THE ENGINEER IN WAR

Are we prepared? (Business men's training camp at Plattsburg, N. Y., 1915.)

THE ENGINEER IN WAR

WITH SPECIAL REFERENCE TO THE TRAINING OF THE ENGINEER TO MEET THE MILITARY OBLIGATIONS OF CITIZENSHIP

REPRINTED, WITH REVISIONS AND ADDITIONS, FROM THE ENGINEERING RECORD

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PREFACE

In presenting this volume to the engineering profession, the author does not aim to provide a treatise on military field engineering. A number of excellent manuals and text-books are in existence, most of which are well adapted to study by the civilian engineer.

After all, military field engineering, as its name implies, is a practical art and cannot be acquired by study alone.

Engineering plays so important a part in all the operations of warfare that it is perhaps no exaggeration to say that modern war is an application of engineering science to the armed conflicts of states.

Those who have considered our military policy cannot have failed to observe how greatly it depends upon the voluntary service of our citizens. The rights and privileges of citizenship carry with them the obligation of service to the state. But the mere tacit recognition of a duty does not insure its efficient discharge. If we acknowledge a duty we must acknowledge the necessity of preparing to perform it. If we do not prepare we are evading our duty. Practical patriotism then ceases to exist and national defense becomes a term without meaning.

In this voluntary preparation of our citizens to fulfill their obligations to the state, the civil engineer will play an important part. The non-professional man cannot under existing conditions be trained in any reasonable time to a satisfactory state of efficiency for the performance of the many and varied duties that fall to the lot of the military engineer. The nation, therefore, relies on the civilian engineers and contractors of America since they alone are qualified to prepare in time of peace for the performance of these important duties.

In the following pages is presented a brief outline of the relation of engineering to the conduct of war and the adaptation of the principles and practices of civil engineering to military requirements. If the author succeeds, to however small a degree, in arousing the interest of the engineering and contracting professions in this important question of national defense, he will feel that his effort has not been in vain.

While intended primarily for the engineer and contractor, it is hoped that the subject matter of this volume may prove of interest to all who contemplate the possibility of military service to the country in case of need. This for the reason that the practice of military field engineering is not limited to officers of engineers. Because of the comparatively small number of engineers that will be available, any officer of the combatant forces may be called upon to practice the art and cannot be regarded as properly trained unless he is prepared to do so.

Cleveland, O.
April, 1916.

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THE ENGINEER IN WAR

CHAPTER I

THE MILITARY POLICY OF THE UNITED STATES

The principal problem confronting the nation today is that of preparedness for defense. There is an indication that our people are awakening, partially at least, from the sense of false security in which they had been blissfully reposing for many years. This feeling of security which has hitherto been characteristic of the American people is the result largely of the ultimate success that has attended our several armed conflicts. The nation has not yet experienced the chastening discipline of defeat. There is also prevalent an idea that great resources in men and materials of themselves constitute great military strength. As to the first of these popular ideas it is to be remarked that our successes have been unearned. We have triumphed, not because of our efficiency, but in spite of our inefficiency. The systematic and intelligent progress that have marked our industrial growth have been conspicuously lacking in our military affairs. We have never entered the lists with a powerful nation trained for the conflict and able to turn its strength against us. To this fact we have more than once owed our national existence. Our popular histories record in glowing words our successes but they do not record the enormous and unnecessary expenditures of blood and treasure with which these successes have been purchased nor the grave risks of national dissolution which we have incurred. For a proper appreciation of the misconception that great resources constitute great strength we have only to consider the case of China, the most populous nation on earth and possessor of vast unorganized resources, yet utterly lacking in military strength and powerless to protect herself from aggression. The military strength of a government at any instant is only the power it can bring to bear upon the field of battle.

War today is one of the most highly developed of the sciences—the field of the expert and the professional. This being the case there is more than at any time in the past a need of adequate preparation in advance of the outbreak of hostilities. Preparation for defense is merely a form of **national life, fire or accident insurance.** When the conflagration has broken forth it is too late to organize the fire insurance company or the fire department. Fire is an unreasoning element which strikes alike the insured and uninsured. War is destruction endowed with judgment and perception, it prefers deliberately to select the uninsured.

The preparation for war is of two kinds: one of material things—the construction of battleships, submarines and coast defenses, the fabrication of weapons, munitions and supplies; the other, the organization and training of the people. While both are necessary, the latter is the more important as well as the more difficult to provide.

The modern theory of war as exemplified in the practice of the so-called military nations, is that all the resources of the state—moral physical and intellectual—should be at the disposal of the government. War is the most critical condition of the modern state with its highly developed and peculiarly sensitive and vulnerable industrial and commercial systems. For the successful prosecution of a conflict, on which the very fate of the nation may depend, every ounce of its strength should be available. The aim is to strike quickly with all the force at the nation's command. That state is best prepared which can most rapidly bring to bear its resources in men and materials. In this modern theory is involved the principle that every able-bodied male citizen owes to the state the obligation of service. This principle is not incompatible with democratic ideals and is recognized in theory by our own constitution. The greater the benefits conferred by the government, the greater the resulting obligation of the citizen. **The nearest approach to perfection** in the application of this theory of war is exhibited by the German Empire. Whatever may be our personal sympathies we can not withhold our admiration for the splendid efficiency of the German military machine and the complete mobilization of the material resources of the Empire. The history of this state shows that the military system is the mother of the German Empire. Bismarck, the statesman, planned the greater Germany, but Von Moltke, the soldier, created it when he destroyed in two short campaigns the military power of Austria and France.

The German system, then, may be regarded as the most effective policy of national preparation for war, and it will be of interest to consider its principal features. In the first place the training of the personnel is what is known as universal, which is to say that it is applied to a very large proportion of the male inhabitants. In the second place, it is compulsory. In the third place, it is regular. The standing army constitutes a school in which all men receive in their youth the regular training necessary to qualify them for field service, after which they are passed to the reserves and allowed to pursue the vocations of civil life, being occasionally called out for short periods of training. They thus constitute a military asset until they reach the age of physical disability, but are not withdrawn from the pursuits of civil life. This excellent system of general training is supplemented and made effective by governmental control of the material resources of the country, including the transportation, agricultural and industrial systems, to the end that they may be instantly brought into efficient service in case of war. This mobilization of the resources of the country, both material and personnel, is controlled by a large corps of highly trained officers known as the Great General Staff. Such, in brief, is the German system, which exemplifies the modern theory hereinbefore referred to, that all the resources of the state, moral, physical and intellectual, should be at the immediate disposal of the government in case of war. Such a system is most effectual under a highly centralized, indeed a despotic form of government. But it is not limited to such, inasmuch as France, a republic, has adopted and carried out practically the same system as Germany. On the other hand, China, hitherto and possibly again to be one of the most despotic of governments, has no military policy whatever, unless peace at any price may be so called.

In contrast with the efficient systems of the continental powers of Europe **the defects of our own military policy** are most glaring. "Whether we may be willing to admit it or not," says Gen. Upton, "in the conduct of war, we have rejected the practice of European nations and, with little variation, have thus far pursued the policy of China." It is not the purpose of the author to dwell at length upon the defects of our system nor to detail the mistakes that have characterized the conduct of our past wars, but to look hopefully to the future. In recent years there has been a marked improvement in our national defense. The regular army has been enlarged, a general staff has been established, and the system of instruction for both officers and men has been greatly extended and improved. The militia of the several states has been brought into closer relation with the federal government, and better methods of instruction inaugurated. We are still, however, very far below European standards. Our military policy has not kept pace with the growth of our population, the advance in the science of war and the constantly augmented strength of other nations.

There is promise that the present agitation for national defense may result in further strengthening and improvement of our organized forces, but the outcome is still uncertain and our discussion is based, therefore, on the policy as it exists today. This policy is perhaps the logical outcome of a firmly rooted national prejudice against large standing armies. Our form of government and the spirit of our people at present preclude that efficient form of preparation adopted by the Europeans and characterized by large standing armies and reserves and compulsory regular training. It is doubtful if anything short of a great national calamity will cause a radical change in this policy. We can and should, however, do everything possible under the restrictions imposed by the temper of our people to make the national defense effective, or rather to decrease its inefficiency, to plan for the future and avoid some of the mistakes of the past.

Our organized land forces at present consist of a well-trained standing army of about 100,000 men, and a partially trained national guard having an enrolled strength of about 130,000 and an effective strength less than this figure. Neither organization is provided with a reserve. The demands of our oversea possessions considerably reduce the number of regular troops available for home defense. In all, we might muster for the field army in case of invasion 125,000 men, most of whom would be only partially trained—not first-line troops as that term would be understood in Europe. This is not an imposing array certainly, for the greatest of nations, having some 18,000,000 men capable of bearing arms. For the rest, we should have to depend upon volunteers or conscripts, men with little or no training, who would require months to fit them even for defensive warfare against the highly trained troops of a foreign foe. In this connection it will be of interest to note that the British government has recently resorted to compulsory service and has announced the policy that hereafter no troops not having at least one year of constant training will be sent to the front. Such is the result of the bitter experience derived from opposing imperfectly trained volunteers to the highly trained German regulars. At present our chief reliance for defense is in these same imperfectly trained volunteers. The prospect is not a cheerful one nor calculated to arouse our pride and fill us with confidence.

What would be required in the event of war? This, of course, is problematical. The nations of Europe assume in advance that their entire strength may be required, and this is actually the case of several of them in the present war. A protracted struggle with a combination of foreign powers might call for several millions of men. The following table, prepared by the General Staff of the Army, shows the expeditionary forces which, in the event that our navy were defeated or bottled up, could be landed on our shores:

State	Strength of regular force	First expedition.	Time, days	Second expedition	Time, days
Austria	4,320,000	72,000	20.7	108,000	40.4
France	5,000,000	161,000	15.8	243,000	30.0
Germany	5,000,000	387,000	15.8	440,000	30.8
Great Britain	695,000	170,000	14.0	....	27.0
Italy	2,600,000	91,000	18.3	136,000	35.0
Japan	2,212,000	96,000	22.5	143,000	41.0
Russia	5,000,000	38,000	20.5	66,000	40.0

To repel possible attacks of this nature the General Staff recommends the following:

500,000 men at the outbreak of war.
500,000 men in ninety days thereafter.
500,000 men to replace casualties.

For the purposes of our discussion then, we will assume that **a volunteer army of 1,250,000 men** will be required. This is a modest figure. It is to be noted that it contemplates strategical defensive measures in particular. Such a force would be totally inadequate to a foreign invasion except of a weak neighbor, such as Mexico. It would not serve to maintain the "Monroe Doctrine" in the face of determined aggression by a great foreign power, especially when the inadequacy of our water transport facilities is considered. Preparedness for defense of our own territory does not, of course, preclude the possibility of offensive tactical operations, and it is the blows which we strike and not those which we fend that win the victory. But it does condemn us in advance to suffer all the ruin and agony of war on our own soil in case of aggression by a great foreign power. And we should not overlook the fact that our Atlantic seaboard, the most populous, wealthy and highly developed, and hence the most vulnerable portion of our domain, might be the theater of the early stages of war. Whatever the final outcome of the conflict, the ruin and suffering in our own fair land would be very great. Germany, the greatest of the military nations, does not entertain the defensive policy of preparedness. Her theory is that an active offensive is the best defense and her thorough preparation has enabled her at the outset to carry the war into the enemies' territory and, thus far, to keep it there. Thus is Germany spared the ravages of war on her own soil.

Without entering into the intricacies of army organization suffice it to assume that this force would consist of 62 divisions of about 20,000 men each. These would be further organized into field armies consisting of two or more divisions, say 20 in all. And, finally, they would constitute four main armies, each including five field armies.

