found flowers growing in such soil,—scattered clumps of petunias, nasturtiums, and snapdragons, the seeds of which had survived many explosions and had doubtless been turned over many times. Often in the most hopeless-looking soil patches of corn, barley, oats, and Indian corn have sprouted, the seeds of which must have been thrown high in the air by repeated explosions. Both the flowers and the grain are stronger and more vigorous than those grown in the original soil, even when richly manured.

The fear that the effect on vegetation of poisonous gases from exploding shells will continue for many years appears to be groundless. Investigation by experts has shown that the fumes bleach the grass and shrubbery, so that it wilts and lies upon the ground, but that the roots are rarely injured and after a few days or weeks will begin to sprout again. Within a month the most rugged shell-holes are usually covered with a heavy, rank vegetation of surprising variety. A few months after the most violent battles the fields and crops are found to be the richest ever seen on French soil.

The battle-fields are often covered with litter that can only be removed by great labor. The barbed wire from the entanglements is easily picked up, while much of it may be ploughed into the soil. The debris includes pieces of railroad iron, sheets of corrugated iron, used for roofing or lining the trenches, pieces of concrete, and many heavy objects,—all of which must be laboriously collected and carted off, much as the farmers at home clear up a stony field.

The problem of leveling the fields and making them ready for the plough and harrow has also been carefully studied by American engineers. To "clean up" the rugged surface of a country, broken by innumerable shell-craters, of course involves enormous labor. Nature has, however, already commenced to lend a hand in the work. An ordinary shell-hole is filled up at the rate of a foot or more a year, merely by the dust blown into it and the silt deposited by the rain. The great shell-crater at Pozières, for instance, was in one year filled to a depth of many feet by the action of wind, snow, and rain.

Ordinary farm-tractors would prove useless on such land. It is even found extremely difficult to draw scrapers and shovels over these holes. A very happy idea has been conceived to solve this unprecedented problem. After the war, the engineers point out, there will be thousands of tanks in France without any fighting to occupy them. The ingenious caterpillar tractors, with their great driving force, are ideal tools to crawl over the most rugged country and drag after them leveling shovels, ploughs, and harrows. General Grant's famous order to let the soldiers keep their horses to use on the fields may be repeated by turning over these great fleets of tractors to the farmers of France.

Let the Germans retreat, surrendering any sector of French fields, and the engineers and toilers of the soil are found in instant readiness to advance. When the enemy swept over this fertile country the peasants were always among the last to retreat. They had been accustomed for centuries to plough a certain furrow, and continued to do so undisturbed, even when they found themselves under fire. French troops often had to use

A man power pile driver

French Official Photograph

Railroad devastation

force to persuade the farmers to abandon their land, when the rich fields had to be transformed into trenches.

Once these fields have been freed from the invader, the rural population sweeps back. In an incredible short time the scars of war begin to disappear. The government engineers lend all possible assistance in restoring farm-machinery or replacing it. If the home and the farm-buildings have been destroyed, which is a common occurrence, they rebuild them,—in part at least,—or a temporary wooden building, manufactured wholesale, is rushed to the place.

American observers in this region are amazed at the thrift and adaptability of the French. An American family under similar conditions would require continued assistance before it became independent. Give a French family a shelter, a pair of rabbits, a few chickens, and some food, and it is soon self-supporting. Upon so firm a foundation rests the future of Northern France.

Engineers have been organized for this herculean work of restoration. Every need of the farmer resident of this restored region is studied with intelligent sympathy. Roads are quickly rebuilt; bridges of every form are repaired, or new structures brought to replace the old ones; canals are rebuilt, and streams are turned back to their ancient courses. In a single year these wastes have been made to yield valuable crops.

CHAPTER V

ARMS AND THE AUTOMOBILE

THROUGHOUT the United States to-day the automobile industry displays "service flags" liberally sprinkled with stars. No class of America's fighting engineers was more prompt to reach the war zone, and none has continued to recruit men more freely. Early in the war thousands of Americans volunteered to drive ambulances, motor-trucks, and automobiles of every type, and their skill and daring became familiar to the French, British, and Italian armies.

On America's entrance into the war the motor industries were quickly mobilized, and their wealth of experience in constructive work was placed at the disposal of our Government. It is not generally realized, perhaps, that the United States, with its 4,250,000 motor-vehicles of all types, has about four times as many cars as all the rest of the world. Considering the vital importance of the automobile in war-engineering, the weight of these resources is certain to prove a vital factor in winning the war. Since 1914 the United States has supplied the Allies with more than 50,000 motor-trucks, together with an army of men to run them.

Since many of the officials of the leading motor manufacturing companies have volunteered and received commissions, the best engineering talent of the country is to-day in the service of our Government. Twenty-five representatives of our leading automobile manufacturers are in France, administering the motor-service. A single organization—the Motor-Truck Club of America—has recruited 2000 chauffeurs, of whom 1400 have been mustered in. At the request of the Government, training schools have been established for transport-officers and men. All kinds of workers in the automobile industry are being specially trained, in order that this great power may be directed efficiently.

No other service of our fighting engineers has been recruited in such force. For every twenty-one men America will have under arms, she will furnish two motor-vehicles. An army of 1,000,000 soldiers will be supplied with 95,000 automobiles of a bewildering variety of types. The greatest mobilization of motor-vehicles heretofore was at Verdun, where the cars, if placed fifteen feet apart, would have extended more than six hundred miles. Even France, however, could only find one motor for every fifty men in her armies. The English army has managed to keep its front supplied with food and other necessities by employing one car for every sixty-six men.

As late as the spring of 1916, when General Pershing was ordered to Mexico, the army was absurdly unprepared as to its motor equipment. Great difficulty was experienced in finding a score or more of motor-trucks adapted to the carrying of supplies to the army. In a period of less than two years the United States Army has become the best motorized army in the world. Until the Mexican trouble the motor was not popular in the army. It is a great tribute to American ingenuity and energy that in this brief period so many new types of cars, suited to every service should have been designed and manufactured at a rate unprecedented in history. During the present year the United States will turn out 2,000,000 passenger-cars and 200,000 motor-trucks.

Among the invaluable services automobiles of every type have rendered throughout the war, three great achievements, at least, will go down in history. The rapid advance of the German forces through Belgium would have been impossible without the support of motors. The transportation of men, ammunition, and food was accelerated beyond all precedent, to the bewilderment of the Allies. Such an advance gave their opponents little time to mobilize, and Belgium was overrun before the French army could be brought up or England's expeditionary force could cross the Channel.

But the French were quick to turn this same weapon against the invaders. Years of preparation had given the Germans great fleets of motor-trucks, which now stood ready to advance at a moment's notice. Within a few hours France had learned its lesson, and when General von Kluck's army threatened Paris it was the automobile that saved the capital.

The French army did not possess motors in sufficient numbers, and Paris was drawn upon with feverish haste. The smooth, level roads running out of Paris proved invaluable. Every form of car was pressed into service. Unbroken streams of automobile traffic were soon set in motion. Motor-trucks, taxicabs, auto-busses, and every form of private car were loaded with soldiers. The men filled the bodies, lay upon the roofs, and clung to the running-boards as the cars dashed forward. So great a force had never before been transported over open country at such a pace. But Paris was saved!

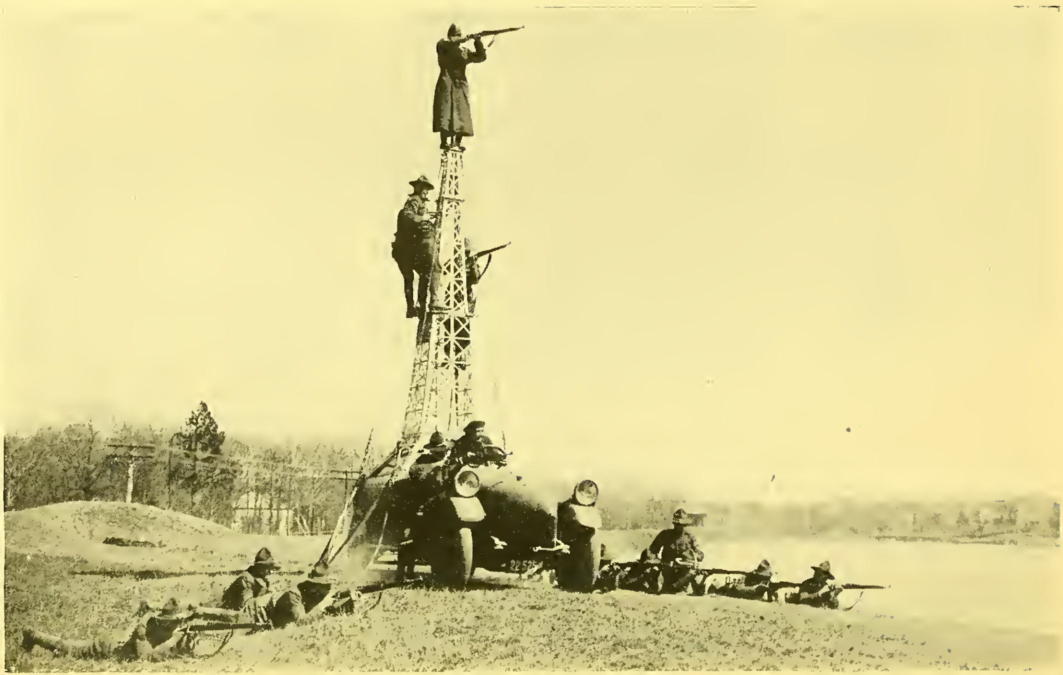
Later, when the enemy concentrated his forces at Verdun, the motor proved the force behind the front that held the line firm. So great a mobilization of motors had never before occurred in history. It is estimated that the ammunition carried by a standard auto-truck will supply one of the French guns for ten minutes. This army of motors moved in an endless stream over the famous

Vergennes loop. On many of the roadways near the front the congestion of automobiles exceeded that on great American thoroughfares,—even that on Fifth Avenue during the rush hours. As the traffic converged at the front, the stream of vehicles knew no interruption through the twenty-four hours.

The rapid evolution of the war automobile was unforeseen. Twenty years had been required to develop the early types of "horseless carriage" to the present models, but the necessities of war demanded quicker action. It is estimated that to-day there are over 100,000 automobiles of various types on the Allies' side of the trenches.

A highly-specialized form of automobile is demanded for war. At first the ordinary type of commercial truck was employed; but under new and untried conditions it proved inefficient. The war truck must be light, yet capable of hauling a trailer and of operating over rough roads. The five-ton truck of commerce answered no better than the originally designed two-ton truck, and a compromise was finally struck by building a three-and-a-half-ton truck.

A trench digger in action



One of our 100,000 war motors

Even to the experienced motorist the results of countless experiments in developing a standard type will come as a surprise. It has been found that four cylinders serve better than six. To get the best staying power out of a loaded car on an eight per cent. gradient, new gears and systems of piston-displacement had to be worked out. The chain-drive is replaced by the worm-drive. Gasoline is the only fuel that will stand up under the strain. On poor roadways a driver cannot hope to get more than 1500 miles out of his tires, and often it is only 200 miles. A hundred details of construction have been changed, reversing the familiar experience of experts in less troublous times.

Early in the war, as the armies began "to dig themselves in," French engineers looked about for labor-saving devices for trench-digging. The problem presented was unprecedented. Thousands of miles of trenches had to be dug; and time was priceless. If the work were done by hand, as in the early stages of the war, a great force of soldiers must be thus employed who were badly needed for fighting. It was at length decided to intrust the problem to American ingenuity.

Thereupon several manufacturers of machinery in the United States were invited to study the problem and devise a new type of ditch-digger, suitable for military work. The trench-digger constructed in America and rushed to the front proved to be one of the most dependable engines of the Great War, and it has released many thousands of soldiers for more active service.

The operation of this trench-digger is as follows: Upon the heavy motor-truck chassis, so familiar in the United States, is mounted an ingenious bucket-excavator of the continuous-belt type. The buckets, carried steadily forward by the belt, scoop up the earth at a surprising rate, and carry it up to chutes which dump it to one side of the machine. The machinery is so powerful that it will attack any soil however hard and rocky. The belt, with its train of buckets, may be quickly adjusted to any angle. By merely shifting a lever the power is supplied by the motor of the automobile. An engine of 100 horse-power has been found sufficient to drive the machine at a rapid pace, and to operate the digging apparatus in the toughest soils. Each digger, manned by a crew of only five men and a chauffeur, readily does the work of one hundred soldiers armed with the primitive pick and shovel. Each battery of ten diggers, therefore, releases a regiment of men.