Now let us consider the **engineer troops** that would be required for service with this force. **The proportion of engineer troops** with an army in the field which experience indicates to be correct is from $\frac{1}{40}$ to $\frac{1}{16}$. Considering the vast extent of our territory, the generally poor condition of our roads and the inexperience of our volunteer troops, it is certain that the services of engineer troops will be urgently needed. It is safe to say that no army has ever had an excess of engineer troops. The demands upon them have invariably been greater than their capacity. Our organization contemplates one battalion of engineers with each division, and an additional battalion as auxiliary to each field army. Each of the four main armies would require as a minimum two additional battalions. Besides this there would be required engineers on the lines of communication and at the main supply depots. The number and efficiency of our railroads would operate to reduce the number of engineers required on the lines of communication, unless these were subject to attack by the enemy

—a not unlikely contingency. Let us assume then the following force:

	Battalions
Attached to divisions	62
Attached to field armies	20
Attached to armies	8
On lines of communication and at depots	10
Total	100

These battalions would include, on the average, 500 men and 14 officers each. **Total, 50,000 men and 1,400 officers.** This gives a proportion of approximately $\frac{1}{25}$ for the assumed force of 1,250,000 men, which is none too large. In addition to this, a considerable number of engineer officers would be required for service in the War Department and on the staffs of the generals commanding divisions and armies. In many of the divisions the senior engineer officer with the troops would act also on the staff of the commanding general. The following engineer personnel (officers) is assumed as necessary for staff duty:

On division staffs	24
On field army staffs	32
On army staffs	12
On lines of communication and at depots	12
At the War Department (General Staff and Office of Chief of Engineers)	20
Total	100

To recapitulate, say—

50,000 men
1,500 officers

The regular army at present includes 12 companies of engineers and 248 officers. There are very few organized engineer units in the national guard. New York has two battalions of 4 companies each, and Ohio a battalion of 4 companies. Certain other states have companies or detachments. In all, the guard might muster not to exceed 6 battalions at war strength, with 84 officers. The regular engineers might, with some delay and loss of efficiency, be expanded into 6 battalions. **Thus the total available personnel** of the regular army and national guard would be 6,000 men and 332 officers. A very considerable number of the regular officers would be required in the training of the volunteer engineers, in the control of civilian contractors and laborers in the land defense works of our important cities and arsenals and works on the lines of communication, the direction of civilian surveyors in the preparation of military maps of the theaters of war, and many other special duties. But assuming that all were available for the tactical duties hereinbefore outlined, there remains a deficiency of 1,200 officers and 44,000 men.

History has demonstrated again and again that **efficient trained officers** are the most important part of an army. In the hands of competent officers green troops have been known to give a good account of themselves, whereas the best troops have been uselessly sacrificed by incompetent leaders. Napoleon is credited with the statement that he would rather have an army of lambs commanded by lions than an army of lions commanded by lambs. These truths will be almost self-evident and they are especially applicable to engineer troops on account of the variety of their duties. To obtain trained officers is more difficult than to obtain trained troops, since the time and effort required to fit officers for the performance of their duties is greater than in the case of enlisted men. The officers for this engineer force are accordingly our chief concern.

An officer to command engineer troops should have the following qualifications:

It is essential that he have a good constitution, able to withstand the hardships of a campaign. He should be a man of high professional qualifications, both as a soldier and as an engineer. Without such qualifications an engineer officer can not properly plan nor execute the varied works that will be assigned to him, nor properly subordinate his work to the needs of the combatant forces; he can not command the respect and confidence of his own men and can not, consequently, maintain discipline. He should be zealous in the performance of his duty—which ordinarily implies an interest in his work, resourceful, and last but not least, a student of human nature, knowing how to handle men so as to produce the best results under trying circumstances. Whence and how, under present conditions, are 1,200 trained engineer officers to be obtained in the event of war?

It is essential under our present policy that we **provide for a large reserve of** at least partially trained men. The object of this partial training is, of course, to reduce as much as possible the time required for the final training of the volunteer army that would be assembled at the outbreak of war. The time required to train the officers will be greater than in the case of the men and accordingly special attention must be devoted to the peace training of the men on whom we must rely to furnish officers for this vast force of volunteers. The officer of engineers must be **not only a trained and disciplined soldier** but in addition **a competent and experienced engineer.** In other words, he must have training along two lines to fit him for the discharge of his duties. It is not sufficient that he be instructed merely in the technical details of his work. He must have his tactical sense so developed as to be able to grasp the situation of the moment and intelligently bend his energies to meet it with suitable works. This means that the volunteer engineer officer could not be brought to the same state of efficiency in his own lines as quickly as the volunteer infantry officer, unless he had previous training and experience in civil engineering. The volunteers taking the field should be trained to a certain minimum standard of efficiency. Otherwise, efficient infantry would be severely handicapped by being forced to depend upon inefficient engineers. If this necessary condition is to be realized it is evident that we must obtain our volunteer engineer officers from a class of men having previous training along engineering and construction lines. The nation then **depends upon the engineering and contracting professions** to furnish these men.

If our volunteer engineer officers are to be fitted to take the field on a plane of equality with volunteer officers of the other arms, special effort in the way of preliminary training will be necessary. **Military engineering in a general sense** is the adaptation of civil engineering to the conduct of war. It is a special application of the engineering art, and its methods and economics are essentially different from those which characterize good civil practice. It is our purpose to inquire into the relation of engineering to the conduct of war and the methods characteristic of military engineering, to the end that the civil engineers and contractors of the United States may partially prepare themselves in advance for the patriotic duty which they may be called upon to perform.

There is no science known to mankind, from astronomy to bacteriology, which does not find its application in the conduct of war. There is scarcely a practitioner or artisan who may not contribute his share to the national defense. Even the clergyman and the musician, the exponents of peace on earth and the gentlest of the arts, are called upon. Thus do we obtain a practical conception of the theory that all the intellectual resources of the nation should be at the command of the government in the prosecution of a war on which the fate of the nation may depend. Of the peaceful arts that contribute the results of their research and practice to the successful prosecution of war, none is of more vital importance than engineering.

CHAPTER II

GENERAL DUTIES OF THE MILITARY ENGINEER AND ECONOMICS OF MILITARY ENGINEERING

The duty of the military engineer in time of war is to plan and execute all works of an engineering nature which are required in connection with the operations of the army. It will be apparent that this is a wide field of endeavor. The engineering requirements of an army include most of those of the average large community, and in addition many others not called for by the gentle vocations of peace. The military engineer must have, therefore, **a thorough working knowledge** of the more important branches of civil, mechanical and electrical engineering as applied to military needs. This might appear to be more than an average man could be expected to know, and so it would be did we demand of the military engineer all the precision and nicety characteristic of civil practice. **Military engineering,** in rather sharp contrast to good civil practice, **is characterized by makeshifts** and temporary expedients. "Build for posterity," says the civil engineer. He places the foundations of his bridge at great expense of time and labor on the solid rock and he has a just pride in the enduring nature of the structure he erects. In his brain is the accumulated knowledge of centuries of painstaking construction. Long after his death the great bridge remains, a monument to his skill and devotion. How different is the case of the military engineer. Not for posterity builds he, but for the exigency of the moment. Not on the solid rock does he place his foundations, but often on the heaving bosom of the stream itself. The army arrives at the impassable stream and the engineer rapidly scans the situation. In his brain also is the accumulated knowledge of centuries of scientific warfare. Aladdin's lamp is rubbed. And lo, in the twinkling of an eye, the wonderful bridge is there and the army with all its animals and heavy vehicles proceeds across. To the frail but still adequate structure are committed, not only the lives of the troops, but the destinies of the nation perhaps.

The military engineer must possess not only a thorough knowledge of construction but also a thorough knowledge of the art of warfare. He must foresee the needs of the army and build to meet those needs, and on his sagacity, energy, foresight and resourcefulness the issue of the campaign may indeed depend.

The duties of engineer troops in the United States Army in time of war may, with respect to location, be classified as follows:

1. At bases, mobilization camps and advance supply depots.
2. On the line of communications.
3. In the attack and defense of fortified places (siege operations).
4. With the mobile army in the field.

Each of these is further capable of subdivision, and may include a great variety of works. **Duty with the mobile army** is the prime function of engineer troops, and is the one on which their organization, training, and equipment should primarily be based. All other engineering duties (except possibly siege operations) must be regarded as special. They will, when necessary, be performed by engineer troops, either regular or volunteer, with such changes or additions in personnel or equipment, civilian assistance, etc., as the special situation or exigency may demand.

The engineer troops for field service should be with the combatant forces at the front, at all times subject to the immediate orders of the commanders of the divisions or armies to which they may be attached. Their duties will be intimately connected with the movements and tactical operations of the fighting forces, and should be characterized by extreme rapidity, full use of local resources, and a thoroughness all sufficient unto the immediate needs and *no more* than sufficient. Subject to these conditions, the operations of the field engineers may be roughly classified as follows:

1. Operations to facilitate the rapid movement of the combatant forces.

2. Operations to increase the offensive or defensive powers of the combatant forces and to limit or decrease those of the enemy.

3. Operations to maintain the health and promote the comfort of the troops. In brief, these duties may be classed as—

1. Transportation.
2. Fortification.
3. Sanitation.

In short, promoting and conserving the operating efficiency of the troops. The works required under these heads will be numerous and varied according to the course of the campaign, the nature of the theater of operations, the season, the weather, and other conditions. The most extended catalogue of such works would still be incomplete, but a statement somewhat in detail of the more important duties ordinarily to be performed, is necessary as a basis for our discussion.

It is of the utmost importance in every case to draw the line of demarcation between the duties of the field engineers at the front and those which properly pertain to the engineer or other personnel on the lines of communication. This is necessary in order to insure smooth coöperation, and the presence in every tactical emergency of the mobile engineer troops with the combatant forces. The supreme commander in the field will in each case prescribe and limit the functions of the two organizations. Those of the field engineers should include no work which might have been performed by others. There will be enough which they alone can execute, and their energies should not be frittered away on work for which other special troops or civilians are or might be made available.

The more important special duties of engineer troops in the mobile army may include:

1. Reconnaissance of the natural and cultural features of the terrain, preliminary to tactical operations, or for other purposes. Reconnaissance of hostile works and dispositions.

2. Collection of maps and other data from local sources.

3. Correction and amplification of existing charts.

4. Mapping of limited portions of the terrain within the sphere of tactical operations, and other minor survey duties.

5. Map reproduction, field methods.

6. Collection and utilization of local engineering resources in personnel and material.

7. Laying out of defensive positions and points of support.

8. Planning and superintendence of offensive or defensive field fortifications, including obstacles, sapping and mining, etc., and the execution of the more difficult tasks in connection therewith.

9. Laying out and improving camps.

10. Sanitation, including water supply and sewage disposal.

11. Construction and repair of roads, railroads and bridges.

12. Construction of temporary buildings, and repair of permanent buildings and other structures.

13. Military demolitions.

—etc., etc.——

Engineer troops must also be trained to take their place on the firing line in battle, the same as the infantry.

The ideal engineer troops are those prepared to execute all tasks which may be assigned them, and the engineers of the United States Army are trained with this end in view. In the field they must not only meet but anticipate the needs of the army. To this end the chief engineer should be at all times in close touch with the commander-in-chief and with the engineer troops, and each battalion and company commander of the engineers must be at all times in close touch and hearty coöperation with the troops of the line with whom he is serving.

On account of the variety of duties exacted of an army in war, we find a **strong tendency in many countries to specialize** the work of the technical troops. By this is meant that certain organizations are trained to perform a certain kind of work and are not supposed to be employed in anything outside of their specialty. Thus we find in the European armies sapper companies, railroad companies, aero companies, telegraph companies, etc. One foreign engineer has even recommended the organization of water-supply companies.

In our own service the duties of the foreign aero and telegraph companies fall to the Signal Corps. **All the remaining technical field operations** demanded by the modern army are to be performed by the engineers—an entirely feasible arrangement. If we were to have special troops for each technical duty there would be no limit to their numbers. Moreover, many of these duties are sporadic in their nature and the troops trained to perform them would necessarily be idle a large part of their time, or else, which is more probable, they would be assigned to other duty, for which they should have been trained. So far as our own service is concerned, a multitude of special troops would be a useless expense, and **our engineer companies can and should be trained** to perform satisfactorily all the engineering operations required by the mobile army, including the mapping of limited portions of the terrain, the construction of temporary buildings, water supply, the hasty repair of railroads, etc. A single organization large enough to have representatives with every command from a brigade up is thus always available and qualified to perform any task that may be assigned. With special organizations for each class of work, the number of each would necessarily be relatively small. It would be impossible to assign them to any except large commands. They would frequently, as a consequence, be wanting when most needed, would be idle part of the time and swamped with work during the remainder. It would be better to have the necessary special workmen and plenty of "handy men" in each company, with officers qualified to superintend and direct all classes of technical work. Engineering operations with the field army are nearly all in the nature of makeshifts. They should be sufficient for the immediate purpose, and no more. Extensive work of a special nature (excepting siege operations) will generally be executed in rear of the army, and special provisions therefor can be made as the occasions arise.

The specialization which has contributed so greatly to the success of the civil engineering profession finds a much more limited application in the military field. The great variety of duties exacted of the military engineer and his frequent encounters with emergencies demand broad general training. He should be well qualified to perform all these various duties but, having such qualifications, he may then in addition specialize along certain lines. Such specialization should not be pursued to the injury of his general efficiency. He should be well qualified for all his duties and his usefulness will be increased if he has special qualifications in certain lines. **The ideal military engineer** is the "all-around man" who can turn his hand to anything. On such a man the nation relies and specialists become tools in his hands. There will be a large field of usefulness for our engineering specialists in time of war, but not to any great extent with the mobile army in contact with the enemy. Even without military training or any conception of the tactical or strategical requirements of the situation, they may be usefully employed on the more formal works in the rear of the army under the direction of expert military engineers who fully understand these requirements and whose broad training enables them to intelligently direct the work of specialists of all classes. We are here concerned, however, with officers for service with the mobile engineer troops forming part of the fighting forces. For all such, **broad engineering training and high tactical efficiency** are essential. Their specialties, if such they have, may or may not find useful application. But as specialists alone they would here be of little value and unable to meet the emergencies which will constantly confront them.

Military engineering, as we have seen, is an adaptation of civil engineering to military needs. The fundamental difference between the two arts is in **their economic aspects.** Military engineering, no less than civil engineering, is an economic art, but the standards by which it is judged are quite different. **In civil engineering** the element of first cost is of prime importance. The matter of time consumed in construction is of importance as a rule only as affecting the first cost and the financial returns on the investment. A considerable time spent in design and other preliminaries to construction will usually be amply justified by a material saving in first cost. The Board of Directors insists that the engineer hold down the first cost. Also the structures of the civil engineer are usually rather permanent in their nature. Generally they are intended to endure for years, often they are made as permanent as possible on the ground that their greater usefulness and lower cost of maintenance will eventually justify the increased first cost. Such are the economics of civil engineering. Those of military field engineering are very different. In order to appreciate this we must first consider the economic aspect of warfare. The cost of modern war between two great nations is enormous.[1] The belligerent government pays immense liquidated damages for every day that the duration of the conflict is protracted. The cost of success is great enough—that of failure is usually much greater. A few days—even a few hours—have decided the issue of a battle and the fate of a nation. Accordingly the march of events is rapid in modern warfare. Everything must move with the utmost celerity. Thus, **time is the controlling element.** The commanding general does not ask his engineer "How much will it cost?" but "How soon will it be ready?" Also **the structures of military field engineering** are essentially impermanent in their nature. Often they are required only for the exigency of the moment—never are they needed beyond the close of hostilities. Thus they are all **in the nature of makeshifts.** In sharp contrast to civil practice we find that any cost will be justified if it results in a saving of time at a critical juncture. The military engineer plays for big stakes. He makes a fatal blunder and shows his utter lack of appreciation of the economics of warfare if he hesitates over details involving thousands of dollars while the fate of a nation trembles in the balance.

As a consequence of these conditions, works of military engineering will usually be conducted with feverish rapidity. **The**

[1] The direct cost of the present European war to all the belligerents has been estimated at about $100,000,000 per day, not including incidental losses to industry and commerce.

best pioneer is the one who produces results just sufficient for the immediate purpose in the minimum of time without regard to expense. Formal and finished works will be left to those in the rear. The pioneer with the mobile army eagerly seeking a tactical decision has no time for niceties. Their presence in his work is almost certain indication of criminal incompetence—lack of appreciation of economic principles. A trail ferry which gets the troops across in time is better than a memorial bridge which does not. The rough-and-ready makeshifts which serve their purpose are the triumphs of the military engineer's art. They have the beauty of utilitarianism.

To be qualified then to meet the heavy responsibilities that will be placed upon him, the military engineer, even more than his civilian confrère, must be a keen student of economics as applicable to warfare. He must be intimately familiar with the structural needs of military works and with the details of design, adaptation to available resources, and methods of construction which promote speed. But this alone is not sufficient. **Works of military engineering are utilized** to meet the tactical needs of the moment. If constructed without due regard to the tactical situation they may be worse than useless. The fleeting opportunities to snatch victory or evade defeat must be seized as they present themselves. They must even be foreseen, for once gone they may never again be presented. To grasp these opportunities and meet the ever-changing needs the engineer must be not only skilled in construction but possessed also of tactical sense and training. His errors in judgment, his lost opportunities are paid for, not in money alone, but in national prestige and prosperity and in blood.

A simple example in the nature of a parallel may serve to illustrate the difference in the economics of peace and those of war. At a certain locality a bridge is needed over a stream. While it is very desirable, the community can wait several months, if necessary. Their resources are limited—they can afford to pay so much and no more. The civil engineer charged with the construction of the bridge makes a careful study of the needs of the situation. Eventually he designs an excellent structure, ample in strength and capacity and durable in its nature, and his estimate is within the stipulated price. The work is advertised for contract, but all bids are rejected as being excessive. Eventually the bridge is erected by day labor. This results in a considerable delay but keeps down the cost. The community believes that the engineer has well discharged the duty placed upon him. They consider that the delay is compensated by the saving in cost.

It is war time and an army approaches the same stream. Its mission is to cross the stream and seize an important position on the other side before the enemy can reach and hold it. The engineer with this force is called upon for a bridge to replace the one that has been unexpectedly destroyed. "It must be ready by day after tomorrow," the Commanding General informs him, "or my opportunity will be lost." Unlike the civil community the army cannot wait for its bridge. The engineer finds that no suitable lumber is at hand. But he perceives a number of costly buildings whose demolition will furnish what he needs. The owners protest their destruction. The engineer is well aware that they will place claims for many thousands of dollars against the government. But he realizes the vital need for the bridge and rightly considers the cost as insignificant by comparison. He is not restricted to the available funds of a small community, but has at his command the vast resources of a great and wealthy nation. The buildings are demolished in spite of protest and the bridge is built. It is not a sightly nor durable structure and its cost proves to be far in excess of that of the splendid bridge built by the civilian engineer. But it is there on time and it serves its purpose. The army accomplishes its mission, which proves to be a contributing cause of ultimate victory. The damage claims are presented and cheerfully paid in full. The nation believes that the engineer has well discharged the duty placed upon him.

They consider that the excessive cost of the bridge is amply compensated by the saving of time at a critical juncture.

How different are the methods of the two engineers! Yet each met correctly the demands of the situation which confronted him.

The two chief essentials of military field engineering then, are:

1. The adaptation of engineering work to tactical needs.
2. Appreciation of the economics of warfare, which ordinarily demands high speed in construction, even at a sacrifice of money and life.

We have seen the very wide range of operations which may be required of the military engineer. That the average man should possess a civilian specialist's knowledge of all these matters is beyond the bounds of possibility. This, however, is neither necessary nor desirable. The pioneer operations with the mobile army are all in the nature of makeshifts or improvisations, characterized by the utmost simplicity. Only the simplest works can be successfully executed in the haste and excitement attendant upon field operations. Nicety, finish, refinement and permanency are deliberately avoided. In the words of one of our most distinguished military engineers—"Simplicity must be the watchword in plans of operation, in orders, in action, and in equipment. Directness can be secured only when simplicity pervades the whole machine." Simplicity is demanded by the requirement of rapidity in construction, by the absence of skilled labor, and by the lack of facilities, such as suitable supplies and materials, machinery and appliances. Skilled labor, special materials and suitable construction plant will indeed be utilized whenever it is practicable to do so, and opportunities for their successful employment should never be neglected. Nevertheless, in the fore-front of operations, often in the presence of the enemy, even actually under his fire, construction can and must be carried on under conditions which would be exceedingly discouraging to the average civilian engineer or contractor. **It is the simplest works,** comparatively few in number, which will most frequently be demanded. It is for the execution of these simple works that engineer officers and troops should primarily be trained. The officers should also, by study and observation, endeavor to fit themselves to meet the special requirements of the less usual situations which will occasionally be presented.

The methods by which speed in construction may be attained are so numerous and varied that a thorough discussion of them would fill many volumes. They constitute a study which no engineer, military or civilian, can afford to neglect. The suggestions which follow are applicable to military operations but will not be new to the civil engineering profession.

The average contractor has an incentive to rapid work in the increased financial returns it usually brings. The military engineer lacks this incentive, but must be actuated instead by an unselfish patriotic devotion to duty and by a common incentive of the salaried professional man—a selfish but commendable desire to excel in his particular line of work and enjoy a reputation for efficiency.

When confronted with a situation the military pioneer seeks not the best permanent solution but the easiest and quickest makeshift which will serve the purpose in view. He does not construct a new bridge if an existing bridge can be adapted to his needs, nor if a practicable ford can be found.

Formal plans are rarely used, ordinarily nothing more than simple sketches is required. These consist of an instantaneous adaptation of military type plans to the materials, tools and labor available. All details which increase the time required for construction without being absolutely essential to the completed structure are eliminated and the remaining details reduced to the simplest form. Unless construction plant is available, which will seldom be the case, very large pieces should be avoided. All pieces should be of such size that they can be readily obtained and easily handled by the men with the assistance of animals and simple tackle.

It is not to be supposed indeed that all military field engineering is in the nature of sudden emergencies. Frequently the need of certain structures can be foreseen days or weeks in advance, and when this is the case, careful and elaborate preliminary arrangements may be possible.

In starting work the necessary tools are laid out, and steps taken in advance to have all necessary material on hand as soon as it may be required. The work should then be divided into a number of definite tasks under the officers and senior non-commissioned officers, and these again subdivided into smaller tasks, under the junior non-commissioned officers. The cost of superintendence, which might be prohibitive on civil work, is justified in military construction if it results in a saving of time. If several of the tasks can be made similar in nature and equal in amount, so much the better. This will create competition, always a stimulus to endeavor. Two identical structures with an equal number of men assigned to each will usually call forth the best efforts of both parties. Of course, that task which will require longest to accomplish should be started first and pushed hardest, if the time required for its completion is the measure of the time required for the work as a whole. The number of men assigned to any task should, as a rule, be the minimum that can properly execute it. Too many men on a task are always a cause of confusion and delay. If there be a superfluity of men it is better to put them on some other work or send them away than to have them standing idle. Extra men, if kept on hand, can be best utilized in—

(*a*) Collecting and preparing materials, or

(*b*) Relieving the men engaged in the more arduous tasks.

It should never be necessary to have any men idle, except when they are actually resting. There always will be tasks in connection with any piece of work, the performance of which will not tire the men as much as standing around, which is very fatiguing. Extra non-commissioned officers should be put to work, on the more dignified tasks, of course. They should not be allowed to entertain the idea that their sole function is to superintend. The senior non-commissioned officers should not scruple to lend a hand when necessary, or to show some man who is bungling his work the proper method. But they should not, in so doing, neglect the more important work of superintendence. The captain or officer in supreme charge should watch the work as a whole, generally leaving details to his subordinates. The foreman of any particular task should, when practicable, be given a specific time in which to complete it, usually the least time in which the task can possibly be accomplished. While he may fail to complete it on time, he will naturally be anxious to avoid the explanations that will then be demanded of him. If no time is set for completion, idling is very apt to result. Two gangs mutually dependent upon each other, as where one furnishes the material which another incorporates in the structure, should be so organized that each will be hard pushed to keep up with the other. This is in the nature of competition. If the number of tools is limited, care should be taken that all tools are doing useful work all the time.

CHAPTER III

TOOLS AND EQUIPMENT EMPLOYED IN MILITARY ENGINEERING

It has frequently been remarked that military engineers **make very little use of construction plant** in their field operations and they have been criticised for not availing themselves thereof to a greater extent. Plant is utilized in military construction whenever practicable, but in operations with the mobile troops at the front the opportunities for its useful employment are decidedly limited in number. Such plant is, of course, less useful on light hasty military structures than on the heavier and more formal works of peace. The work of the military engineers is spread over a considerable area, they move rapidly from place to place, and they must at all times keep up with the mobile fighting forces. Heavy construction plant is not sufficiently mobile to meet such requirements. Often it would not be on hand when needed. One of the chief purposes of such plant is to save manual labor, and of this there is seldom a dearth in military operations. **The military pioneer is greatly concerned** in preserving his mobility and accordingly must not be unduly hampered in his movements by the necessity for transporting heavy machines. This is especially true in America on account of the deficiency in good roads. Therefore the engineer places his chief reliance on the most mobile and adaptable of all machines—man himself.

In the occupation of a defensive position, each soldier intrenches his own section of the line. It is quite apparent that the troops can be disposed in the position and can complete the excavation, each man using his own portable tool, in a few hours of time. In such a situation, trenching machines could not compete with manual labor. If concrete be employed in such intrenchments, it would be distributed in small masses over a considerable distance. Neither large nor small machine mixers would be as rapid and efficient as hand mixing. The case is somewhat similar to the construction of concrete sidewalk. The contractor constructing a block of such sidewalk economizes on labor and employs a small mixing plant. But were it necessary to lay such sidewalk throughout the city in a few hours the only practicable means of accomplishing such a task would be the employment of an army of laborers and hand mixing. The cost would be great from the civil contractor's point of view, but in military operations the element of time usually outweighs that of cost. The men are present and must be paid and maintained in any case and, incidentally, it is in the interests of discipline to keep them employed.

These examples might be multiplied but those given may be regarded as typical. They indicate that the economics of military field engineering in general preclude any extensive employment of heavy construction plant. For the more formal work in rear of the fighting forces, conditions will be different and plant may be more frequently employed. Such works would include roads, railroads and bridges on the lines of communication, buildings at supply depots, the preparation of secondary lines of defense, the rather deliberate fortification of important cities, arsenals, supply depots, etc. Here labor will be less plentiful than at the front, more time will be available, and structures of a somewhat more permanent nature will be appropriate. The intrenchments of the field army are often quite elaborate, but they are in general located and prepared in haste and are later extended, improved and developed to meet the tactical needs of the situation.