A fleet of trench-diggers is probably the most mobile unit among all the constructive machinery employed in the Great War. These machines are held in instant readiness for any movement, like so many fire engines. The crews sleep beside their machines, ready to spring to their places and rush their engines to any part of the field. Let the enemy retreat or advance, so that a new line of trenches is required, and the trench-diggers are rushed to the point as quickly as our firemen respond with their engines and ladders. The digging machinery is set in rapid motion. While the troops a few feet away may be checking the enemy's advance, a trench is scooped out of the earth, and thus by the aid of this shelter the day is saved.

It is estimated that if all the trenches dug in the present war were straightened out and placed end to end, they would more than circle the earth. It would have been impossible without the trench-diggers to dig 25,000 miles of trenches of the modern type. Much of the work, of course, is carried on well behind the firing-line. As the trench is cut out, workmen strengthen the sides with boards, limbs of trees, or metal plates. Grooved steel plates, about ten inches in width and six feet in height, are often employed. These may be slipped into place and securely locked without the use of screws or hammers.

Another characteristic American invention is a searchlight mounted on a collapsible tower and carried by a fast motor-truck. It resembles the familiar water-tower of our fire departments. The searchlight is of the powerful type used in the navy. When under fire, or when traversing rough country, the tower is folded back, so that the car is no more exposed than is an ordinary automobile. The electricity for the lamp is generated by the automobile-engine.

The searchlight may be rushed to any

point to which an automobile can penetrate, and the light may be raised to its maximum height as quickly as our tower-hose is brought into action. Its powerful rays will illuminate an object many miles distant, thus revealing the activities of the enemy when he least expects it. Again, from its elevated position it will light up a large tract of land, turning night into day. The first of these American searchlights accompanied the First Regiment of United States Engineers.

Among countless types of specialized automobiles for war use now built in America are a number of trucks equipped to repair shoes. These are manned by crews of expert shoemakers and carry the latest shoemaking machinery. The waste of shoes at the front is enormous. After a battle discarded shoes are picked up by the thousands, and the perambulating cobblers set to work. No shoe is so badly worn that some part of it cannot be utilized. When the leather is stiff it is soaked in chemical baths until pliable, after which it is scraped and patched. Even when a shoe is hopelessly worn out, some part of it may be cut away and used again. Thus nothing is wasted. A single shoe-repairing unit will sometimes turn out two thousand shoes in a day.

Were it left to a popular vote, the favorite unit of equipment carried by our engineering regiments to France would doubtless prove to be the motor-kitchen. The perambulating kitchen,—which is really a marvel of completeness,—is mounted on a powerful motor-truck, and may be rushed along ordinary roads at a forty-mile pace if occasion should demand.

The kitchen has three main compartments: a refrigerator at the front, a storage place for perishable foods amidships, and a large three-open range at the rear. On this range four large kettles or pots may be heated at a time. Overhead, an ingenious system of derricks and block-and-tackle devices enables the cook to move his cooking-utensils about with ease.

In no branch of the service is the motor-vehicle so indispensable as in the Ordnance Corps. Trucks to carry ammunition and tractors to haul the big guns have been constructed for this corps on a lavish scale. It is estimated that the Ordance Department will have in all about 60,000 motor-vehicles, and of these fully 10,0000 will be tractors. A three-ton truck, which seems so efficient in our city streets, will carry enough ammunition to supply one of our ten-inch howitzers for about ten minutes. It is obvious that an unbroken line of motor-vehicles must span the spaces between the supply-bases and the great batteries, if the artillery fire is to be continuous. The Quartermasters' Department will have about half as many trucks as the Ordnance Department.

No engine of warfare has undergone so complete a transformation in so short a period of time as the "land-ships," or tanks. The armored automobile, from which tanks have been evolved, had appeared in several forms before the war, but no great conquest was hoped for it. In the construction of the primitive machine a conventional chassis was employed, and the more vulnerable parts were protected with light armor-plate. A light field-gun was sometimes mounted on it. In no sense, however, was it a fort, being designed to carry despatches or to convoy troop-trains in exposed territory. During the early stages of the war in Belgium such cars were used with good effect in small frays, in attacking enemy outposts, and in surprise attacks preparatory to a general advance.

As the great armies settled down to trench-warfare all roads in the vicinity of no-man's-land disappeared, and even the lightest cars found the open country impossible. The usefulness of the armored automobile seemed at an end. The tanks, which are perhaps the most sensational achievement of the fighting engineers, came as a complete surprise. In their present form these tanks are virtually perambulating forts whose defenses are proof against any ordinary attack that field-troops can direct against them.

To the enemy, the most baffling feature of the tank is its ability to move at will over land that would be impassable for ordinary vehicles. The gaping shell-craters and furrows of these areas, though cut wide and deep, are, nevertheless, readily surmounted by the new engine of war. The tank is

German efficiency in bridge obstruction

An example of German bridge building

mounted on endless corduroy belts, and is steered by large flange-wheels at the rear. In passing over the roughest land the tank maintains a speed of 1000 yards an hour, or something more than a half-mile. When the first of these tanks appeared in America, taking part in a military parade on Fifth Avenue, it moved over the paved street at the speed of an ordinary pedestrian and with surprising smoothness.

The British land-ships are of two forms, known as the "male" and "female" tanks. The male, which is the more formidable, has sponsors built on either side, in which six-pound guns are mounted behind movable shields. The sponsors are sometimes built with five sides, so that the guns may be swung in a wide arc, covering the ground at the sides, and can be fired parallel to the axis of the tanks.

Each of these cars also carries several machine-guns, or at least four "Lewis" guns, to serve as a supplementary battery. The female tanks are less deadly than the male, and each carries six "Lewis" guns. The tanks weigh thirty tons. They are driven by 105-

horse-power motors of the silent type. The crew of each tank consists of an officer and seven men.

These perambulating forts are impregnable when attacked by either rifle or machine-gun. The armor employed at present consists of plates one fourth of an inch in thickness, made of steel of a special composition. The openings for the guns are so contrived that the crews are comparatively safe from attack, even though the tank be surrounded by the enemy. These tanks are painted fantastically in brown, yellow, and green, to make them harmonize with the landscape. While advancing at night or in a fog they are very difficult targets to hit.

The sensations of the crew in an attacking tank furnish experience unique in warfare. The interior of the traveling fort barely accommodates the crew of seven men. The steering-wheel is placed forward, so that the driver may look ahead through narrow slits in the armor. The two field-guns are mounted amidships. The tanks have no springs of any kind, which makes rough going for the crew. Since the forward end rakes up at an angle of thirty degrees, to enable it to climb trenches, the tank is often pointed at an even steeper angle, when the crew must hold on by main strength. The jolting when passing over rough ground is extremely painful. It is said that if the tanks moved faster than 1000 yards an hour over such surfaces, the movement would become dangerous for the crew. Increase this motion by the violent vibration of the steel walls as they are peppered with the fire from rifles and from machine-guns, often discharged point-blank at the tank, and a ride in the enemy's territory becomes a strenuous experience.

In the famous advance of the tanks at Cambrai one of these traveling forts became separated from the fleet, and at a critical moment its engine suddenly stalled. The Germans, who had been keeping at a respectful distance, hailed this accident with shouts of joy, and rushed forward. As the driver struggled frantically with his engine, the enemy swarmed about the tank, climbed upon it and sought the observation openings, in order to shoot the crew like rats in a trap.

At such short range the guns of the moving fort were useless, and to open the doors and make a sortie against such overwhelming forces would have been hopeless. At this critical moment the engines—as is the way of engines—suddenly "picked up." The tank moved slowly forward, and then, gathering momentum, shook off the enemy clinging about it and soon crawled within the protecting range of its brother-tanks.

The French tanks differ materially from the English models. In the former the belts are better protected from shell-attack and are less liable to break. They are shorter than the British, however, and such tanks are likely to get stuck in crater-holes from which a British tank might readily crawl out. The French tanks carry on their roofs a camouflage canvas, which can be readily unrolled and let down to cover the tank when at rest. Many of these machines carry the famous French 75's, mounted inside the car, with their muzzles pointing directly ahead.

With America's entrance into the war has come a new development and a more general application of the tank. The British used the American tractor as the basis for their tanks, increasing the motive power and paying special attention to heavy armor and large guns. The result has been the construction of formidable moving forts, with a corresponding loss of lightness and mobility, which thus renders them rather clumsy in supporting infantry action. The French made fewer changes in the original American model and employed lighter armor and guns. At the same time their tanks are less cumbersome and less powerful than the British type.

Profiting by the experience of the English and the French, the latest form of American tank combines the two systems. A great fleet of tanks of several types has been built for General Pershing which includes both heavy and light machines, the fleet being thus adapted to a variety of purposes. The heavier American tanks will be used to support our artillery in the field, while the lighter models may be used for transporting artillery and motor-lorries over rough roads where ordinary automobiles could not pass. A battery of field-guns may thus be drawn into action under a fire that would prove deadly to exposed troops or ordinary automobile-tractors. In other words, American tanks will fight the enemy and bring heavy guns into action at the same time.

American forces have been provided with tanks in the same liberal spirit that marks the supply of other equipment. An appropriation of over $50,000,000 has been set aside to construct these fleets of tanks. Their motors will range from 12 to 250 horsepower. Many of our tanks have already been completed and shipped safely to France. With such a fleet at his disposal, General Pershing, thanks to American engineering ingenuity, will have enough tanks to keep up with infantry advances and maintain a sustained offensive action unique in the history of warfare.

CHAPTER VI

THE FAMOUS 11TH ENGINEERS

GENERAL GRANT is credited with saying that his troops, recruited from many trades and professions, formed the most efficient army ever assembled for solving engineering problems. In recruiting the 11th Engineers this ideal of general efficiency has been completely realized. The regiment is believed to be unique in the history of warfare. Among its 1300 engineers and skilled workmen is enlisted much of the best talent in America. Many of the engineers have cheerfully given up large incomes in order to devote their skill and, if need be, their lives to the service.

In no department of engineering is America better prepared to lend assistance than in work connected with the water-supply. Throughout the United States every conceivable problem of supply has been encountered, and this varied experience has served to train a great body of highly efficient workmen. The Catskill Aqueduct, for example, outclasses any similar work abroad, while the famous Roman aqueducts seem primitive by comparison. A number of engineers prominent in the Catskill project are to-day in France, as are hundreds of others whose names are associated with the greatest engineering projects of our country. In a recent letter from the front a former Catskill engineer writes that he finds the work abroad the most difficult in all his experience.

Several of the engineers of this regiment have been assigned the ambitious task of supplying water for great bodies of troops, as well as for cities and towns throughout France. Projects which would require years to plan and build at home must now be rushed through, for a day's delay may cause disaster. Much of the work must be done under fire. A lucky shot from a German battery may destroy at a stroke the labor of weeks, but the engineers must be ready day and night for any such emergency.

Watersheds have been selected and surveyed. Dams are built and water-mains laid for miles up hill and down dale. The mains are carried over rapidly-constructed trestles, or, again, are concealed from the German fire by ingenious camouflage. It is often difficult to find suitable material, and ingenious makeshifts have to be resorted to. The regiment includes several bacteriologists whose judgment is followed in anaylzing water or the soil through which it drains. One of the first duties of these bacteriologists on reaching reoccupied territory is to make careful analysis of the wells and water-courses, since the Germans frequently poison them when evacuating the country.

To complete the work of devastation, the enemy, on retreating, often floods great tracts of land. The skill of American engineers had not been counted upon in these plans. It is just such problems that our engineers, fresh from great Western irrigating projects, are prepared to face. No time is lost in theorizing. Surveys are quickly completed, and large forces of men attack the work. By some ingenious arrangement of dams and sluices, or the hasty construction of new water-channels, large areas of country have been drained in a few hours. Invaluable work is being done in purifying the water-supplies of camps and cities by modern methods employed in the United States.

A well-known American engineer, now in France, recently wrote to a friend at home, asking him to send some illustrated catalogues of the American machinery commonly used in water-supply. He explained that he did not wish to buy such machinery, and could not get it over if he did, but he wanted to have the satisfaction of showing the catalogues to the French and English engineers, who could not believe that such machinery as he described actually existed.

The war has necessitated mining operations on an enormous scale. Expert geologists are enlisted to examine the soil and decide what material will be encountered at different levels in the regions to be tunneled. One tunnel 1663 feet in length has been excavated, for example, from which 2200 cubic yards of earth and rock were removed. The miners use pneumatic rock-drills and all the latest mining machinery. The working-squads consist of twenty-five or thirty men, laboring in shifts of six hours.