The foregoing considerations will also make evident the economic necessity for utilizing to the greatest possible extent the construction materials which are available at the site. The necessity of bringing materials from a great distance would often cause most injurious delays. Accordingly, earth, timber, brush, gravel, etc., will be the favorite materials, and works

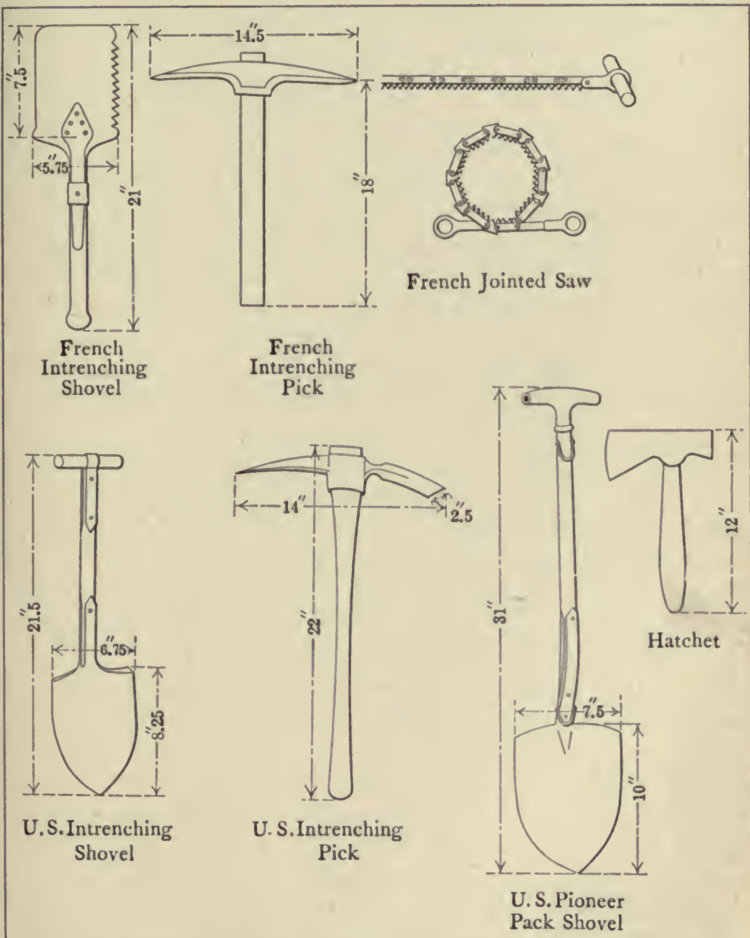


FIG. 1.—Portable tools employed in field fortification.

should be designed to utilize these as far as possible. Accessory materials of construction which must be transported to the site should be of a portable nature. Chief amongst these will be cordage, nails, spikes, wire, barbed wire, etc.

The principal construction work of the combatant troops will be field fortification. For this work the troops are supplied with **special miniature shovels,** pick mattocks, saws and hatchets, which are carried on their persons (Fig. 1). More efficient work could, of course, be performed with the commercial types of tools. But these must be carried in wagons or motor trucks and often would be missing when most needed. "The soldier," said Napoleon, "should never be separated from his rifle or his intrenching tool." What was true in Napoleon's day is more true in this day of trench warfare. The operations of the engineers being more varied, they require a more elaborate equipment. But it must never be forgotten that mobility is a prime requisite and neither the infantry nor engineers should be hampered in their movements by the transportation requirements of an unnecessarily elaborate equipment. The engineers then will carry such tools and materials as will facilitate their operations without unduly restricting their mobility. The duties of the engineers are so numerous that to attempt to provide an equipment to cover all contingencies would destroy their mobility, without which any equipment would, of course, be useless for operations with the mobile army. An equipment provided for service in Virginia would be unsuited for the Philippine Islands, and one provided for duty in the field would not be entirely suitable for siege operations. The work of the engineers in the field, while varied, is all of a rough-and-ready order, and simple in its nature. For the performance of this work **an ample number of the simple tools** should be provided. For example, an adze is a most useful tool in the hands of a man who understands it. But it can not do much which might not have been accomplished with an axe; whereas the axe is capable of much for which an adze is useless. Hence, for pioneer operations, take the axe and leave the adze. Of course, there will occasionally be a call for an adze, so there should be a few of them in the company equipment.

While the proper outfit for a company would never be the same in any two situations, nevertheless it is possible in a general way to decide upon the types and numbers of the more important tools. Lists of such tools would constitute the "paper equipment." A sufficient number should be issued to the troops for their training in time of peace, and a reserve should be kept on hand in a depot, sufficient at least to equip the first troops to take the field in case of war.

The tools and equipment of the engineers may be divided into two classes, viz.:

(*a*) Commercial types of tools and materials.

(*b*) Special tools, apparatus and equipment used only by the army.

Under (*a*) would be included the great bulk of engineer equipment, not including the ponton material. Under (*b*) would be included such equipment as can not be readily obtained on short notice in the commercial markets; *e.g.*, ponton material, the miniature intrenching tools issued to the infantry, tools for military mining and other siege material, wagon and pack equipment (army standard), portable map reproduction outfits, etc., etc. An ample reserve of the second class (*b*) should be kept on hand at all times, as there would be a considerable delay in obtaining this in sufficient quantity on short notice, in the event of war, on account of its "special" nature. An additional source of supply, besides arsenals and home markets, is the immediate theater of war, whose resources should be utilized to the fullest possible extent. In a thickly settled civilized country great quantities of supplies would be locally available. In a thinly settled or uncivilized country it would usually be unwise to count on anything except the materials of nature.

In equipping engineer troops to take the field, the chief engineer officer of the army will consider the probable nature of the operations and course of the campaign, the local theater and its resources. He would then consult the list of tools and equipment available at the home depots or bases of supply, and select such as seemed best calculated to meet the most probable needs. Possible needs should be provided for by having tools on hand at the base or at more advanced points, so that they can readily be forwarded when needed. The weight and volume of the equipment should be such that t can be carried in the regular authorized wagons or motor trucks of the engineers. It should include only such material (as distinguished from tools), the need for which can be foreseen, as there is no reasonable hope of obtaining in sufficient quantity in the theater of operations. It is to be remarked that it will usually be better to over-equip rather than under-equip the engineer troops at the opening of the campaign. Any excess of equipment over the immediate needs can always be left behind on the lines of communications, and brought up again when required. Additional supplies which may be required as the campaign progresses can be sent up as needed.

Tools for pioneer work, like the structures built herewith, should be of the simplest character. A man trained to their use can do excellent work with the simplest tools. The standard pioneer tools and supplies of the engineers should include picks, mattocks, crow-bars, axes, adzes, shovels (mostly D hdl., r.p.), hammers (asstd.), machetes, hatchets, saws, two-man saws, wire cutters and pliers, a few light jacks, augers (large sizes), a few short rock drills, canthooks or peavies, pulley blocks (up to four sheaves), a couple of small chain blocks, lanterns, marline, rope for lashing and tackle (⅜ in. suitable size for lashing, ¾ in. to 1 in. suitable for tackle, nothing larger), wire (10 to 14 AWG —a copious supply), spikes and nails, various sizes; flat and round iron for straps, bolts, driftbolts, dogs, etc., a little tool steel, some tapped nuts of same sizes as round iron, and washers (wrought), machine and black oil and oil for lanterns, one or two light portable forges and anvils with a little coal, a couple of grindstones, leather, etc., etc. In addition to these general tools and supplies, there should be several small and compact carpenter outfits, a simple blacksmith's, machinist's and horseshoeing outfits, a farrier's kit, saddler's and shoemaker's equipments, sketching instruments (to be carried on persons of sketchers), a couple of light transits (to be used also as levels), stadia rods (used also as level rods), a number of metallic tapes, 50 and 100 ft.; a simple plumbing kit, twine, tracing tape (for laying out intrenchments), a demolition outfit (40 per cent. dynamite is the handiest explosive), a camera and simple photographic supplies, a simple drafting and map reproduction outfit, a field desk and portable typewriter for the company office, etc. The entire equipment is ordinarily carried in wagons divided into compartments to permit ready accessibility. It should however be such that it can be carried on pack mules, in which case survey instruments, photo equipment and the smaller and more delicate tools such as carpenter's outfits are packed in boxes of a suitable size. Each company of engineers ordinarily includes a section of mounted men and a small pack train carrying their equipment. In very rough country, where wagon transportation is impracticable, the entire equipment would be carried on pack mules. There should be an ample supply of the more common tools (especially picks, axes, mattocks and shovels) so that when occasion arises the labor of other troops or of civilians can be utilized.

Most of the tools and materials listed above should be carried by each company of engineers, but some of them will be needed only with battalion headquarters, such as surveying equipment, lithographic outfits for map reproduction, etc.

With this simple equipment the engineers can perform all the operations which will ordinarily be required of them utilizing such materials as may be found at hand.

Beyond this it does not seem advisable to recommend any standard equipment, except the regular ponton-bridge equipage. There is a large number of special tasks for which special equipment may be used to advantage. Such equipment should be obtained locally or sent forward from the base as it is needed. Some of it may be taken with the company, or in the division train if transportation is available and the need can be foreseen. Plows and scrapers are most useful for road work, intrenching, and many other tasks. In a civilized country they can be obtained in almost any locality. For extensive railroad work the necessary special tools must, of course, be provided. They will generally be found wherever there is a railroad. For simple railroad repairs a few claw and tamping bars, track jacks, spiking hammers, wrenches, hack-saws, track drills and a "jim-crow" rail bender will be sufficient. Traction and hoisting engines and the commercial types of trenching machines may be used to advantage in fortification work and almost any heavy construction. They can not, of course, accompany the engineers in their more rapid movements, but for elaborate works in one locality they may be sent forward when needed.

The battalion headquarters may carry some equipment in addition to that of the companies. Extensive survey work and map reproduction should preferably be under the immediate charge of the battalion commander; the equipment therefor, especially lithographic (zincographic) outfits being with battalion headquarters, operated by special skilled men.

For rapid communication between the separated portions of an engineer command, engaged in section work at various localities, a small micro-telephone outfit and a few bicycles should form part of the company equipment. All engineer officers should be mounted.

The development of the motor truck will greatly increase the efficiency of engineer troops, making possible the more rapid transportation of tools and materials. It has also made possible the transportation of small, compact **gasoline power plants,** which may have a wide field of usefulness. Up to the present time few such plants have been developed, inasmuch as the present war is the first in which the automobile has been extensively employed. Amongst the possible gasoline power plants for military purposes are the following: Portable searchlights, winches, hoists, pile drivers, drills and boring machines, saws, trenching and mining apparatus, concrete mixers, stone crushers, etc. Very little has been done along these lines and there is room for great improvement.

Military field engineering, as we have seen, is an adaptation of civil engineering and, in practice, differs from the latter insofar as it is governed by different economic principles and conducted under different conditions. Fortification works executed in time of peace are essentially similar to civil engineering construction, and the same is true of many engineering operations conducted in time of war on the lines of communication in rear of the fighting forces. On such works, civilian engineers without military training may often be employed to advantage. We are now concerned, however, with field engineering, the pioneer operations of the fighting forces. Here we find a sharp contrast with civil practice. **The conditions which govern** the military pioneer may be recapitulated as follows:

1. All works must be designed and executed to meet actual tactical needs. If constructed without due regard to the tactical situation they may be worse than useless.

2. A very large proportion of the works will be constructed to meet sudden emergencies. Opportunities to plan and carry out works a considerable time in advance of need therefor will be comparatively infrequent.

3. The fundamental economic principle of military engineering is that time is of the essence. Cost and durability of works are ordinarily matters of minor importance. The quickest makeshift is usually the best solution.

4. Simplicity must characterize all designs.

5. Materials which are available at or near the site of the work must be utilized to the fullest possible extent.

6. There will usually, but not always, be ample common labor available, but a dearth of skilled labor of all classes.

7. As a rule, no heavy construction plant and only the simplest tools and materials will be available.

The works resulting from these conditions are of a very simple nature. **The highest expression** of the skill of the military engineer is this very simplicity, and the rapid adaptation of his designs to the tactical requirements of the situation and to the resources in men, tools, materials and the time at his disposal.

The following brief summary of some of the more usual and important operations of the military field engineer will serve to illustrate the principles hereinbefore enunciated.

CHAPTER IV

STREAM CROSSINGS

The ability to cross streams is essential to the mobility of the army and to facilitate such passage is one of the chief duties of the engineers. The history of war is replete with examples of delays and failures due to the lack of equipment for the rapid construction of bridges.

On the 26th of January, 1814, Napoleon writes, "If I had had 10 pontons, I should have captured 10,000 wagons, beaten Prince Schartsenburg in detail, annihilated his army and closed the war; but for want of proper means I could not cross the Seine."

Writing to the Adjutant General under date of May 18, 1846, General Zachary Taylor says: "My very limited means for crossing rivers prevented a complete prosecution of the victory of the 9th (Palo Alto). A ponton train, the necessity of which I exhibited to the department last year, would have enabled the army to cross on the evening of the battle, taken this city, with all the artillery and stores of the enemy, and a great number of prisoners—in short, to destroy entirely the Mexican Army."

BRIDGES

The passage of streams is so very important and necessary that the mobile army can not afford to rely entirely upon make-shifts improvised from materials collected at the site, as the above quotations will show. Indeed, in the case when a large army with its heavy trains is confronted with a wide and deep crossing the construction of an improvised bridge might require weeks

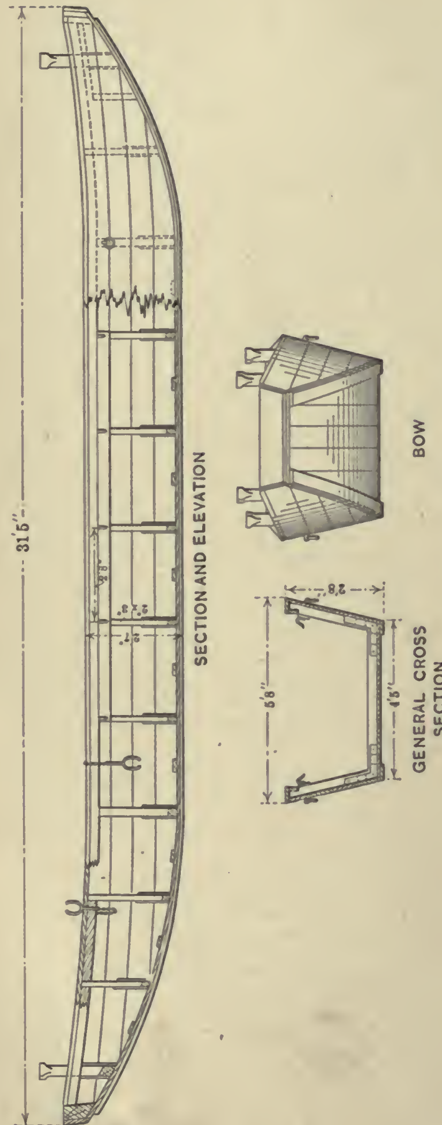


FIG. 2.—Wooden ponton—heavy equipage.

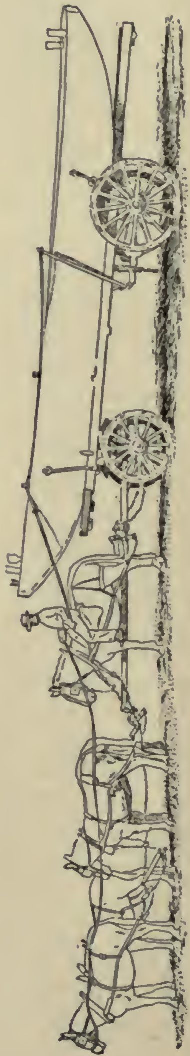


FIG. 3.—Wooden ponton and balk for one span on wagon.

of time. The shifting tactical requirements do not wait on such delays and to meet such situations some form of **portable bridge with floating supports** is absolutely necessary. Accordingly, all modern armies carry such bridges which are known as ponton equipage.

The equipage in use in our army was devised prior to the civil war and used with conspicuous success throughout that great conflict. It is a tribute to the wisdom of those who devised it that in over fifty years no radical changes have been made. The equipage is one of the simplest and most cunning of military expedients.

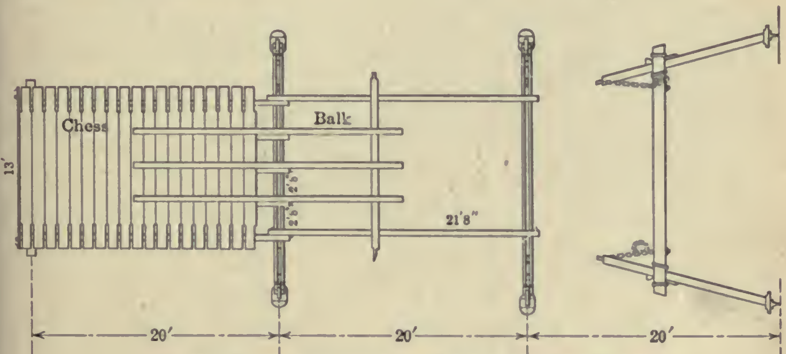


FIG. 4.—Trestle span of portable bridge equipage.

There are two forms of the equipage, known as the heavy and light. In the heavy equipage the supports or piers are wooden boats called pontons (Figs. 2 and 3). They are 31 ft. × 5 ft. 8 in. × 2 ft. 7 in., weigh 1,600 lb. and have a displacement of 9½ tons each. For the shallow portions of the stream, portable trestles consisting of two legs and a cap, which is held in position by wedges, are provided (Figs. 4 and 5). The roadway is supported by stringers or balk of white pine, 27 ft. long and 5 in. square. The number of balk in a span varies from 5 to 11, according to the load to be carried. In the first boat the balk rest on a saddle in the middle, which forms a hinge to allow for changes in the level of the water (Fig. 11). In the other boats the balk rest on the gunwales. All fastenings are by means of lashings. The deck consists of plank 1½ in. × 12 in. × 13 ft. of white pine, called chess. They are held in position by side rails laid on the deck at its edge and lashed at intervals to the balk below, the lashings passing through notches in the plank (Fig. 5). The pontons are held in position by a system of upstream and downstream anchors. The distance from center to center of supports is 20 ft.

Fig. 5.—Portable trestle bridge of regular equipage. Note abutment sill, balk and side-rail lashings. This bridge can be constructed in a few minutes. It will carry the heaviest loads which accompany the army.

The light train is similar to the heavy, except that the ponton boats consist of a framework covered with heavy waterproof canvas and can be dismantled for transport (Figs. 6, 7 and 8). They have a buoyancy of 6 tons, the balk are shorter and lighter, the span between supports is 16 ft., and the roadway narrower. The two trains may be combined in one bridge.

This material is all transported on wagons (Figs. 3 and 7) and is sufficiently mobile to accompany the troops on the march.

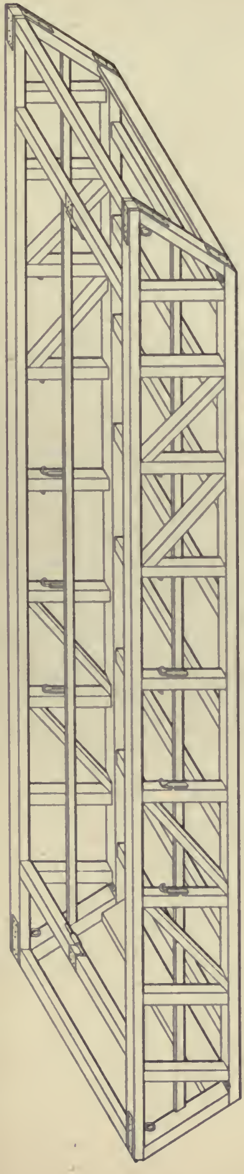


FIG. 6.—Frame of light (canvas) ponton assembled.

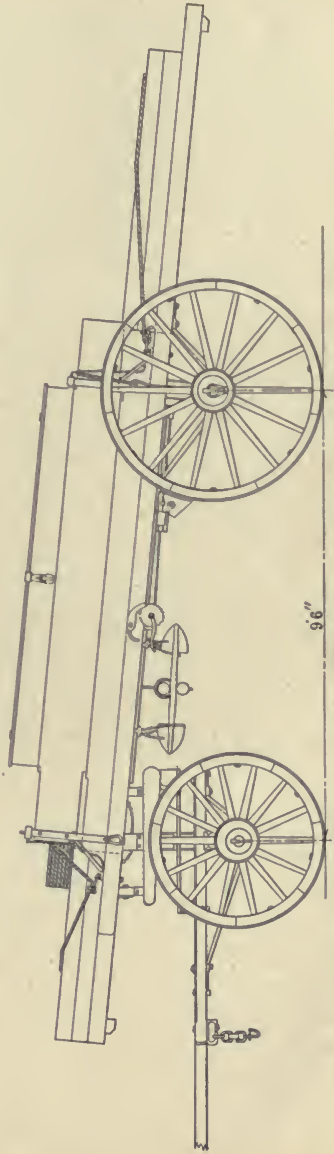


FIG. 7.—Canvas ponton complete and balk for one span on wagon.

The light train can keep pace with cavalry. The roadway will support the heaviest loads that accompany the army with a factor of safety of four. This bridge can be laid, crossed and taken up in far less time than any other form of bridge ever devised can be constructed. The weight of the heavy equipage, including the wagons on which it is carried, is 315 lb. per running foot of bridge; of the light equipage, 275 lb. Not including wagons, the weights are 169 lb. and 128 lb. respectively. It will be interesting to compare these weights with those of other forms of bridge of equal capacity.

FIG. 8.—Assembling the canvas ponton.

There is a regular routine for construction and so wonderfully simple is the equipage that unskilled men can be taught to use it in a very short time. The bridge may be constructed by pushing out successive pontons from one or both banks (Figs. 9 and 10) by constructing parts along shore and floating them to position, or by constructing the entire bridge along the bank and then revolving it into position. The first method, known as "successive pontons" is the one usually employed. The procedure, as laid down in the "Engineer Field Manual, U. S.

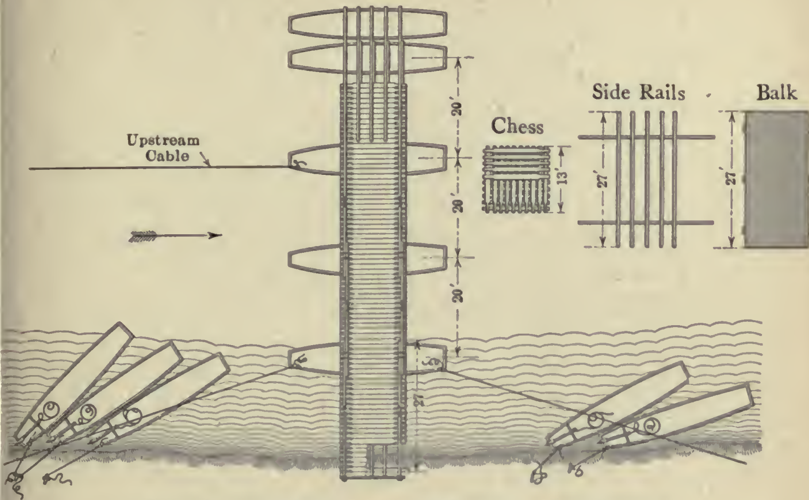


FIG. 9.—Constructing bridge by successive pontons.

FIG. 10.—Constructing bridge by successive pontons. Two trestles are placed, and the first ponton with saddle in center is in position.

FIG. 11.—Completed bridge of heavy equipage. Note saddle in first boat.

FIG. 12.—Completed bridge of light (canvas) equipage.

Army," is as follows: In a trench the abutment sill is laid perpendicular to the bridge axis and secured by pickets, two at each end (Fig. 5). If necessary, one or more trestle spans are then placed and the first floating support is brought to the bank opposite the abutment. The free ends of cables fastened to the bank 30 paces above and below are passed to men aboard the ponton. A set of balk is brought up and the cleats engaged on the saddle of the ponton and lightly held by lashings. The

FIG. 13.—Draw span in ponton bridge. (Spanish ponton equipage.)

ponton is pushed off until the cleats at inner end of balk engage the abutment sill and the mooring lines made fast. The balk are then lashed securely to the saddle and the chess (deck plank) laid. The next ponton is then brought alongside and its anchor lines (previously placed by another boat) passed aboard. The operations are repeated until the other shore is reached. The bridge is dismantled in reverse order (Figs. 11 and 12). If the bridge is to be in position for some time a movable section

or draw may be placed in the middle to allow the passage of vessels, drift, etc. The draw consists of two boats with a span of decking between (Fig. 13).

The construction of these bridges is one of the most picturesque and interesting of military operations. The adaptability of the equipage is very great and improvised floating supports, such as boats, rafts and casks, may be used to supplement the regular equipment.