Excavations usually take the form of long tunnels, dug at a slight incline to the horizontal. Such tunnels are often run ahead of the front trench for a length of 100 to 125 feet under no-man's-land, which carries them directly beneath trenches occupied by the enemy. On reaching the desired point, the tunnel is widened to a chamber where explosives may be placed. In such work the dimensions are kept as small as possible, leaving only room enough for the dirt and stone to be removed. The longer tunnels are usually kept three feet wide and from four to six feet high. When not over 100 feet in length they are only three feet high, while the width is often not more than thirty inches. In order to save time, which is priceless under such conditions, the men work in tunnels that compel them to stop over and crawl about the excavations like moles.

The progress of the work depends, of course, upon the nature of the material to be removed. If conditions are favorable, a tunnel may be pushed forward at a rate of from fifteen to twenty feet every twenty-four hours. When the earth and stone offers great resistance, progress may be reduced to three feet a day. The earth may prove to be so soft that the roof of the tunnel must be continually braced with timbers. As the tunnels advance, narrow tracks are laid and small cars, pushed by hand, are used to carry the earth to the opening of the shaft. One of the greatest dangers that faces these fighting engineers is that their work will be discovered by the enemy and a counter-mine be employed against it. It sometimes happens that engineers will locate the position of an enemy tunnel, force a hollow pipe under it, and explode a mine directly beneath the workmen. An alert watch must constantly be maintained by the miners far underground to detect the approach of an enemy tunnel. It can readily be seen that modern American machinery and methods, such as the electric and pneumatic drills employed by our American engineers, are proving invaluable.

The idea in such work is, of course, to un-

With the forestry regiment

Building a bridge against time

dermine the enemy's position, while excavating soil that offers the minimum amount of resistance. When the tunnel has reached its maximum length, the explosives are set in position and electrically connected with the base. The tamping is done with concrete, sand-bags and heavy wooden beams. The famous ridge at Messines was undermined by ninety excavations, in which five hundred tons of high explosives were simultaneously exploded.

In recruiting a large force of mining engineers and experienced mine-workers America draws upon a large and skilful body of men. Only those men were selected who had had much actual experience as engineers. They are men who know rock and soil and who can judge its strength at a glance. In this force men are to be found capable of solving every possible mining problem that may be encountered.

It is a high tribute to America's reputation in this field that the French Government has entrusted some of its important mining operations to this regiment. Both coal and iron mines are being worked in France to-day by complete units of American miners. One of these units can take over the entire work of operating a mine—the location of ores, the construction of tunnels, the building of supporting timbers, and the laying down of railroads for the purpose of getting out the ore.

The miners cheerfully face a lively danger in their tunnel-work in the front-line trenches. Here they must select the most vulnerable point in the German lines and run long tunnels forward under the enemy position. By exploding mines directly beneath the trenches, the way is prepared for an advance. In order to carry out such enterprises, the miners must know earth and rock, and must stake their lives upon their judgment. A mistake in calculating the strength of materials may cause them to be buried as they work, or may attract the attention of the enemy before the tunnel is completed.

The workers in subways or tunnels are objects of sympathy, but their position is safe by comparison with these men. One of the most perilous tasks the mining engineer workers are called upon to perform is to extend hollow pipes from the front-line trenches under the enemy's position. High explosives are set off at the end of these pipes by an electric-spark. The position of the soldiers in the front-line trenches is at best perilous, but that of the workmen, whose retreat is practically cut off, calls for rare courage.

In preparing for General Byng's famous drive, it was found absolutely essential that a considerable amount of engineering work be completed before the advance was ordered. This work was entrusted to American engineers, assisted by American workmen. A British officer high in command urged that the work be rushed as fast as possible, and asked for an estimate of the time required. It was decided that even by working on an American time-schedule more than eleven days would be required. The censor has not permitted any description of the nature of this work to come through.

The British staff decided that they could not wait eleven days to begin the drive, and urged greater speed. A great force of coolie labor was offered to hasten the work. This offer was refused, the American engineer much preferring his own workmen. The construction work was completed, nevertheless, in less than five days, and the famous advance started on schedule time. The engineer in charge of this work has written home that he found time for only eight and a half hours sleep during more than five days. The end of the job found him so exhausted that he lay down beside a battery of twelve-inch guns, and even their bombardment failed to disturb him. The work of the Americans has received most enthusiastic praise from British officers.

When the proportion of deaths and casualties is definitely counted after the war, it will doubtless be found that the fighting engineers have suffered severely. Apart from the obvious danger of working under fire, these men are exposed to every kind of accident common among workers with machinery. In the building and operating of railroads on rush-schedules, under new conditions and while using new and unfamiliar materials, the risk is naturally great. Reports of such accidents are already coming in, and the demand for false limbs, glass eyes, and other surgical material tells its own story.

The first man of the American engineers to be invalided home is, at this writing, in a hospital in Baltimore, suffering from a broken hip. A railroad accident is likely to be more serious than a bullet-wound, and the fighting engineers face both dangers.

The spirit of the American engineers at Cambrai, which has been so highly praised abroad, was no surprise to their friends at home. The British Commander in Chief, Sir Douglas Haig, has especially praised and recommended for a decoration Lieutenant Paul McLoud, of the American Engineering Corps, for his bravery in the Battle of Cambrai.

The Americans were busy on the morning of November 3, 1917, building a railroad-yard near the British front, when they were surprised by a sudden German advance. Without a moment's warning, the Germans concentrated a heavy artillery-fire on the yard. Lieutenant McLoud collected his men and calmly marched them through the German barrage to a point of safety. They had retreated about two miles, when they chanced upon a number of British soldiers. McLoud at once took command and, rallying the troops, returned to the firing-line. On the way back the Americans met a British staff officer, and with his aid they succeeded in getting additional arms and ammunition with which to equip the engineers of the party.

Once armed, the improvised troops rushed forward and were soon in the thick of the fight, giving an excellent account of themselves. Lieutenant McLoud was formerly chief engineer of the New York State Highway Department, and was one of the first to enlist in an engineering regiment. It is from such material that America has recruited her regiments of fighting engineers.

The bravery of the fighting engineers at Cambrai called forth the following letter from Colonel Henry W. Hidge, U. S. A., to Mr. Mac Isaac the father of one of the men. The colonel writes:

I want to write you a line of congratulation on the conduct of your son in the recent conflict with the Boches.

Every one here says that, but for his heroism and those who were with him from the —— Engineers, we might have had a serious fall-back, but that he and Lieutenant McLoud and a few others rallied their men and our soldiers and held the Boches. I hear that the Allied commander will probably give especial recognition to their gallantry, and I am sure that you will be glad that your boy is one of the first to show that we Americans are going to do our part in this great struggle.

At the present writing, at least fifteen members of the 11th Engineers are known to be prisoners in Germany. The capture was made in the famous advance at Cambrai, and indicates that the Americans must have been very near the first-line troops. In this campaign an advance was originally planned on a thirty-mile front, with the assistance of the famous tanks. Later the forces were concentrated, but, as all the world knows, the British troops pushed forward for five miles.

The wedge thus driven into the enemy's territory was open to attack on three sides, which rendered the position extremely precarious. The American engineers, nevertheless, pushed forward into this territory, in order to consolidate the position. A simultaneous attack quickly developed on three sides, and the position proved untenable. Doubtless our engineers could have saved themselves, but they remained at their posts until overtaken and made prisoners.

The relatives of members of the 11th Engineers have formed an association in New York, an example that may well be followed elsewhere. Headquarters have been established, a paper is published in the interests of the organization, and monthly meetings are held. The work of communicating with the men at the front and of caring for their families at home, if need arises, is carefully organized. An attractive feature of these meetings consists in reading letters from the men at the front, and plans are discussed for lending every possible assistance to the men in the camps, the wounded, and to prisoners. The honor list of the month, including the dead and wounded, is read, patriotic songs are sung, and prayers are offered. A collection for the engineers is taken up by passing around a German helmet captured in the war.

CHAPTER VII

THE MAN BEHIND THE GUNS

MANY revolutionary ideas in the science of gunmaking have had their origin in the United States. By some bold stroke the American engineer has repeatedly set aside the usage of years and opened up an entirely new field of scientific conquest. Later the idea has been seized upon by Europeans, carried to perfection, and, in its ultimate development, turned against us. It is a proof of the peaceful ideals of one nation that, after originating ideas that may revolutionize warfare, we have allowed others to apply them.

So rapid has been the advance in military science that the weapons of a generation ago are to-day only fit for decorations,—of doubtful artistic value,—in our public parks. The best guns of the Civil War period, made of cast-bronze or wrought-iron and strengthened with metal bands, are as extinct as the stage-coach. Even the field-guns of the Spanish War are hopelessly outclassed. The field-artillery of the United States Army, previous to the Great War, comprised seven or eight types of guns, varying in bore from three to seven inches, which armament compared favorably, however, with the best European ordnance.

The marvelously complex gun of modern warfare dates from the Crimean War. With the appearance of the breech-loading weapon, the ordnance which had determined the issue of battles for centuries began to disappear. Even the guns heard at Trafalgar and Waterloo were soon silenced forever.

The first great cast-iron guns to be used in actual battle were of American make, although they were heard in Europe during the engagement between the *Kearsarge* and the *Alabama,* in the English Channel, in 1864. At that period American guns were acknowledged to be the best, since American iron had a tensile strength of 40,000 pounds per square inch, as against 20,000 pounds for English iron.

But the heaviest guns of cast metal could not long withstand the explosions of modern charges, which appeared after the Crimean War, and the barrels were soon made of concentric tubes welded together. American guns were strengthened by hoops of iron shrunk around the breech. Many experiments were tried, and the modern gun slowly took shape. The steel tubes that form the lining were first forced into the guns, but later the outer case of the gun was shrunken about them.

By the year 1874 guns were made in England with an inner tube of steel encased in no less than five coils of wrought iron. The largest of these guns fired projectiles weighing 1258 pounds, the power charge weighing 170 pounds. Wrought-iron gradually disappeared, and the guns were made entirely of steel. The first all-steel gun appeared in France at so recent a date as 1881.

The best engineering talent of the world has been engaged upon this problem of gunmaking. After countless experiments, all countries seem agreed upon the best method for turning out gun-barrels, much as details or workmanship may vary. The steel is first cast in ingot molds in the form of solid, truncated cones. The ingots are roughed out with several reheatings of the steel, and are then turned and bored roughly. The core is cut away and taken out in a single piece. An oil bath is employed in tempering the steel, when the rings are shrunken on, and the gun is ready to be filed. It has been found that a wire-wound gun offers greater resistance than one strengthened by any system of hoops. The tension the gun must withstand is, of course, calculated in advance; nothing is left to chance.

The secret of the enormously increased effectiveness of modern ordnance lies, of course, in its power of resistance. There are two ways of increasing the firing-power of a gun: by lengthening its tube and by increasing the charge. The early guns had a length of twelve diameters. Some of the latest guns are fifty times that of their bore. The muzzle velocity of the high-powered guns of the past was 7000 foot tons, as compared with about 53,000 foot tons in the case of the largest modern ordnance. An increase of 800 per cent. in driving force is thus obtained.

The force of explosions has been increased by using nitro-explosives in place of gunpowder. Again, by using smokeless powder a much larger volume of gas is obtained than by the use of black powder, and hence its increased effectiveness. The wrought-iron guns had an elastic limit of twelve tons per square inch, while the limit of steel is twenty-one tons.

Before the opening of the Great War the artillery available for use in the field included several types of direct-fire gun, ranging in caliber from three to four inches, with high-angle-fire guns or howitzers of from 4.7 to 7 inches. The largest of these guns in the United States fired seven-inch projectiles. Some European countries were known to have larger guns,—even eight-inch guns.

Meanwhile Germany had been secretly building and testing guns of unprecedented power, which for a time were to spread consternation among her enemies. The Krupp gun-works had turned out giant howitzers of 12 and even 16.5 inches. Tests were made on carefully-guarded proving-grounds, and the "Busy Berthas," as they came to be called, were held in readiness.

In designing this unheard-of ordnance the German engineers had definite targets in mind. The guns were intended to reduce the concrete foundations of Liége, Namur, and Maubeuge, which were supposed to be impregnable. The idea, by the way, did not originate with the Germans; for similar guns had already been used by the Japanese against the Russians in Manchuria. Borrowing the idea, the Germans stole a march on their adversaries. Experts are not yet certain whether these great guns should be classed as howitzers or mortars. The true howitzer has a barrel somewhat shorter in proportion to its bore. The mortars of late years have been growing larger, but then, again, the new guns are too large for this classification.