An indication of the astonishing capacity and speed of construction of which the ponton equipage is capable is afforded by **the following historical example:**

In his attempt to reach the south side of the James River for the attack on Richmond in 1864, Grant decided to throw a bridge across at Fort Powhatan, near Charles City. The approaches were built on June 13th. The floating equipage was brought up from Fort Monroe on June 15th and the bridge was laid between 4:00 p.m. and 11:00 p.m. of that day. It was built from both ends. The bridge was 2,200 ft. long and 101 wooden pontons were used. The depths were so great and the current so swift that several schooners were moored in the river to carry the upstream cables of the bridge. In a letter to the Chief of Engineers, Gen. Benham, who constructed this bridge, says:

". . . I presume you will be glad to hear of the success of our ponton bridge, over 2,000 feet long, over the James River just above Fort Powhatan, which I had placed there on the evening of the 15th. . . . About 11:00 a.m. on the 15th I received the order, and was under way in half an hour, arriving at the position selected at about 5:00 p.m. There I found Gen. Meade and Gen. Weitzel, which latter had prepared the approaches and had the abutment commenced. I was at once directly charged with the laying of the bridge by Gen. Meade with the regulars to assist the volunteers, and he smiled when I told him I should not sleep till the bridge was laid.

"I distributed my men at once, the regulars at the east end, the volunteers at the west end, and a company of volunteers to prepare a raft by my plan of simultaneous bays.

"At about 10:30 p.m. I received a dispatch from Gen. Meade asking the progress of the bridge, to which I was able to reply at once that the last boat was in position, and the raft of three boats built ready to close the gap he had ordered left for the present, and that it was ready for completion in fifteen minutes at any time he ordered. . . .

"For the next forty hours after 6 a.m. of the 16th, a continuous stream of wagons passed over the bridge (from 4,000 to 6,000 wagons), some said fifty miles of wagons—and nearly all the artillery of this army, and by far the larger portion of the infantry and all its cavalry present, and even to its herd of 3,000 or more of beef cattle (the most injurious of all) without accident to man or beast.

"My officers and men were scarcely allowed any sleep during this time nor myself as much as four hours in the eighty hours preceding the taking up of the bridge, for it was in anxiety, not to say trembling, that I saw the destinies of the whole army of our country even committed to this single, frail, boat bridge, with steamers and other boats drifting against it and with much of its planking previously worn almost entirely through by careless use upon the Rappahannock, and I dared not stop the living stream of men or matter to sheath or protect it.

"At length by 7 a.m. on the 18th, the last animals were over and I breathed free again, and although the shelling of our troops across the river just before sunset within a mile above us gave us little hope of withdrawing the bridge in safety, it was ordered up and all rafted into three tows before 3 a.m. of the 19th, and on its way to this point, which it reached about sunrise, the most successful effort on a large scale with ponton bridging that has ever occurred in our country, if it does not rival those in any other land. . . .

"You may be sure I was very well content and satisfied and felt like 'him that putteth off his armor,' when the affair was over."

This is an interesting chapter in the annals of bridge engineering.

While great reliance will be placed upon the ponton equipage, it can not entirely obviate the necessity for hastily constructed **bridges of other types, which must frequently be improvised** from materials found near the site. Such bridges are known as "bridges of circumstance." Considerable skill on the part of the engineer officers will be required to **adapt the bridge to the** site and materials available to produce the quickest results. The construction of a bridge is an interesting task, and there is a strong tendency to put in a bridge when a reconnaissance a little up- or downstream would have revealed a practicable ford, or to build a bridge at a site where an improved ford with suitable approaches would have served the purpose at a far less expenditure of time.

The engineer confronted with a stream crossing seeks first a practicable existing bridge and in contemplation of a movement

FIG. 14.—Simple pile trestle.

of troops all important bridges that may be used should be seized in advance to prevent destruction by the enemy or his sympathizers. Even if the bridge is insufficiently strong or has been damaged it can often be repaired or strengthened in less time than a new bridge could be built.

The number of types of these improvised bridges is naturally very great, but a few of them have been found especially adapted to military uses.

The most common type is **the simple two-legged trestle,** frame or pile, which can be adapted to a great variety of conditions. The relative time and difficulty of constructing the piers and spans will fix the economic length of span. For military purposes this will usually be 10 to 15 ft. and for such a span longitudinal bracing will usually be unnecessary (Fig. 14). But if the water is very deep or the banks high, so that large trestles

Fig. 15.—Driving piles with portable driver. The float is of ponton equipage, and the hoist is operated by a gasoline engine.

are required, it will often be better to reduce their number and increase the span, employing more stringers or some form of light truss. To reduce the size of trestles the approaches may be cut down. **In selecting a site** the time of construction for bridge and approaches should be considered. Ordinarily a locality where the stream banks are low and firm and of equal height with a short span will be the best site. If the depth be moderate and the bottom firm the framed trestle will be best. If necessary a mud sill may be used to increase the bearing power and, if the depth is considerable or the current swift, the trestles may be weighted down by boxing their sills and filling with stone.

While the two-legged trestle is the favorite type, three or four-legged (sawhorse) trestles may be employed. Cross bracing

FIG. 16.—Portable pile driver with swinging leads and gasoline hoist.

of trestles is always necessary and for long spans longitudinal bracing may be required. For very high trestles, two or three stories may be used. **Almost any materials can be utilized** for trestle bridges, even bamboo has been successfully employed to carry heavy loads. In considerable depths with a soft bottom pile trestles are often to be preferred. **A hasty pile driver** may be improvised with a heavy block of wood raised by tackle and guided by a "spider" and a few upright poles. Of course a light portable power driver or hammer will be very useful in such situations if available (Figs. 15 and 16).

For very soft, yielding bottoms, especially if suitable piles are not available, **simple log cribs** filled with stone, if necessary, may be employed in conjunction with trussed spans. Material suitable for cribs is usually easily obtained and handled.

FIG. 17.—Truss bridge constructed in field by engineer troops. The spans are 90 ft. and the roadway 16 ft.

The purpose of trusses is to reduce the number of supports. In military field operations the use of trusses will usually be limited to situations where they can be placed with the aid of animals and tackle and without false-work. If it be necessary to place false-work, this will usually serve to carry the deck and no truss will be needed. If the bridge is to be used for some time and there is danger from flood or ice, large trusses may be placed. Such work would seldom fall to the lot of the pioneer engineer

4

troops. An excellent example of a large military truss bridge is that built over the Kansas River at Fort Riley, Kans., by the 3d Battalion of U. S. Engineers, and described in *Engineering Record,* July 11–18, 1908 (Fig. 17). The usual forms of truss will be the simple king-post (or triangular truss) and queen-post, erect or inverted, with tension members of iron rods or steel cable. Small Howe or Pratt trusses and lattice or bow string girders of plank spiked together are often employed

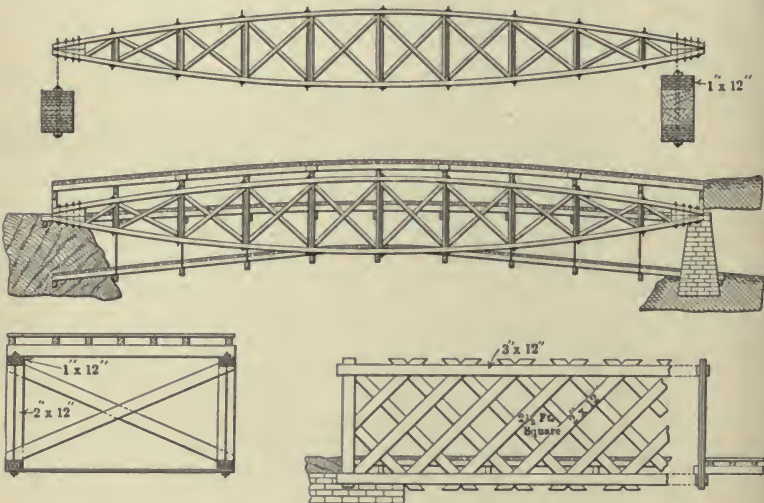


FIG. 18*a*.—Simple trusses.

(Figs. 18*a* and *b*). The difficulty of placing trusses without the aid of plant ordinarily limits their span to about 40 ft. the larger trusses being built in place when practicable. Under special conditions, as where the truss may be floated to position on a barge, greater spans may be practicable.

In many situations the spar lock bridge, which in double lock is practicable up to 45-ft. span, may be constructed more easily and quickly than a truss. The supports of this type consist of two tall trestles erected on or near the bank and tilted over

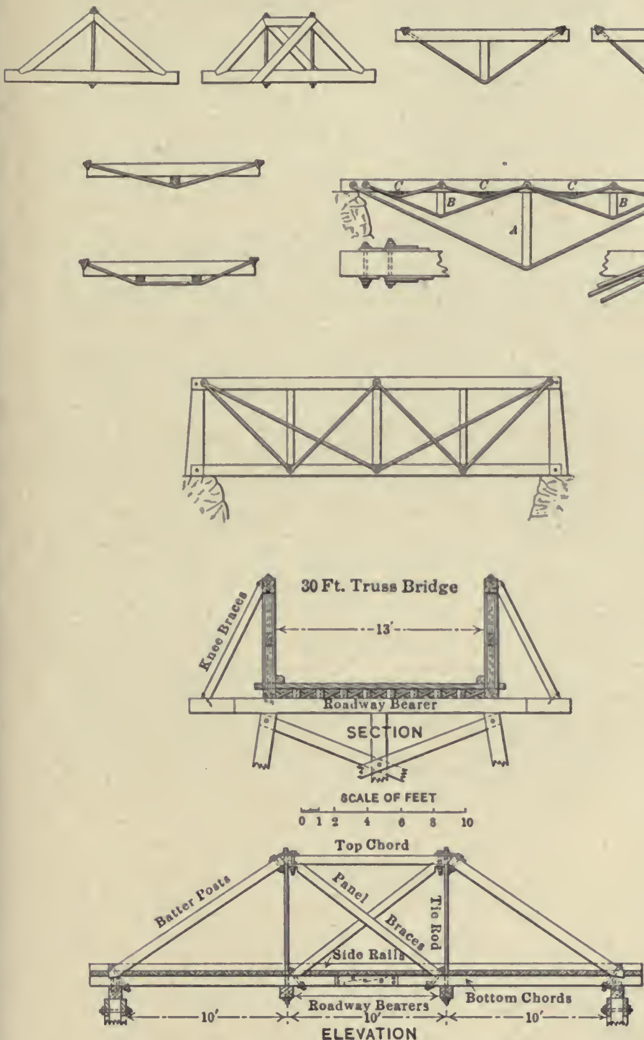


FIG. 18*b*.—Simple trusses.

until their heads lock amidstream, forming a point of support. This is called single lock. In double lock the trestles are tilted until they lock with a frame placed between them, this frame forming one central span. This type has peculiar advantages from the military point of view as, where applicable, it can be very quickly constructed of the roughest materials (Figs. 19, 20 and 21).

Clear spans of more than 50 ft. should usually be avoided by seeking a more favorable site. When such can not be found a **suspension bridge** will usually be the only type which will meet

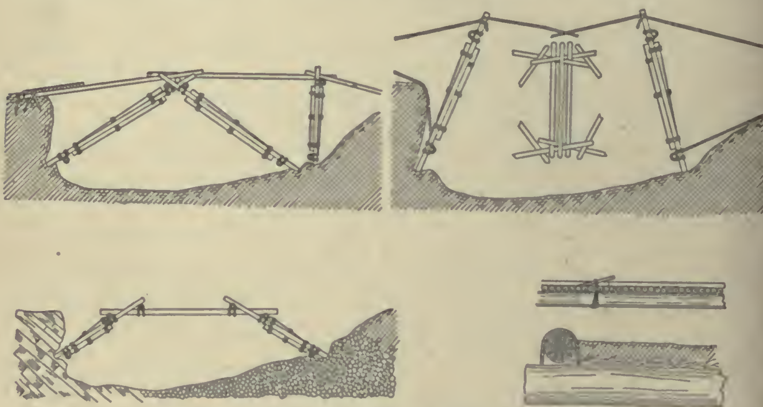


Fig. 19.—Spar bridges.

military requirements and, for moderate loads, is practicable for long spans. The essential part of a suspension bridge is **the cables,** and if these are available, the balance of the material is usually readily obtained. A great variety of materials have been employed for cable including manila rope, chains, bamboo, etc. The best material for cables, of course, is wire rope, and when the necessity for such bridges is possible a supply of rope with fittings should be carried by the engineers. Adjustable suspension rods or hangers may also be provided in advance—cable will serve this purpose. On account of the difficulty of handling and fastening large cables they should be limited to ¾ in. or 1 in., multiple cables being used when necessary. The first step in construction is to erect the towers and prepare the anchorages for the cables. **The towers** will usually be of timber and of the sawhorse trestle type, to resist overturning both during construction and subsequently, as no roller bearings are employed and vertical reactions can not always be insured.

Fig. 20.—Double lock spar bridge.