The world was not prepared for the explosions of the "Busy Berthas." The shells, weighing 1000 pounds or more and aimed with amazing accuracy, crumpled up the scientific foundations of modern forts eight miles away. For some anxious days it seemed as though they could batter their way to Paris. Later they were used with appalling effectiveness to destroy trenches at Verdun. A single shot has buried fifty men, and their explosion is said to kill men within a radius of 150 yards. The Austrian "Skoda," a howitzer of 17 inches, throws shells weighing 2800 pounds. In the bombardment of Dunkirk fifteen-inch shells were hurled twenty-two miles.

The efficiency of such guns is due to the fact that they are readily portable and may be carried with surprising speed from place to place. Heretofore, guns of enormous power have been stationary and have only been available for coast-defense purposes. The new guns are cast in three parts, each of which may be loaded on a motor-truck of special construction. The gun is trundled on one truck, the carriage on another, and the foundation on a third. A crew of several hundred men is employed to transport them. If the country permits, trucks are employed, while specially constructed railroad-cars are sometimes used. It is said that the gun-crews are always ready, on a moment's notice, to destroy the guns by blowing them up, if they are threatened with capture.

Against the unprecedented attack of the "Busy Berthas" the Allies for a time could bring no adequate defense. But the reign of the "Busy Berthas" was short-lived. Although they were met only by guns of inferior size and range, the French set up an impregnable barrier, and the giant guns never arrived within range of Paris. By the time the Battle of Picardy was fought, the British were able to utilize great howitzers that threw shells weighing 1700 pounds a distance of seven miles, at a rate of one shot a minute. Like the German and Austrian ordnance, these guns were brought up on motor-trucks. In the Battle of the Somme the pendulum had swung back, and the Allies, completely outclassing the enemy, directed against them the heaviest artillery-fire known in warfare.

Type of modern ordnance

Work of the "Busy Berthas"

The gun-makers of every country at war realize that probably the greatest problem in building modern guns is that of overcoming the recoil. Until recently the kick of a gun was considered a necessary evil, and no effort was made to control it. A cannon, on being discharged, would run back several feet, and the aim would be completely lost. A crew was then forced to labor to bring it again into position, and the difficult work of sighting it had to begin all over again. The time lost between shots was, of course, priceless; but since both sides worked at the same disadvantage, it was accepted as a necessary evil.

With the present system of non-recoil employed, a battery of field- or even siege-guns can be made to fire from twenty to twenty-five shots per minute. The problem has been solved in different ways in the several embattled countries, but the construction is essentially the same. The carriage of the gun remains fixed, and the gun recoils on this carriage and returns to its original position. The force of the recoil is enormous, but this is taken up by a highly ingenious system of hydraulic cylinders, counter-weights, and counter-recoil springs.

It is difficult for the lay mind to realize the power of such guns. In the case of a twelve-inch gun the counter-weight consists of 140,000 pounds of lead. The recoil-cylinders are filled with oil, which has been found best for taking up the stupendous shock of the discharges. The guns are returned to their carriages by releasing the great counter-weights, thus forcing the weight of the gun forward to its firing position.

In no other branch of engineering, it is safe to say, may be found mechanism at once so powerful in its execution and so delicate in design. One type of our seacoast guns measures fourteen inches in caliber. This measurement means little to the average mind, although our respect for the gun will rise when we learn that it fires a projectile weighing 1660 pounds, which, in turn, carries a bursting charge of eighty-five pounds of high explosive.

The largest gun in our fortifications is of sixteen-inch caliber; it is mounted on a disappearing gun-carriage. The almost irresistible force of this gun is cleverly utilized to operate much delicate, but powerful, machinery to bring it back into position in the shortest possible time.

This gun-projectile weights 2400 pounds, —a weight equal to that of a large wagon or automobile filled with passengers. Its speed on leaving the gun, or its muzzle-velocity, is 2700 feet,—rather more than half a mile per second. The energy exerted by such a discharge is equal to 121,430 foot tons. This power will raise a projectile weighing more than a ton to a height of eight and a half miles, an altitude equal to that of several of the highest mountains in the world.

The extreme range of such a gun is twenty-seven and one third miles. To visualize this distance, describe a circle of twenty-seven miles from some familiar point. Incredible as it may seem, every point within this imaginary boundary would be within range of this gun.

Great engineering skill is displayed in designing guns with an extremely high-angle fire. The shells from such guns climb to great heights, and after describing a graceful parabola, drop with wonderful accuracy upon the target. In defensive work along our seacoasts such batteries are, of course, likely to be more effective than more powerful guns of longer range. The idea is to have the shot strike vertically, or as nearly so as possible, upon the deck of a ship. Since such shots are more likely to cause internal explosions than is direct fire. The mortars used in seacoast forts usually consist of batteries of four guns, which are fired electrically. Four shots may thus be fired simultaneously, or two of the mortars may be set off singly by touching a button. The man behind the gun must be a highly technical engineer, with all his forces, trained by long schooling, constantly on the alert.

The complete field-gun consists of two parts: the gun, and its limber or caisson, the latter carrying the ammunition. In action the two parts stand side by side. The method of serving field-guns has been made familiar to the most peaceful citizen through the medium of the motion-picture. Every one has seen the guns brought forward,—

often with hysterical speed,—loaded, sighted, and discharged, while courage, daring, or fear are "registered" by the hard-working actors.

The patron of the "movies" need scarcely be told that modern field-guns do not recoil with each shot and have to be hauled back into position. The gun is aimed by means of a telescopic sight. The carriage is fixed in position by means of a spade, at the end of its tail, dug into the ground. The shell is inserted in the open breech, which is then closed and locked. The gunner pulls a lanyard, there is a flash from the muzzle, and the gun springs backward. By beating on a drumlike instrument somewhere back of the screen the illusion is made complete.

The action is probably too quick to be caught by the eye; but in this fraction of time the gun compresses a coiled spring, while the main force of the kick is taken up by a cylinder filled with oil and water. A moment later the spring forces the gun back, sliding it on its fixed carriage, or base, to its original position, where it may be sighted and fired without loss of time.

There is important economy of time in using modern cartridges. The metallic cases are slipped into position in a flash, the breech-block being operated by a single action. An ingenious device throws out the empty cartridge-case. Some cartridges are placed beside the breech in their original package, and are pushed into position without being touched by the hand, thus keeping them free from dirt or grease. Compare this method with the violent exertion of swabbing out the old-fashioned breechloaders and ramming home the shots, the charge of powder, and the bullets. Our gunners can fire fifteen shots to a minute with these guns, while in France constant practice enables a gun-crew to fire twenty times a minute.

The machine-gun, which, by the way, must not be confused with revolvers or magazine-rifles, was used in our Civil War in more than a score of different forms. Little progress was made in developing it, however, until about 1870, on the appearance of the new torpedo-boats. The rapid movement of the new craft eluded the guns of that period, and the ordnance engineers set to work to invent some new gun to overcome this advantage.

The early machine-guns had from six to ten bores, which revolved around a central shaft. Each shot had to be fired by hand, the gun being operated by turning a crank. It was at best a cumbrous method. Although the idea of utilizing the recoil of the shots to fire a gun was old, it was not successfully utilized until the appearance of the Maxim gun.

The machine-gun has had a wonderful development in the last few years. The older forms of rapid-fire gun have been completely outclassed. The gas-operating type of gun made and used in the United States appears almost magical to the layman, as, indeed, it would have appeared to the trained soldiers of another generation. It is an air-cooled gun, which is operated automatically by the escape of gas after each explosion. The gas escapes through a port a short distance from the muzzle and sets in motion the complicated machinery that operates the gun. As long as one holds back the trigger, the gun discharges at the rate of from 450 to 500 shots per minute. A small battery of such guns fires as many shots as a regiment of men.

The cartridges—hundreds of them—are fastened to a woven canvas belt, which is fed into the gun with bewildering speed. When the gas, after each explosion, passes through the port, it acts on a piston which moves a lever, and the sharp impulse of the gas is instantly transmitted to a train of lever-springs and feed-wheels, all working in amazing harmony. As each cartridge comes into position, it is plucked out of the belt, delivered to a carrier, raised into position, and the cartridge-chamber is closed, ready for firing. On being discharged, the cartridge is thrown out and a new one takes its place.

Imagine the delicacy and precision of the mechanism which performs this complicated operation almost ten times in a second and keeps up sustained action indefinitely. By way of comparison, it is interesting to recall that the first guns used in warfare, which were adaptions of the ancient crossbow and were "loaded" by winding-up devices, required about half an hour to wind up or load. Battles were fought in which only seven rounds of shots were exchanged.

A few years ago a gun of any size without some recoil would have seemed impossible. With the development of the aëroplane the makers of ordnance busied themselves to design a weapon that could be discharged aloft. The balance of an aëroplane is, of course, so delicate that the recoil of an ordinary gun, even a small one, might mean a fatal plunge. For some time the problem presented to the gun-makers proved baffling, but the advantage of directing artillery-fire from the air is so great that the engineers of ordnance returned again and again to the task. Until a good non-recoil gun was invented, a machine-rifle was the largest piece of ordnance an air man dared carry aloft.

In the first type of non-recoil gun the weapon was fired to the rear. When discharged in the air, the gun fell and was lost, so far as that particular flight was concerned. This proved an expensive method of aërial attack. The present non-recoil type of gun is a marvel of ingenuity and workmanship. In a word, it consists of two guns, firing two projectiles, which exactly balance each other. The recoil of one gun cancels that of the other, so that the delicate balance of the aëroplane is undisturbed. With this invention, the aëroplane suddenly became an efficient weapon of attack.

This aëro-gun is, in reality, a double-barrelled or, more accurately, a double-length gun. Placed end to end, ready for firing, it appears to be a very long, single-barrelled gun. The two guns have the same bore, so that when discharged breech to breech, the force of the recoil exactly balances. Two projectiles are fired in opposite directions. A steel shell leaves the forward barrel, speeding toward its target, while the second projectile speeds toward the rear. A man directly behind the gun would occupy a dangerous position.

The cartridge fired from the front barrel is of the conventional form used in ordinary guns. The rear barrel fires a charge of wadding which breaks up, losing its initial velocity in a few feet. By the time the wadding has fallen to the ground it becomes entirely harmless, and even if it should chance to hit some one, no injury would result. This highly ingenious form makes it possible to build guns firing two-, six-, or twelve-pound cartridges, weighing from 60 to 210 pounds. The muzzle-velocity of these shots is in excess of 1000 foot seconds. The aëroplane can thus carry aloft a battery of cannon which, as regards bore and efficiency, enormously increases their deadliness.

One of the most interesting forms of modern ordnance is the anti-aircraft gun that has appeared in very recent times. An aëroplane in flight naturally is an extremely difficult target to hit. It moves at a rate of 100 miles or more an hour, and often at an altitude of one or more miles. Its course may be a rapid zig-zag, which greatly adds to the problems of the gunner. The extreme range of these anti-aircraft guns is about 21,000 feet, or about four miles. When firing directly upward, the shot requires about twenty-two seconds to reach its destination. The gunner must therefore calculate the speed of the aëroplane and aim his gun in advance of it in such a way that it will intercept its course almost half a minute after the gun is fired. Such guns obviously fire shrapnel.

Air defense remains one of the unsolved problems of the war. The anti-aircraft guns are marvels of ingenuity, but the problem they must face is extremely difficult. Much progress has been made, and the guns are to-day so effective that the Zeppelin has been practically driven from the skies. By night such work is greatly complicated. The most powerful searchlights can do little to pick out aircraft several miles high. The discharge of the batteries drowns the sound of the aëroplane's propellers. Such guns, of course, can be readily aimed at any angle and, despite their size and weight, are extremely mobile. The guns are often mounted on motor-trucks that may be rushed from point to point at top speed.

The aëroplanes that raid London as a rule reach England somewhere above the mouth of the Thames and follow the line of that river. When the approach of a hostile fleet is discovered, a barrage is put up at the mouth of the Thames. This usually proves very effective, and it is believed that one half the attacking fleet is often brought down at this point. In using anti-aircraft guns above any city, there is danger, of course, that the shrapnel will fall back, and, gaining immense momentum in dropping several miles, inflict damage upon friends. It is commonly said that everything that goes up is Allied, while everything that comes down is Boche.

A complete revolution in artillery methods may follow the invention of guns of such extreme range as are now being employed by the Germans in the fourth year of the Great War. In the spring of 1918 the world was startled by the announcement that shells discharged from German guns had reached Paris, inflicting loss of life. The first reports were discredited, so impossible did such a bombardment appear. It was estimated that such shells must travel for more than seventy miles, or nearly four times as far as the most powerful guns heretofore used. The continued long-range bombardment of Paris, with considerable loss of life, soon convinced a sceptical world, however, that a seventy- or perhaps eighty-mile gun was in operation.

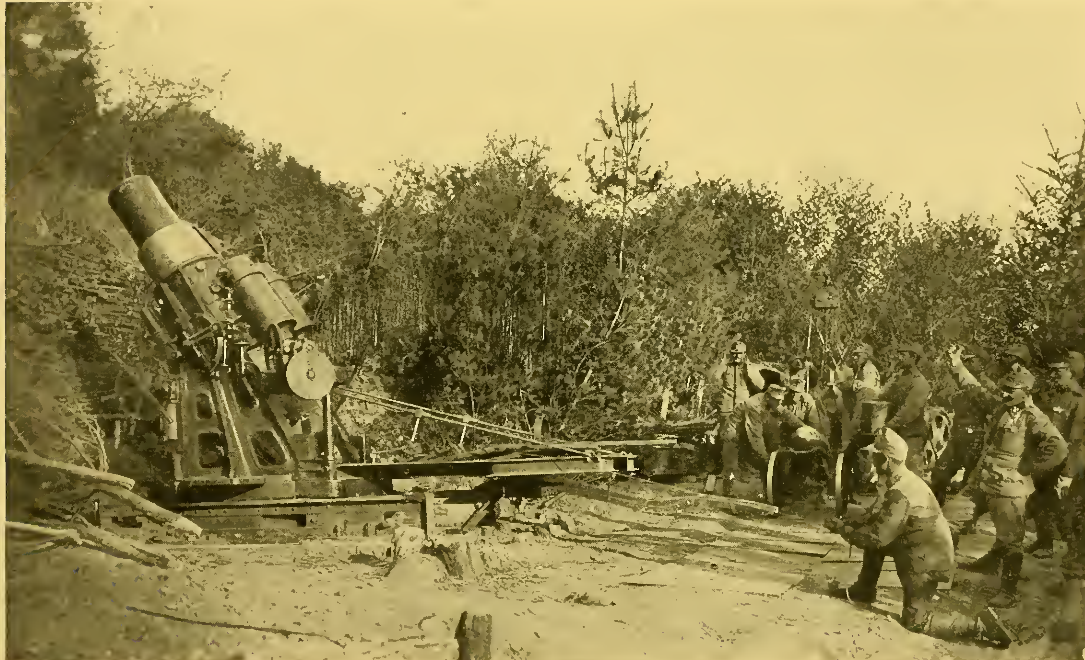
Although the secret of these guns has been closely guarded, it is known that their barrels are about sixty feet in length. The shells fired measure eight and one quarter inches in diameter. The empty shell weighs 330 pounds, and the charge has the same weight. The projectile rises to a height of 18.6 miles and then descends from the sky, gaining velocity as it falls. By climbing to this height the shell, of course, reaches rarefied air. This is said to simplify the problem of throwing it this immense distance. It is estimated that the shell requires more than three minutes to reach its target.

The Lewis gun depends for its marvelous speed in firing upon the tension of springs acted upon by the force of exploding gas. Although weighing only twenty-one pounds, it will fire from 400 to 700 shots per minute. Its action is entirely automatic. The cartridges are arranged in a spiral shell that holds fifty rounds. This shell can be replaced in two seconds. The gun is cooled by means of a long tube of aluminum, along which air is drawn.

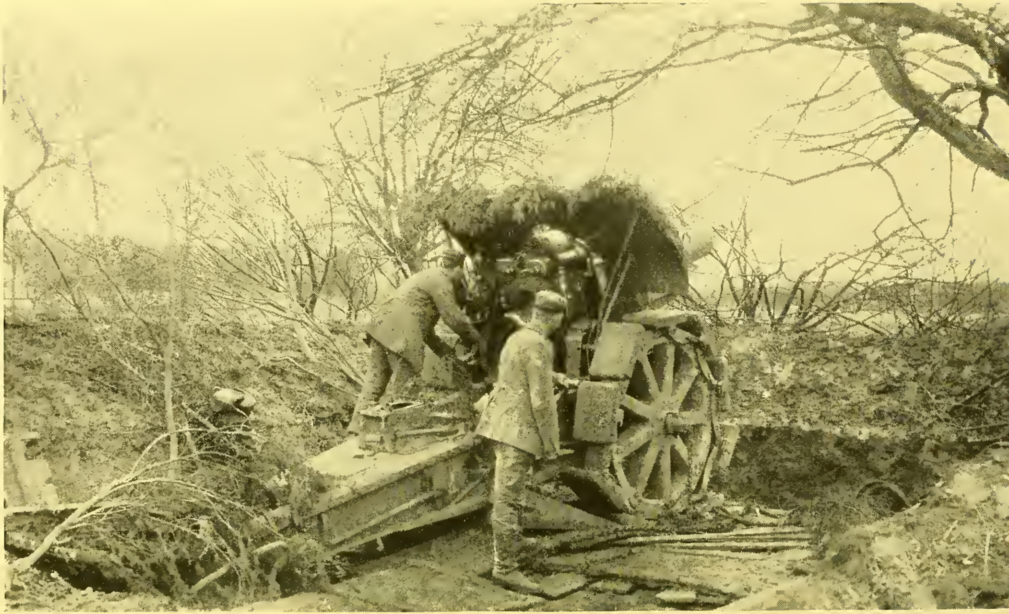
Doubtless the most mobile batteries in service are the motor-cycle machine-guns. The English army alone has thirty thousand machine-guns mounted on motor-cycles. Over any passable road these motors can cover thirty or forty miles an hour, or better, and therefore prove indispensable in supporting infantry. The cyclists are daring riders, and hundreds of such guns may be brought into position with bewildering speed. A company is often rushed forward to hold a position until reinforcements arrive. The machine-guns may be fired from the motor-cycle by using a rigid tripod. Distance is covered so quickly by the motor-cycles that repair-shops are usually placed well in the rear.

The most completely equipped motor-battery in the service to-day is said to be the Ninth Heavy Field Artillery of the United States Army. Motor-tractors of many forms have completely superseded the horse-drawn units. The colonel of a regiment travels about the field in a light automobile, thus keeping in touch with widely separated units with the least possible delay. Officers travel rapidly in motor-cycles equipped with "bathtub" side-cars. A complete equipment of motor-trucks, driven by all four wheels, are used to rush up ammunition and supplies of every kind. The heavy guns are drawn by "caterpillar" tractors, which trundle slowly but surely over ground that would be impossible for horses. The tractor part of a regiment's equipment includes forty-five machines. One of the great advantages of these tractors is that much heavier guns may be drawn into action than is possible by the use of horses. Such equipment replaces at least one thousand horses that would otherwise be required for each regiment.

The work of arming millions of men with rifles is one of the main engineering problems of war. Several rifles are turned out, complete, for every man in the ranks. In all these millions of weapons the greatest accuracy of every part must be assured, and the fabrication of the parts requires a high degree of technical skill. The barrel is the



A modern gun in action



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Modern ordnance on caterpillar wheels

most difficult problem. At present the material most favored is smokeless barrel-steel, which is found to resist the corrosive action of the gases set free by the explosion.

The methods of manufacture vary considerably. A common method is to cut a rod of uniform diameter, and then upset one end and thicken it to form the breach. Some barrels are rôlled by special machinery, in order to get the proper taper. The barrels are next roughly straightened. The boring is done by rotating the barrel at high speed, while the metal is cooled and lubricated by a stream of oil, after which the bore is smoothed. It is so vital that the bore be absolutely straight that the work must be done by experts, with the greatest precautions. The barrel is ground on a grindstone, and then is repeatedly tested with a bullet. The rifling comes next, when the bore is cut with the grooves that give the bullet its rotary motion on being discharged. The rifle is then "browned," as it is termed, by a chemical bath, although its color, as all the world knows, is really a dark blue.

Before leaving the factory every rifle is subjected to a high-powder test. A heavy leaden plug is driven into the muzzle, and a charge equal to two or three times any normal charge is exploded. Such a rifle may be discharged 250,000 times without losing its accuracy.

The general public has no conception of the difficulties that face the engineers of the ordnance department in constructing vast supplies of guns and ammunition. It has been necessary to supply our troops with 100,000 different items, ranging from the tiny firing-pin of their rifles to the complete 16-inch gun with its emplacement. One of the great guns mounted on a modern disappearing-carriage consists of 7,990 parts, not including the sights and accessories. Even a 3-inch gun-battery requires 3,876 different tools, accessories, and supplies. For every gun in use there must of course be a reserve supply of all parts. Since hundreds of thousands of such guns must be supplied in "rush time," new engineering problems must be solved in quantitative production.

It has been necessary to build new plants on an unprecedented scale, finance them, and assure an enormous production in the briefest possible time. In times of peace the Government directed eleven small arsenals. Within a few months it directed the output of 14,000 private manufacturing establishments. A great army of workers is employed to turn out shells of all calibers, rifles, ammunition, grenades, and bombs. The housing of these supplies alone presents a serious problem, since more than 23,00,000 square feet of storage-space will be needed for such supplies. An efficient system of handling supplies has been worked out by army engineers, and this has necessitated the building of hundreds of miles of special railroads. More than 10,000 carloads of explosives, for instance, are handled every month.

In the first year of our participation in the Great War the Army Ordnance Department increased its staff from ninety-seven to over 5,000 officers, a large proportion of whom are highly skilled engineers. Its expenditures during our first twelve months in the conflict aggregated $4,756,500,000. The output of rifles was increased to 45,000 a week, and during the past year 1,400,000 guns were supplied. The delivery of machine-guns was increased from 20,000 to 225,000 a year, while the output of field-guns of all types was jumped from 1,500 to 15,000 a year.

CHAPTER VIII

MODERN SHELLS AND ARMOR

THE old-fashioned, cast-iron cannon-balls, which we see piled in neat pyramids in public parks, are as obsolete as the guns that used to fire them. They have been replaced by a complicated contrivance of steel some thousands of times more effective than the old missiles. The deadliness of the shell is immensely increased by a secondary charge of bullets,—several hundred of them,—which are scattered by a second explosion, much the same as a rocket explodes after a long flight. The base of the shell carries a charge of powder and several hundred bullets, the interstices being filled with a smoke-producing mixture. A time-fuse is arranged at the nose of the shell, which may be set with reference to the range and the time of flight, so that the powder will explode when the shell nears its target, usually when above a body of troops. The time-fuse must be constructed with mathematical accuracy, —in order to measure the time in minute fractions of a second.

The fuse-device in a modern shrapnel shell and in a high-explosive shell contains marvelously delicate mechanism. There are shearing-wires, centrifugal bolts, safety-pins, needles, and hammers adjusted with the utmost delicacy. Although these shells are capable of destroying every object in their vicinity, they are perfectly harmless until the safety-pins are removed, when their complex mechanism is permitted to function. The safety-pins resemble the familiar domestic articles only in name. A generation ago the soldiers often cast their own bullets and cannon-balls by melting lead and pouring it into crude molds. To-day a scientific metallurgist is required to prepare the materials. Some knowledge of chemistry is required, even to read the formulas that describe their composition. Every detail of the work is highly specialized.

The shells must, besides, have just the right hardness, for if they are too brittle, they may be shattered in the gun, and if too soft, they will bulge and widen before leaving the barrel. The most minute detail is of vital importance, for the period of explosion must be brought within absolute control. The balls in such a shell are discharged from their case with an additional velocity of from 250 to 320 feet per second. These guns have a range of several miles, and so delicate and accurate is this mechanism that the point at which they will explode may be determined within a few feet.

Among the most complicated of these missiles are the aërial bombs dropped from aircraft. It might be supposed that any container loaded with an explosive would prove sufficiently deadly when dropped from an altitude of two or three miles,—but engineers have succeeded in greatly increasing its deadliness.

The cross-section of such a bomb appears hopelessly complicated to the layman. The mechanism is so arranged that a drop of fifty feet starts its extremely complex machinery. A small propeller at the end of the bomb is spun by the resistance of the air, and this sets the involved machinery going. The aviator, having calculated his altitude, the speed of his aircraft, and the resistance of the wind, and having solved a rather difficult equation, determines how long his missile will take to reach its target. The time-fuse in the nose of the torpedo is set accordingly, then released. In the fraction of time taken for the heavy bomb to plunge down to the earth the machinery functions with scientific precision. A plunger is released, which brings the chemicals together, a primer is fired, and at a prearranged distance from the earth the bomb explodes. Before these time-mechanisms were employed a great deal of energy was lost, since the bomb only exploded on striking its target, and was likely to plunge deep into the earth, where it could do comparatively little damage.