Standing trees may occasionally be utilized for towers. **The anchorages** consist of large logs in trenches (deadmen), standing trees or stumps, large boulders or ledges of rock, where available. Occasionally concrete is employed. **The cable may be dragged across the towers** or laid out, measured and anchored (temporarily at one end to allow adjustment) on the ground and then lifted to the towers. The sag of the cables will usually be considerable. This decreases the strain on the cables but makes the bridge very liable to undulation under live loads. Slings or suspension rods may be cable, wire rope, manila rope, round iron, or even wood. From each pair of slings hangs a transom or roadway bearer, on which the stringers and deck are placed (Figs. 22 and 23).

FIG. 21.—Double lock spar bridge with suspended roadway. All fastenings are lashings.

Oscillations and undulations may be controlled by lateral trussing of the roadway, by a trussed guard rail, by drawing the cables together at the center of the span, and by guys.

In many situations **a combination of types** meets requirements better than any single type. Such combinations might include

FIG. 22.—Field suspension bridge, roadway of ponton material. The wagon is the standard engineer tool wagon.

FIG. 23.—A Spanish suspension bridge in the Philippine Islands rebuilt for military use. Only the towers of the old bridge remained.

frame and pile trestles, trestles and truss spans, a combination of trestles and floating supports, the latter being a very usual expedient.

The deck or roadway should be no wider than necessary, both because of the weight and extra time required for construction: Ordinarily two lines of vehicles will not be passing in opposite directions at the time same. Twelve feet is usually quite sufficient for a wagon bridge, allowing for the passage of foot or horsemen alongside the wagons. For a foot bridge alone a less width is required. Side rails are always provided but hand rails are seldom used except on through truss and suspension bridges.

The stringers may be of round or sawed lumber. **Planking** 1½ in. or more in thickness makes the best deck. Where this is not available the deck may be of poles held in place by side rails and covered with brush, leaves and earth or gravel. This makes a satisfactory deck but, except in short span trestle bridges, is objectionable because of its weight (Figs. 19 and 20).

The fastenings are of the simplest nature, lashings, spikes and bolts being used. Elaborate framing is avoided as far as possible.

FORDS

Before entering upon the construction of a bridge **search should be made for a practicable ford,** if the nature of the stream gives any promise that such may be found. Fords which have been used by the local inhabitants should be first examined. In determining **the practicability of a ford** the considerations are: (*a*) nature of approaches; (*b*) nature of bottom; (*c*) depth of water; and (*d*) velocity of current. For the passage of mounted troops and wagons the approaches may be improved by cutting down the banks to ease the grades, and by surfacing the roadway with plank, brush, gravel, etc. A sandy bottom is the most favorable and usually requires no improvement. If the bottom be rocky or yielding it may be made practicable by a deposit of sand or gravel, by fascines or bundles of brush, or by a woven mattress sunk in position. **The limiting practicable depths** of fords where the current is sluggish are: for infantry, 4 ft.; for cavalry, 5 ft.; for artillery or wagons, 2½ ft. If the current is swift the depths for infantry and cavalry are 3 ft. and 4 ft. respectively. A life line may be stretched across the stream to facilitate the passage of infantry. **Ice 2 in. thick** will support infantry in single file; 4 in. thick, cavalry at intervals; 5 to 6 in. heavy field pieces.

Fig. 24.—Landing wharf and pile driver of ponton material.

FERRIES

When fording is impracticable and there is not time nor material for a bridge, **resort may be had to a ferry.** These will be used especially in cases of wide crossings, where time is of special importance and when the number of troops to cross is small. The ponton equipment heretofore described is specially designed with a view to its use for ferrying purposes. **The pontons of the heavy train** will carry from 20 to 40 foot troops, in addition to the crew. A raft or catamaran made of two pontons with a span of flooring between will carry cavalry, artillery and wagons. In the absence of the ponton equipment rafts may be constructed of logs, casks, etc.

If the current be swift a rope may be stretched from bank to bank and the float drawn across by hand. Or the current may be made to furnish motive power by attaching a block to the rope and securing the float to the block in such a manner as

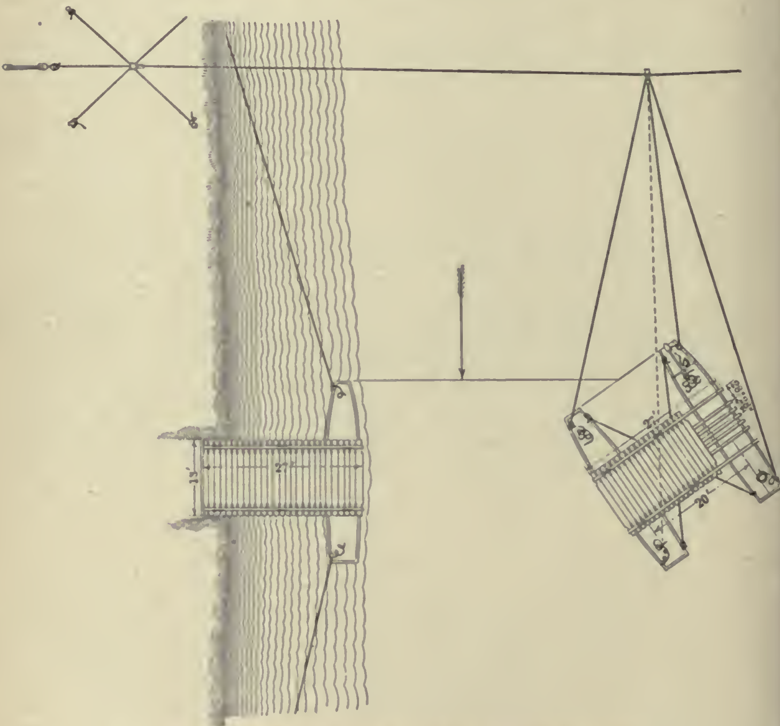


FIG. 25.—Trail ferry and landing of ponton equipage.

to hold it at an angle to the current. In the flying bridge the float is attached to and swings in a circle on a line anchored well upstream. The current may be made to furnish motive power, as in the former case, or the ferry may be drawn across by an auxiliary line secured to the bank (Figs. 24, 25 and 26).

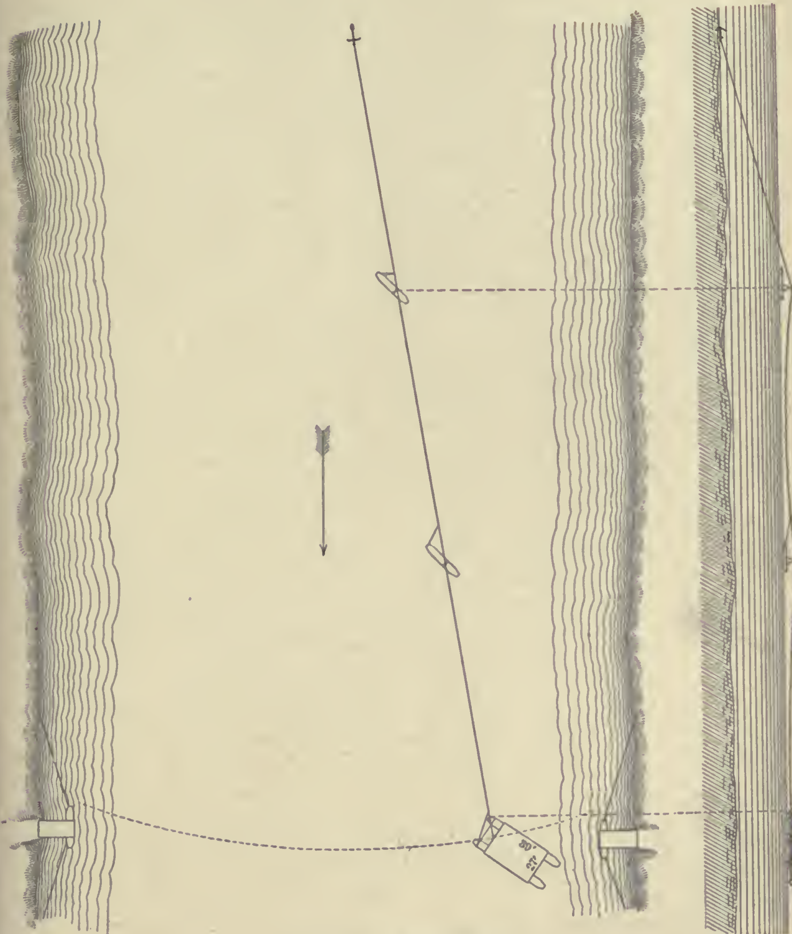


Fig. 26.—Flying ferry.

EXAMINATION AND REPAIR OF SIMPLE HIGHWAY BRIDGES

An important problem with which the military engineer will often be confronted is that of determining the supporting power or safe load of an existing bridge, and the methods that may be adopted to strengthen the structure. Good civil practice has resulted in the adoption of type plans for the various forms of bridges, the safe loads of each being carefully specified. Commercial traffic is usually heavier than that which accompanies the mobile army and accordingly a well-designed bridge may generally be pronounced safe for military use, provided an examination shows that it is in good condition. **Also the factor of safety** may, in such a case, be reduced from 5 or 6 to 2½ or 3, if this be necessary. But in our country we encounter **many bridges which are not designed** in accordance with good practice. Many of them are not designed at all, and in many steel bridges economy of material is carried to an extreme, the designers trusting in Providence that the bridge will never be tested to the specified loading.

The quickest method of determining the carrying capacity of a bridge is by comparing it mentally with other similar bridges whose capacity is known. This will require considerable experience and great power of observation on the part of the engineer. To calculate accurately the carrying capacity of a bridge may be a tedious operation, but approximate methods or "rules of thumb," which any competent engineer can devise for himself, will usually give results sufficiently close for practical purposes.

An examination of the bridge by an experienced engineer will usually serve to indicate the weakest or critical parts of the structure, to which special attention should be given.

A useful formula for bridge stringers of wood, such as are often encountered, is the following:

Safe center load in pounds times span in feet equals A times BD^2. In this formula A is a factor depending on the kind of wood, and B and D are the breadth and depth of the stringers in inches. For a factor of safety of 3, A may be taken as at least 100 even for rather poor timber. Hence, if a wooden stringer is to be safe, BD^2 should equal the span in feet times the center load in hundred weights, $BD^2 \times L \times \frac{W}{100}$. The weight of the beam itself may be disregarded. The safe uniform load may be taken as double the safe concentrated center load. If the deck is sufficiently heavy the equivalent center load on any one stringer should not exceed about 30 per cent. of the weight of the army wagon or artillery carriage. Under this assumption the rule gives the following:

For loaded wagons or light artillery, $BD^2 =$ or $> 20 \times$ span.

For heavy field artillery, 4.7 in. guns, $BD^2 =$ or $> 30 \times$ span. If the span is less than 15 ft., the span multipliers may be reduced one-third.

A convenient rule of thumb for the deck, if of wood, is that the thickness of the deck in inches should be as great as the intervals between stringers in feet. Thus, if the stringers are 3 ft. apart the decking should be 3-in. planking.

If the stringers are standard steel I beams their safe loads vary approximately with the square of the depth. Also the fiber strength is about 10 times that of wood. Hence the rules become for long spans:

For loaded wagons, $D^2 =$ or $> 2 \times$ span.

For heavy field artillery, $D^2 =$ or $> 3 \times$ span.

These rules are but rough approximations, but they serve for practical purposes, and afford a test of the strength of the floor system. If this be safe the remainder of the bridge timbers are probably right, since good design demands this condition, and the floor system is most subject to wear and decay.

However, similar approximations may be applied to trestle caps of two-legged trestles or the roadway bearers of small truss bridges. Assuming the weight of a bay with its load at 20,000 lb., we have, $BD^2 =$ or $> 100 \times$ length of caps; or for steel I beams, $D^2 =$ or $> 10 \times$ length of beam. For spans of less than 15 ft. the multipliers may be reduced by half.

The strength of simple Howe or Pratt trusses may be quickly determined by the well-known method of "shear and chord increments."

These rules are applicable to structures which closely follow standard design for the types considered and to the usual loads with the army. **Any bridge which exhibits a radical departure** from the usual designs should, in the first place, be looked upon with suspicion and, in the second place, should be examined with more than ordinary care. If unusual loads are to be brought upon the structure a more thorough examination is, of course, demanded.

If the deck planking is thin, worn or decayed, longitudinal planks may be laid under the wheels. A weak stringer may be braced by placing a post under its center, or a trestle or crib may be inserted at the center of the span, which supports all the stringers. Sometimes it will be easier to take up the flooring and insert additional stringers. If **trestle legs** are over 10 or 12 ft. in length they should be cross braced, and if the spans are over 15 ft., the trestles should be braced longitudinally. **Wooden trusses** may be strengthened by spiking or bolting additional timbers to the chords and inserting web members of timber. **A weak steel truss** may be supported by one or more trestles or cribs inserted beneath.

These are but a few of the expedients that will suggest themselves to the resourceful engineer. It will usually be easier to reinforce an old bridge than to build a new one.