New figures of speech must be found to describe the unprecedented volume of sound in modern cannonading. Cannons no longer "thunder." Never before have so many guns of great caliber been massed together or served so continuously. Observers, both on the Allied side and the German, have remarked the peculiarly impressive roll that follows the discharge of a high-powered gun. This sound is heard to best advantage in rugged land of irregular contour, well-wooded and set with many buildings. The report of the cannon is followed by a majestic, echoing roll, which has been described as like a great brass orchestra, with a more distinctly musical note than thunder. The report is frequently mistaken for the actual roar of the shell, while in reality it is produced by the combined echoes from thousands of recesses and inequalities in the earth over which the shell passes.

One of the curiosities of the war is the tricks of acoustics played on the gunners and the enemy in artillery duels. It is a well-known law of acoustics that intensity of sound grows less in proportion to the square of the distance. Double the distance, and the sound has but one fourth its original volume. We are likely to apply this rule instinctively when locating or comparing any sound.

To the bewilderment of the soldiers at the front, the enemy's guns often sound much louder than their own batteries. Men well behind their own cannon have often been alarmed to hear the attacking guns sound much more formidable than their own. The evidence of their senses would seem to tell them that the enemy's battery was the more powerful.

The explanation is simple. Sound is concentrated in the direction of artillery fire. The reports of these great batteries, heard from the rear, merge into a great, dull roar of incredible volume. The reports from the guns aimed directly at one have a sharp, staccato note, although the guns may be of similar type. It is this sharp, staccato note that has been frequently compared to the tattoo of a giant drum. During the bombardment on an unprecedented scale of the massed Allied artillery on the Somme, the Germans described this curious phenomenon as *trommel feuer,* or drum-fire, and the phrase has come into general usage.

The destructive power of the great guns has been carefully measured. The seventeen-inch howitzers, which hurl shells filled with explosives weighing 2800 pounds a distance of twenty-four miles, are practically irresistible. No structure nor fortification has yet been devised that can withstand such a blow. One of these shells has penetrated a barrier of twenty-six inches of steel armor, backed by twenty feet of solid oak timber, and then a thickness of twenty-one feet of granite and concrete masonry, making a total of forty-three feet of the hardest materials that can be assembled.

As the weapons of warfare have become more deadly of late, several forms of armor, long ago discarded, have returned. A soldier of the Middle Ages, who had never heard of gunpowder or firearms, would find the trenches, with their steel-helmeted soldiers, a familiar sight. The gas-mask bears a faraway resemblance to the visors that protected the knights of old. Within a few years the appearance of the fighting man has been transformed, and if the war should continue and newer and more deadly missiles be invented, modern armor may assume unexpected forms.

The soldiers of Rome and Greece wore no armor, except the shields they carried to ward off the blows of spears. As side-arms and the lower-power projectile came into use, the complicated armor of the Middle Ages gradually developed. To ward off attacks of crossbows or javelins, the soldiers first wore thick garments of skins and furs, and then came the helmet and cuirass.

The period of armor reached its complete development by the middle of the fourteenth century. The soldiers then fought under a heavy weight of metal, so that often it was necessary for a knight to be accompanied by a follower to assist him to carry his fighting equipment. The legs and arms of the mounted men were protected by steel plates, the hands by articulated gauntlets, and the feet by iron shoes. It was impossible for men on foot to carry such armor, and they were less well-protected. They wore helmets, shoulder-pieces of metal, shields, arm- and thigh-pieces, a protective piece for the knees, and short coats of mail.

The use of gunpowder quickly changed the appearance of fighting men. In a period of ten years, as firearms grew more effective, most of the protective armor disappeared.

French Official Photograph

American foresters at work in France

A wayside repair shop

The saving in weight of equipment that men had to carry into battle was, of course, an enormous gain. Warfare was revolutionized. Instead of converting each man into a movable fort, as it were, every effort was now made to gain individual invisibility, and the familiar service-uniform next appeared.

To-day, with steel helmets, gas-masks, and spectacles, we are, in a measure, returning to the ancient methods of protection. The first form of this modern protective headgear in the present war consisted of metal caps worn under the kepi, which assured ordinary protective covering. It was found, however, that this headpiece caused headaches and other discomforts, and its convenient form often tempted the soldiers to use it as a cup or a cooking-utensil. The present form of helmet has gradually evolved. It is designed along scientific lines, so that a missile striking it, even at an angle of fifty degrees, will glance off.

The steel helmets worn by our soldiers in France afford a unique problem in engineering. Four fifths of all the casualties in modern warfare are head wounds. The protection of the soldiers' heads, therefore, becomes a matter of supreme importance. Profiting by the experience of the British, French, and Germans in designing these steel protections, American engineers have improved upon earlier designs. The helmet worn by American soldiers follows the general lines of the British type of inverted "soup-plate," rather than the French "casque" or the German "coal-scuttle." Penetration tests show that no helmet is more efficient than that of the American type.

Every helmet issued to the American soldier has passed a severe test and is absolutely free from cracks or flaws. To turn out this complicated headgear by the million, using only the highest grade of materials, is a big order; but the great manufacturing resources of the United States have proved equal to the work of quantitative production. Steel helmets had never before been made in the United States; but new machinery was designed, and the supply has never fallen behind the demand. The helmets are made by stamping and punching sheets of steel, so that thousands may be turned out in a day, with great saving of labor. Each steel sheet is one foot square and one sixth of an inch thick. The pieces sheared off and other wastage are returned to the Government, so that nothing is lost.

Careful tests are first made of each sheet, to determine if it is free from flaws. The lives of thousands of men depend upon the thoroughness of these tests. Each sheet is then placed between "male" and "female" dies, and under enormous pressure it is forced into the familiar shape. The process is accompanied by a piercing shriek from the steel. The next machine cuts away the edge, or brim, with a single blow. An electric welding apparatus is used to join the parts and smooth the rim.

It is important that the steel be colored, so that it will not reflect the light and thus make a conspicuous target for the enemy. The French color their helmets blue, while the British sprinkle sand over theirs. The American helmets are treated with a secret preparation that kills reflection and at the same time is a poor conductor of heat. Our helmets are finished by inserting a special lining that keeps the head from touching the steel sides and absorbs the shock of all impacts. The American helmet, complete, weighs less than two pounds.

Since the adoption of these helmets the number of cranial wounds has considerably increased, but a large proportion of such wounds are curable. Before a helmet was worn, fewer men were treated for cranial wounds, for the simple reason that wounds of this nature were usually fatal. The latest form of helmet that has been found in captured German trenches is designed to resist even direct rifle-fire. It is made of Krupp steel one fourth of an inch thick, which makes the head-piece too heavy to be carried about. These helmets have only been picked up in first-line German trenches, and it is supposed that they are only worn when the men are on duty, to protect them against snipers.

Many engineers in America and Europe believe it possible to construct a bullet-proof shield or cuirass sufficiently light and portable to be made part of the modern soldier's equipment. Several years ago it was thought that the problem had been solved by a German inventor who devised a shield the height of a man, consisting of four or six hinged parts that could be rolled up and carried about with ease. It was found to successfully resist bullets fired only twenty-three feet away. Before any general use could be made of the invention the penetrating power of bullets was increased, and the shield proved useless, except to turn aside glancing blows or pieces of shrapnel.

A later plan has been to make the cuirass of steel covered with special padding of cotton, over which, in turn, is placed thin metal bands. A flexible cuirass has been made of a series of metal spheres held together by hooks and eyes. Still another plan is to build up a resisting fabric by means of a series of hollow metal balls. A French inventor has devised an elastic cushion, a combination of springs and sockets filled with rubber. The theory of these cushion-formations is that the bullet will embed itself without penetrating, the force of the impact being taken up before the missile passes through the fabric.

Many designs have been suggested for applying such protection. It is urged by some that it be used exactly as were the metal plates in early armor, or that portable bucklers or shields be fastened by leather bracelets to the left arm of the soldier and used in an advance as a shield.

Many military authorities also believe that great advantage may be gained by utilizing the knapsack carried by soldiers, his entrenching tools, and even his clothes for defensive purposes. Many forms of knapsacks have been designed to resist bullets and shrapnel. When fully loaded they offer considerable resistance. By placing them upright, a miniature breastwork is formed that protects the soldier from ordinary rifle-fire. Scientific tests have been made with various forms of knapsacks by firing at them from different ranges. It was found that two knapsacks placed together would resist forty per cent. of all balls fired at them from a range of eight hundred paces. The metal tools used by the infantry, and especially by the engineering regiments, are also used with good effect. A trench-spade driven into the ground and backed with a few shovels of earth often proves surprisingly effective. The ingenuity of the engineers now fighting at the front is expected to devise many new forms of protection.

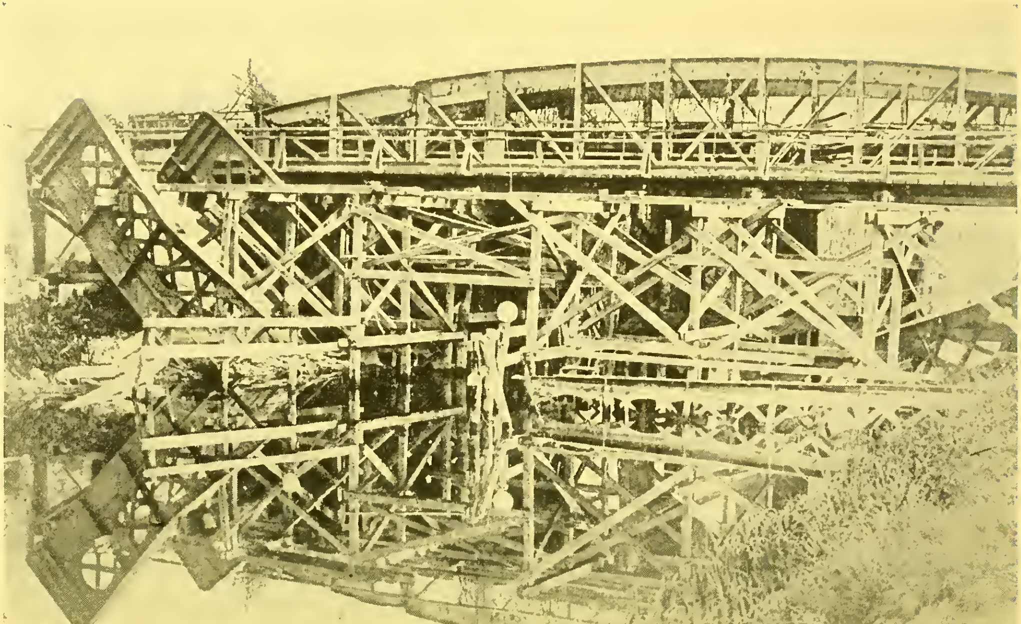
CHAPTER IX

AMERICAN VERSATILITY

THE great industrial army recruited in America will comprise some forty regiments, elaborately equipped for service in France. Within a year the engineering forces of our army have been increased 1660 per cent. Meanwhile the purchasing power of the Engineer Corps has been raised 2250 per cent. During the first three months of mobilization the General Engineering Depot spent $175,000,000, and during the fiscal year the total was about $375,000,000. The cost of the Panama Canal, which heretofore was the high-water mark for all engineering expenditures, seems trifling by comparison. This immense budget has made possible the designing, specification, purchase, gathering into central depots, and forwarding of all engineering materials and equipment supplied

French Official Photograph

A problem for the waterways engineers



Temporary bridge construction

our army, as well as all engineering operations in the field.

The names of the regiments of engineers already recruited will give some idea of the energy and versatility of these forces. The classification is as follows:

Water-Supply	Mining
Highway	Quarrying
Light railroading	General Construction
Standard-gage Railroading	Engineers' Supplies
Gas and Flame	Surveying
Forestry	Army and Pontoon Post

When America entered the war France designated certain seaports for the exclusive use of the ships landing our armies and supplies. Our engineers found these were tidal ports, and special docks had to be built to accommodate the unprecedented demands of our fleet. The work was handed over to the engineers, who quickly prepared complete plans for building elaborate docking facilities.

These docks were fabricated in America

and sent to France to be placed in position. Every detail of their construction was prepared on this side of the Atlantic, including the piles for the docks, the flooring, and houses for the protection of men and provisions. An immense amount of machinery for handling heavy weights, including many powerful cranes, was designed to meet the peculiar demands of this work. With the aid of these American-built docks and machinery, the enormous task of disembarking an army of hundreds of thousands of men has been carried on without mishap.

A favorable impression has been made in France by the system of repair-shops built and operated by American engineers. The steel for many buildings was prepared in the United States in an incredibly short time, and put together in France with a speed that suggests the erection of Aladdin's palace. An order was placed in America, for instance, for 4000 steel hangars, measuring 68 by 165 feet, each to house four aëroplanes. This order was executed in less than sixty days. The field repair-shops, incidentally, are usually placed as near as possible to the front to save time in transporting broken machinery. They are never built close together, but at intervals of a half-mile or more, so as to offer an inconspicuous target.

Equipped with American machinery and manned by skilled workmen, these shops are prepared to mend every conceivable form of fighting-machine. The guns, large and small, require constant attention. Should a great gun get out of order, every moment of delay in bringing it into action may be priceless. Again, the tens of thousands of automobiles behind the front require constant repairs. The life of some of the more delicate aëro-motors proves to be only about forty hours at the front, after which they must be reground.

In recruiting these engineering regiments every conceivable service seems to have been anticipated. The engineering regiments include a number of expert workers on bicycles. From the tons of litter picked up on the battle-fields, the broken parts of bicycles are carefully sorted out and put aside.

Many of the wheels used have been standardized, which simplifies the work. The wrecks of wheels that seem beyond hope are combined in order that nothing shall be wasted. Companies of motor-cyclists use up their wheels very quickly, and by keeping the workers busy, thousands of wheels are reclaimed. There are, besides, many hospitals for broken rifles, where injured weapons are repaired or parts of guns are stored for future use. The saving that results from this scientific economy amounts to millions of dollars a year.

As might be expected, the electrical industries of America are well represented in the engineering regiments. Several of the largest manufacturing plants have sent their officials, who are well-known engineers, while hundreds of experienced workers in every branch of constructive work have volunteered. These American units are prepared to take over bodily every imaginable electrical enterprise, install a new system or operate an old one, without an hour's delay. So many American inventions are in common use abroad, and the French have made such general use of our electrical machinery, that American electricians report that they find themselves much at home in the work.

An immense amount of electrical work must be carried on at the front and immediately behind it. Great distributing systems for operating electric-lights and supplying power have been established and operated in the war zone. A large and uniform supply of current must be provided for headquarters, cantonments, artillery repair-shops, and hospitals, as well as for the air service and the reconstruction bases. If, through any carelessness or inefficiency, the power should be cut off for a single hour, the loss would prove serious. Again, a well-directed shot may at any moment of the day or night destroy conduits vital to the machinery, and repairs must be made, however difficult the conditions, with the greatest expedition. The linesmen, as well as the engineers, in the electrical stations near the front frequently perform highly technical work while under fire.

The ingenuity of our engineers has proved valuable in the conservation of electrical power in many cities and towns in France. The electrical industry has often been demoralized, especially in cities near the front. Thousands of Frenchmen have had to go to the trenches, and production has consequently suffered. American engineers have accomplished marvels in meeting this power-famine. In some localities the electrical system has been completely reorganized. Important plants have been combined, and all unnecessary waste has been eliminated.

The allotment of power to street-cars and for street-lights has been systematically reduced, in order that manufacturing industries essential to the war might not suffer. In some sections a census has been taken of all the electrical machinery, so that every part may be utilized. The new power-plants constructed and the system installed by introducing the latest American methods will prove of great permanent value to France.

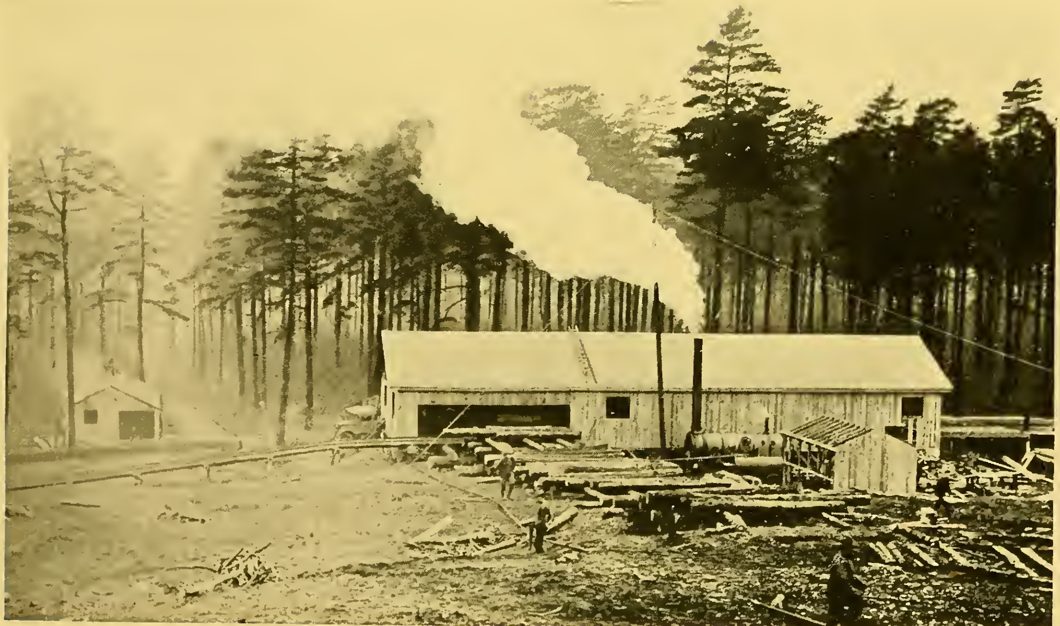
The engineers of the Signal Corps often have to face great peril. Telephone communication is so vital a matter at the front that communicating lines of wire must be laid at any cost. When an advance is prepared, the telephone linesmen, with their material in hand, are held in readiness. They carry an ample supply of heavily insulated copper telephone-wire,—for the lines are often run along the ground,—with their equipment for setting up a loud-speaking telephone. First the heavy artillery-fire prepares the way and sweeps the front trenches of the enemy. Heavy smoke-bombs are then thrown to conceal the advance, and at a signal the men go "over the top."

The signal-men follow closely. They carry reels of wire, which they run out as they struggle forward. If a linesman falls, another takes his place. There is no time, as a rule, to arrange supports for the wire, and in the barren wastes of no-man's-land no tree nor stick remains to which to attach them. The wires are run rapidly from point to point, until the field is covered with a network of communicating lines. A chance shell from the enemy may destroy these wires at any moment, when the work must be repeated.

Such work is often complicated by lack of supplies. In a hurried advance the electrical equipment may be lost, and the signal-men must then work with whatever makeshift material they find at hand. An engineer, finding himself one day on a battle-field hopelessly far from his base of supply, improvised a working-station entirely of waste material. A switchboard, capable of serving five stations, was contrived entirely from material picked up on the battle-field. The metal was supplied by an eighteen-pound cartridge-case. This was fastened to boards with screws taken from ammunition-boxes. The plugs consisted of .303 rifle cartridge-cases, and fuses and pieces of picked-up wire completed the installation.

As the infantry advance, it is of vital importance that the heavy batteries far in the rear be informed of their progress and their exact position. The signal-men rush forward, the wires are connected with the instruments they carry, and news of their progress is sent to the batteries at the rear. Artillery fire can thus be directed from a position perhaps miles at the rear; otherwise the shells might fall alike on friend and foe.

Few of the fighting engineers face greater



Familiar American architecture in a French forest

French Official Photograph

All that remains of a French forest

danger than do the men recruited for the Gas and Flame Regiment. As the name suggests, these engineers direct the work of producing liquid fire, which is employed before an attack. These men must be experienced chemists, and the preparation of inflammable solutions is left to them. Streams of burning oil are often shot forward a distance of 150 feet.

The Gas and Flame Unit is officially known as the Thirtieth Engineers. In enlisting this regiment, men between the ages of eighteen and forty-five have been taken. Every member was obliged to have some technical experience which fitted him for the work. The regiment, therefore, includes chemists, mechanical engineers, explosive gas-workers, electricians, gas-experts, mechanics, pipe-fitters, and special interpreters. The regiment was quickly mobilized as early as October 15, 1917, and was sent to Camp American University under command of Major E. J. Atkinson. A number of English officers who were experienced in the work, were sent over to train them.

One of the engineering regiments includes a company of twenty "skyographs," a service new in warfare. These men, who are experts in their profession, are employed to analyze the bird's-eye photographs taken by aëroplane scouts. From long training, they are skilful in constructing the military maps used in planning campaigns and directing military operations. The aëro-photographers fly regularly over the lines, and take thousands of photographs from various elevations with the aid of special aëro-cameras. Such photographs are then compared with the maps of the region, and the information available and everything of military importance is indicated upon them. A few hours after the pictures are made, a general, perhaps miles behind the lines, by the aid of such map-photographs may be said to look directly down upon the enemy.

The varied experience of American bridge-builders has proved a valuable asset. The regiment recruited in the United States for this work is officered by a number of engineers selected from railroad companies, the Army, and official bodies, while the rank and file is made up of men trained by years of experience in actual construction work. With such a force, every problem abroad may be attacked with confidence. Widely scattered over Northern France, American engineers are to-day actively engaged in building a variety of bridges, great and small.

Compared with European standards, American engineering work sets a fast pace. In the present operations every effort has been made to improve upon our own best records, often with amazing success. Unloading of ships in France has been speeded up, so that the work is being done to-day in less than one third the time usually required. The first order in America for standard-gage locomotives of the ninety-ton type, calling for three hundred units, was placed on July 19, and delivery was required in October. The first locomotive was delivered, complete, on August 1. This was followed by a second order for 680 locomotives of the same type.

In some respects the most notable constructive work of the American engineers is the great ordnance base "somewhere in France." It is really an industrial city in which every unit is carefully organized for constructive work. The cost of building this plant is estimated at $25,000,000, while the tool equipment cost is an additional $5,000,000. The plant includes twenty large storehouses, twelve shop-buildings, and one hundred smaller shops and magazines.

One of its important features is a great gun repair-plant, equipped to handle more than 800 field-guns of all sizes each month. In connection with this is a gun-carriage repair-shop of large capacity, where 1200 vehicles may be repaired monthly. The small-arms repair-shop has a capacity of 50,000 small-arms and machine-guns a month. Furthermore, there will be a large shop for repairing horse and infantry equipment. The reloading plant is capable of renewing 100,000 artillery cartridge-cases a day. In connection with this tremendous activity there are innumerable forges, carpenter-shops, and auxiliary buildings. A population of 16,000 men and 450 officers is required to carry on this base. More than 8000 men have already enlisted in America for the work, and the training of these highly technical troops is progressing rapidly.

The Allied governments have been amazed at America's facilities for turning out steel and iron constructive material. In building thousands of steel structures throughout the country the number of constructive plants has been greatly increased in recent years, and the time required to fill orders has been cut far below European standards. The facilities of such plants were well illustrated in the filling of a recent order for one hundred steel warehouses. The buildings were to measure 50 by 400 feet, with a height of 16 feet below the trusses, the sides and the roofs to be made entirely of galvanized steel. Each building required 175 tons of steel. The order was received at the depot on a Thursday afternoon at four o'clock. By the following Saturday at four,—within forty-eight hours,—the entire job had been designed in detail, and orders for the parts had been placed with seven different fabricating shops. Seventy-five of the buildings were delivered, complete, in six weeks, and the remainder followed shortly. An order was recently filled for 750,000 sheets of corrugated iron, to be shipped at once.

On retreating from any occupied territory the Germans and Austrians often content themselves with destroying the central support of a bridge, leaving the spans to fall to the bottom of the river or ravine, as the case may be. Such a bridge is restored in a surprisingly short time by rebuilding the central pier and raising the spans to their original position. The bridge-building engineers employ a make-shift pile-driver, which works with surprising rapidity. Power-plants are usually hard to find, but man-power is likely to be plentiful. A heavy weight is quickly rigged with pulleys, and a hundred or more men, pulling on the rope, raise the weight, then let it drop, forcing the pile into the earth with slow but steady blows.

Every detail of the work that can be prepared is, of course, done in advance. Not only are the plans made in detail for bridging a variety of openings, but bridges of various designs are built and then knocked down, ready to be carried away and put together again. For small spans, a steel bridge is sometimes used. This can be set up in different lengths. The parts are cut and drilled, so that when put in place they will fit as neatly as a puzzle. No riveting is required, the parts being fastened together with bolts that may be driven with an ordinary hammer. Such bridges may be set up very quickly.

The engineering regiments are liberally supplied with expert photographers equipped with up-to-date apparatus. The skill and daring of the camera-man is proving invaluable in a variety of war activities. In many cases the photographers form an advance-guard, and may be compared to the sharpshooters or pickets who fight in advance of the main body. It often happens, for example, that the advance-guard will reach a bridge, or the site of a bridge, made untenable by the enemy's fire. It may be imperative that the bridge-builders at once survey the location and make their plans for building a new structure with the least possible delay. A deadly fire, meanwhile, may render the position practically impossible. For the engineers to expose themselves, while they examined the injured structure and made the necessary measurements, would mean almost certain death.

The alert camera-man, however, readily solves the problem. By slowly crawling forward, taking advantage of every tree and rock, or it may be by a rapid dash, he secures snap-shots of the bridge from one point of view after another, with the details of the approach. Such a set of photographs are well worth the risk. The exposed films are then rushed to the rear, to be developed and enlarged with the least possible delay. The prints serve as rough working-drawings from which the engineers, in this case the experienced bridge-builders, may calculate the size of the parts required to restore the bridge or to construct a new structure. The parts are quickly prepared and hurried forward, where a corps of engineers assemble them, and the chasm is bridged or the old structure is sufficiently repaired to enable the troops to advance. The fearlessness of the camera-men has thus saved many valuable days.

The camera serves the road-builders in

An example of destructive engineering

After a "retreat to victory"

much the same way. If a railroad is to be laid, the photographers accompany the surveyors in advance of the workmen, and incidentally often face a very lively peril while working in disputed territory. The photographs thus obtained show the engineers the nature of the ground to be traversed and assist them in preparing material in advance. The builders of highways have also learned to depend upon the camera-man. A section of road that is to be repaired, for instance, is photographed in detail from various angles. From this evidence the road-construction engineers can readily determine the nature of material needed for repairs and can calculate the quantity required. When a road is projected across new territory the staff-photographers are first sent out to make detailed pictures of the ground. From these the engineers at the bases far in the rear may make their plans in detail. So much depends upon the highways in this war that the work of the camera-men in facilitating such construction often proves invaluable. When any territory is to be evacuated, once more the photographers picture every detail of the ground, the buildings, bridges, possible observation-posts, streams, and other natural features. If the country falls into the hands of the enemy, they thus retain an accurate, detailed record that will prove valuable to the artillery and to the aëroplane scouts in subsequent operations.

In no other country is the camera so common as in America. In some form it is in the hands of all classes, even to the furthermost corners of the land. Years of practice have served to develop a surprisingly high degree of skill in picture-taking. The Government therefore draws upon an inexhaustible supply in recruiting men for photographic work.

The fighting engineers so often find themselves under fire that elaborate concrete shelters, or *abris,* are built at frequent intervals. These shelters are built of brick or concrete, with solid, concrete roofs two feet or more in thickness. They are practically shell-proof. The entrances are convenient to the roads, so that workmen may quickly find shelter. From long experience the engineers have come to think scarcely more of such fire than they do of a passing thunder-storm; and as soon as it shows signs of letting up, they hurry back to their work.

The rapidity with which a towering sky-scraper rises in the United States, or a "boom" town is built on a Western prairie, has been surpassed by the erection of the great cantonments throughout the United States. A more severe test of our resourcefulness than the building of these vast wooden cities could not be conceived. The order came as a complete surprise. No material was at hand, an army of skilled workmen had to be recruited overnight for the task, and every hour had to count in the work.

The task might have daunted Aladdin himself. Sixteen wooden cities had to be built, comprising 26,500 buildings, for the housing and care of 675,000 men; two embarkation camps for 43,000 men; one quartermaster's training camp for 18,000 men; additions to the regular army barracks for 100,000 men; repair shops, units and their structures at sixteen National Guard camps to care for 462,000 men; and many large plants for our army in France. A force of 200,000 trained, skilled mechanics had to be recruited for this work. The cost of the operations,—about $187,000,000,—is more than three times the annual outlay in building the Panama Canal.

The work progressed with military precision at an unheard-of rate. The sites of the sixteen National Army cantonments were not approved until dates ranging from May 31, to June 27, 1917, but the contracts were issued, nevertheless, between June 15 and June 23, and work was commenced between June 13 and July 6. In less than three months, or on September 4, half a million men could have been accommodated at the cantonments. By December the camps were practically completed.

The total area of the cantonments is 261 square miles. In these camps alone over 800,000,000 feet of lumber were used, or enough to fill 37,000 cars, and 40,000 more cars were required to bring the other materials, making a total of 77,000 cars. Some idea of the magnitude of the task may be gained from the fact that 172,000 doors were used, 34,000,000 square feet of wall-board, 106,000 kegs of nails, 314,000 barrels of cement, 282 miles of pipe, 23,550 hydrants, and 75 miles of fire-hose. The building of these great wooden cities has been a unique achievement, one that will go down in history as a monument to the loyalty and ability of American engineers.

Preparations on this side of the Atlantic for expediting the delivery of war supplies are most impressive. A vast system of interior depots and port-terminals has been designed, which doubtless establishes a new standard of efficiency. Under the direction of the cantonment division of the quartermaster-general's office, a large force of designers perfected plans on an enormous scale. The type of construction was selected with an idea of early completion, although most of the buildings will be permanent and will be used by our Government after the war.

A series of interior depots of great capacity were first designed at points readily accessible by railroad to the large manufacturing centers. In connection with these, a number of port-terminals have been located at tidewater, where ocean-going vessels might dock, or, at least, be within lighterage distance. The products of the factories are first assembled in the interior depots by railroad or motor-truck. These depots thus come to form great reservoirs for feeding the terminal warehouses. An enormous volume of supplies can thus be moved from the interior of the United States to the coast, and finally to France, with the least possible delay.

Interior depots have been built at St. Louis, Chicago, Pittsburgh, and elsewhere convenient to the great manufacturing centers. The type of buildings varies with different localities, some being constructed of reinforced concrete, while others are entirely of steel. The first of the great port-terminals was erected at Philadelphia. One of these terminals occupies a tract of land 3800 feet in length, along a ship-canal that has a depth of 25 feet and a length of 1600 feet. Special tracks have been laid, connecting the terminal with a main-line railroad half a mile away. Along the sides of the canal two open sheds have been constructed, measuring

1100 by 160 feet, nine large storehouses, an open shed 1200 by 500 feet, together with quarters for the stevedore troops. A series of warehouses have also been built 160 feet in width, in multiples of 140 feet in length. Another of the great port-terminals has a pier extending 1500 feet, and utilizes 400,000 square feet of shed-storage.

In organizing our resources, an important use has been found for the skill of the moving-picture men. It is well known, of course, that a large proportion of the moving-pictures used the world over are made in America. A large force of men has thus been trained in the new art, and, as might be expected, this group has reached a high state of efficiency. The Government has added to its engineering regiments hundreds of men recruited from "movie" studios to assist in preparing camouflage material. Every frequenter of moving-picture theaters knows that these artists perform wonders in building villages or the semblance of cities over night. In a few hours they can produce scenes from any country or century so convincing in every detail that the most critical moving-picture audience is readily deceived.

It has been a happy idea to utilize this skill in safeguarding our armies abroad. The ingenuity displayed and the amazing facility of these war artists in their work may well be a source of pride to Americans. Working with lath and canvas or papier-mâché, the magic of the movies has been adapted to many surprising uses. After long experience in building scenes that deceive millions of "movie fans," it is an easy task for them to produce the same illusion for German military audiences. One of the most successful "sets" is a reproduction of devastated buildings in the war zone. It often happens that a fragment of a house or a church, perhaps only the corner of a wall, is left standing in no-man's land. The camouflage artists quickly reproduce the piece in life size with light wood or papier-mâché, and then paint it to duplicate the original. On some dark night, perhaps under cover of artillery fire, the original ruin is removed and the duplicate set up in its place. A day or two is allowed for the enemy to detect the deception. If the forgery passes muster, it is cautiously moved forward a few feet every night. It is often found possible to advance the piece of scenery a considerable distance nearer the enemy's lines without arousing suspicion. Meanwhile, an alert scout from a look-out at the top of the fake ruin spies upon the enemy and by means of telephone communication keeps his base supplied with information. A similar deception is often worked by keeping the ruin stationary, but to increase its height a few inches at a time until the ingenious observation-post reaches the desired elevation. Thus it becomes a matter of life and death as to how skilfully the scene-painter can practice his art.

A piece of landscape having a thousand details to deceive the eye is sometimes reproduced with perfect success. At one point on the long battle-line a road chanced to cross both trenches at right angles, so that the enemy could look for some distance up this thoroughfare. An elaborate piece of staging was prepared to reproduce this scene, and this was set up one night across the road. Viewed from a short distance, the enemy imagined that he still looked up the empty road. The painted scenery meanwhile concealed the actual road, which was quickly utilized by trains of automobiles bringing supplies and ammunition. This surprising activity went on for several weeks, until a chance shot destroyed the scenery across the road and revealed a very different picture to the amazed Germans.

Every object found on the battle-field is reproduced by these skilful stage-artists to serve some purpose. When the ground is apparently absolutely barren, some means will still be found to deceive the enemy. A stone, a log, or some piece of débris will be selected and carefully reproduced. Under cover of darkness the stone, or whatever it may be, is removed and the imitation put in its place. A day or two is given the enemy to discover the forgery. If he does not, a hole will then be hollowed out beneath the stone large enough to conceal a man, and here he may sit with his head covered by the piece of stage scenery. He must take up this perilous position at night, and remain there until the following night, but if he survives, he may be able to telephone back some highly valuable information. One of the favorite "properties" of this kind is a reproduction of a dead horse, with distended body and stiff legs pointed upward. The observer thus protected has an unusual amount of room in which to turn about and to operate his telephone.

Years are required for an industrial, peace-loving people to recruit and train a great army. Brought face to face with the forces of a distinctively military people, the United States is, of course, for the moment at a great disadvantage. Her great army of engineers, with its innumerable conquests in every field behind it, has, however, been mobilized in force at a moment's notice.

The American engineer is in no sense a superman. He has brought average skill to his work with perhaps a liberal share of American energy and alertness. His versatility is due to the simple fact that he has been trained in the greatest school of experience in the world. He has encountered every conceivable engineering problem in the United States, and with these achievements behind him, he is well prepared for any new undertaking. A New York fireman, for instance, enjoys a reputation for skill, not because he is more alert or more intelligent than the firemen in small communities, but because he fights half-a-dozen fires of all kinds every day.

In the early days of the war, when Atlantic steamers were crowded to capacity with home-coming Americans, a number of engineers were already bound in the opposite direction. Mr. William J. Hillgas, the well-known engineer, was one of the first five to reach the front, and he has since been actively employed in France. One of the first American engineers to join our forces was Mr. (now Major) William Barclay Parsons, who, it will be remembered, was the chief engineer of the Rapid Transit Commission who directed the building of New York's first subway. The foreign staff to-day includes Mr. W. S. Buck, who built the Manhattan Bridge across the East River and one of the great Niagara bridges. The engineer who built the East River Tunnel is also in France. The list might be continued indefinitely.

A force of American sanitary engineers has been entrusted with the work of cleaning up Palestine. Since the days of the Roman occupation at least, the sanitary situation throughout the Holy Lands has been a constant menace. Jerusalem with a population of 100,000 has had no water supply and no sewage system. Throughout Palestine the better classes have been obliged to import their drinking water from Austria. The system of drainage has remained extremely primitive. It is necessary to educate the public in the most fundamental principles of sanitation.

A new era will be opened for the Holy Lands with the adoption of modern American methods. Our engineers have taken with them, for instance, a complete filter system with a special chlorinator apparatus which will make it possible to supply thousands of the population of the region, with pure water. It is planned to supply at least two gallons a day for every person. For the first time in recorded history the Holy Lands will be made a decent place to live in.

The American forces will be directed by several of the best known sanitary engineers of the country, including Captain Groemiger, President of the American Society of Sanitary Engineers, Captain Pease of the Worcester Polytechnic Institute, Captain Carson, Chairman of the Research Committee of the American Society of Sanitary Engineers and others. The work of the American engineers will include the scientific drainage of great areas of swamp regions to insure permanent relief from the menace of disease. It has remained for American ingenuity and energy to utilize the pools of Solomon to purify its historic waters by modern methods, and make it available for the capital of Judea. In lending the genius of its engineers, America is making a contribution worthy of our country's best traditions.

DONALD THOMPSON IN RUSSIA

By DONALD THOMPSON

This book constitutes an amazing, contemporary, eye-witness record of Russia in revolution by an American who had to be in the midst of the cataclysm and who was interested only in seeing the facts.

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