A bridge which has been examined or strengthened should be placarded to indicate its safe load.

CHAPTER V

MILITARY ROADS

We have seen that mobility, the power to maneuver in strategical and tactical combinations, is essential to success in military operations. Roads accordingly play an important rôle in the conduct of war. In modern warfare, with the vast number of combatants engaged and the great extent of territory covered, roads will be of more importance than in the past. While military operations of any magnitude will be dependent upon the railroads yet the motor truck has become a most important aid to the railroad in the transportation of troops, artillery and material of all kinds. To realize the advantages that may be derived from its use an extensive system of good roads is essential. Good roads saved Paris from falling into the hands of the Germans during the present war. It was the steady stream of soldiers poured into the firing line by automobiles on the magnificent *chaussées* of France that turned the tide of invasion at the Marne.

In road work, probably more readily than in any other branch of military field engineering, the engineer with civil training can adapt his knowledge and experience to war conditions. Military road building is similar in many respects to civil practice. The civil engineer who has a thorough knowledge of the methods that produce good roads and the broad common sense which will enable him to apply them to military needs will be successful in time of war. It is only necessary that he should thoroughly appreciate the economics of warfare which we have heretofore discussed.

Motor transport demands good roads and even for animal transport they are to be desired. The construction of a modern paved highway takes time and therefore military operations will be greatly hampered if they are conducted in a country which has not been provided in time of peace with a complete system of good roads. In many parts of Europe such systems exist and the principal highways have been built with a view to their usefulness in war as well as in peace. **The United States is poorly equipped** both as to the quantity and the quality of its roads. In any military operations conducted in our territory, extensive road construction must be carried on by both combatants.

Military road work will consist very largely of the **improvement, repair and maintenance** of existing roads, but in many of our possible theaters of war, including the United States and other parts of the American continent, extensive new construction work will also be necessary.

In the location and construction of a military road the peculiar economics of warfare, which have been heretofore mentioned, should be kept constantly in mind. In the construction of a civil road or railroad the amount of money which may be profitably expended in reducing grades, securing good alignment and in paving (in the case of a road) is determined from the estimate of the nature and amount of the probable traffic. In military construction the element of cost is of secondary importance, but the question of **time is paramount.** The road must be opened for traffic in the least possible time. Nevertheless **the nature and amount of the traffic** and the period during which the road will probably be required are not, of course, entirely disregarded. The road will usually be constructed to meet the exigency of the moment and may later be altered and improved to meet the development of the situation.

Common labor will ordinarily be plentiful, but often no plant at all will be at hand. Wheelbarrows can usually, although not always, be supplied, and for extensive work plows and drag or wheel scrapers should be obtained. Explosives will be available and may be liberally employed. **The use of more elaborate**

plant, such as graders, steam shovels, etc., will seldom be either practicable or advisable under war-time conditions. The stretches of road to be constructed will usually be relatively short and built to connect existing roads. Motor trucks will be utilized on the good existing roads where they can move at the relatively high speed which is necessary if their economical advantages are to be realized. But on purely military roads built under service conditions much of the traffic especially in our own operations, will be by wagons drawn by horses or mules. **Four and six line teams** may be and are employed in military operations when civil economics would demand two line teams (Fig. 27). Also, **military traffic moves in trains** and teams may be doubled up and loads shifted when necessary. Extra teams and relay stations may be provided. Such traffic moves but slowly on the best roads, and hence **the greatest improvements in the road** will effect only **slight changes in the speed** of transport (though they may reduce its cost), unless motor trucks be substituted for wagons. A rough

FIG. 27.—Four mule team and escort wagon, army standard.

surface, if firm, is of little disadvantage to slow-moving traffic and the same is true of poor alignment, though, of course, very sharp curves should be compensated by widening the road.

Brick roads are, of course, out of the question, except possibly along the main motor routes on the lines of communication. For wagon traffic their advantages are not sufficient to justify their cost and, more particularly, the time required for their construction. Even common water-bound macadam can seldom be advantageously employed. **The military road** will usually be a **common earth road.** If the soil is very sandy it may be mixed with clay for a wearing surface, and conversely. Gravel

FIG. 28.—Road improved for military use by paving of logs and brush. Constructed by the Germans in Russia.

may occasionally be used to good advantage if it can be obtained along the line of the road. Pit gravel usually compacts very satisfactorily under traffic if shaped up occasionally. Stream gravel usually requires the addition of a binder. If the gravel contains many large pebbles or stones it should be screened. If stone is available a rock fill covered with a layer of earth may be employed at soft spots where the drainage is bad. In swampy or poorly drained ground a plank or "corduroy" road will usually be the simplest and best expedient. The logs or poles are seldom covered, and the surface, while rough, is firm and suitable for slow-moving traffic. **A great variety of materials** may be used to temporarily increase the supporting power of a roadbed, including branches of trees, bunches of brush, grass, turf, leaves, etc.

It is to be remarked that **the advantages of very low gradients** can not be fully realized unless a good surface is also provided and, conversely, the advantages of a good surface can not be fully realized unless the grades are held down. Accordingly it is of little use to strive for very low grades on a road which is not to be paved, or to incur great expense of time and money in providing a macadam paving on bad grades. A good macadam road must have low grades. Also, for slow-moving military traffic neither low grades nor good surfaces are as advantageous as for motor transport.

Military traffic moves in trains and its use of the road may be regulated. Loaded wagons generally move in one direction only and empties in the opposite direction. Under these conditions a 10-ft. or even an 8-ft. **width of road** may be made to meet requirements, passing points being placed at the necessary intervals and where the extra width may be cheaply provided. Such a narrow road would, of course, be very unsatisfactory for unregulated civil traffic with loaded wagons passing at random in both directions and meeting at all points. A width of 16 ft. which permits the easy passage of two lines of wagons in opposite directions, is desirable if it can be obtained without excessive excavation. It will seldom be advisable to provide more than an 8-ft. width of metal if the road is to be paved.

In the location of a military road the foregoing facts must be borne in mind. In order to reduce the excavation to a minimum the road should lie close to the natural surface of the ground, even if this results in occasional steep and adverse grades, poor alignment and consequently increased length. **Heavy cuts and fills** with the great yardage and the relatively long hauls which they involve should be avoided. **A gradient generally not exceeding 4 to 5 per cent.** with occasional short maximum stretches of 6 to 7 per cent. may be regarded as quite satisfactory for military wagon transport if better grades can not be secured without excessive labor. A road having a grade generally not exceeding 8 per cent. with occasional maximums of 10 or 11 per cent. or even more, will be practicable, but will require relaying if the distance be considerable. It may be adopted if the nature of the terrain does not allow better natural grades. Adverse grade should, of course, be avoided, even if this requires more distance. In the original location an effort should be made to keep the grades generally as moderate as the nature of the terrain will permit without excessive excavation, and to **concentrate the steeper grades** in a few localities. The road is thus opened up and the bad grades may later be reduced if necessary by cuts and embankments. By thus concentrating the unfavorable grades in a few localities subsequent improvements may be effected with the least possible relocation and interruption to traffic. Thus if there is a possibility that the road may be used for transport for a considerable period it will usually be better to adopt a general grade of about 4 per cent. with occasional sharp maximums 8 to 10 or even 12 per cent. rather than a general grade of 7 to 8 per cent. with nothing exceeding this. In the former case a few relocations in the maximum sections, involving perhaps some heavy excavation, will eventually produce a good 4 per cent. road, whereas if the steeper general grade were adopted, complete relocation and reconstruction would be necessary to produce the same result. In the first instance the heavy work is avoided by a steep climb or a detour which is later eliminated and abandoned. Thus the locator should consider what may eventually be required and so plan his original location as to enable the ultimate requirements to be met with the least possible reconstruction, even at the cost of temporary disadvantage in the way of occasional very steep grades. If the future requirements are uncertain it may be advisable to adopt a somewhat higher general grade, suited to the nature of the terrain and to avoid steep maximums greatly in excess of the general grade. It will be apparent that the problems of the military locating engineer are not greatly different from those of his civilian confrère. He must consider the demands of the immediate situation and meet them promptly, but so far as practicable he should also give consideration to the ultimate requirements. In locating a road for military purposes the engineer enjoys one great advantage in that he is not hampered to so great an extent as the civilian by questions of right-of-way, property values, etc. And, as in all military construction, first cost gives way to speed, which often simplifies the problem.

The general location of the road is selected from a map, if one suitable for that purpose is available. The next step is a hasty reconnaissance or preliminary survey to fix the general location on the ground, determine the grades which may be obtained and the special difficulties to be encountered, the materials available along the route, etc. For this examination **very simple instruments** will serve, an aneroid barometer for elevations, a hand clinometer to measure gradients, distances measured by pacing. A rough sketch of the route should be prepared and it should be marked out by placing flags (pieces of red cloth on sticks), blazing trees, etc. The detailed location may be satisfactorily executed with the same instruments in the hands of skillful and experienced men. A light transit with a vertical limb and a tape or stadia rod are better and will usually meet the requirements.

The removal of trees, especially their stumps, is a slow process and it is therefore well to avoid timbered areas if practicable. Also, the **absence of sunlight and poor ventilation** increase the difficulty of maintaining an earth road in a wood in passable condition. If it be necessary to pass through a wood the road may be curved or zigzagged to avoid the very large trees. The best way to remove a large tree is to dig around it, cut the larger roots and then pull over the tree with blocks and tackle. This removes tree and stump. If stumps are encountered they can be removed only by explosives which may be used liberally to save time. For military purposes a wooden trestle or viaduct, which may be constructed in a few hours or a few days, is often preferable to a long high embankment which may require weeks to construct with inadequate plant, and will generally also have to be paved in some manner to render it passable. Skill in location will reduce the number of culverts required, often it is true, at the expense of alignment. The road should follow the high ground or ridges, and the side ditches may be led off into adjacent ravines. Also, sun and air are very important aids in the maintenance of an earth road. **Culverts when employed** should be of the simplest type, plank and corrugated iron pipe being the most suitable materials and sufficiently durable for military purposes.

The bearing power of a road surface depends upon the paving and upon the **drainage of the roadbed.** Military roads will seldom be paved and accordingly particular attention should be given to drainage. Sub-drainage will usually be impracticable but ample side ditches should always be provided, except in very dry climates. The material from the ditches is used to raise and crown the roadbed. The best form of ditch is one wide and shallow rather than narrow and deep, since it is more easily constructed and kept open. Such a ditch may be constructed with a drag scraper, with a plow to loosen the earth. If the road is constructed on a steep sidehill, surface or intercepting ditches may be provided to keep the water from the hillside off the road. **Retaining walls** should be avoided if possible, as they require much time to construct. Zigzags or **switch-backs** may be employed to save labor on sidehill work. Retaining walls if used are built of log cribs, dry rubble, etc. Concrete will seldom be employed.

One of the economic advantages of a well-paved road from the civil engineer's point of view is the decreased cost of maintenance during a period of years. We are realizing more and more that increased first cost and longer time required for construction are usually economical for permanent roads in view of the lower maintenance charges and the greater satisfaction from the use of the road, the beneficial effects on the growth, the business and social life of the communities affected, etc. But we should also realize that from a military point of view these considerations have little weight. The army does not expect and does not demand that good roads shall be built under war conditions in the theaters of actual conflict, and moreover it can not brook the delay that their construction would require. Prompt results are demanded, cost is disregarded and makeshifts cheerfully accepted. As military roads are often used for a very short time only and never beyond the end of the war, **the question of maintenance** over a period of years does not arise. It will be economical to build an inferior road in the first place and to keep it passable by relatively expensive maintenance measures during a relatively short period. Earth roads to be passable must be kept drained and free from ruts and for military roads ample labor for maintenance will generally be available. The roads should be kept shaped up, ruts filled, ditches kept open. The most efficient method of maintaining earth roads is by dragging, supplemented by hand labor.

CHAPTER VI

FIELD FORTIFICATION AND SIEGE OPERATIONS

Field fortification is the most important and the most distinctively military of the many operations of the field engineer and constitutes an art and a science in itself.

The art of fortification includes two branches, known as **strategical** or deliberate, and **tactical** or hasty fortification.

Strategical fortifications include defensive works executed largely in time of peace for the protection of important harbors, cities, arsenals, etc. Tactical fortifications are those executed to meet the immediate tactical needs of the mobile army in the field, and are hence known also as field fortifications. The line of demarcation between the two classes is not clearly defined. Strategy and tactics are intimately connected and so the works constructed to meet their needs vary from the elaborate coast defense works to the simple trenches of a rear guard fighting a delaying action.

The purposes of military operations are to destroy the organized resistance of the enemy or to seize and hold territory which is important to him. For the accomplishment of either purpose aggressive action is required. This aggressive action consists in the **concentration of overwhelming force** at certain critical points while the enemy is held in check at other points, and it contemplates the probability of similar operations on the part of the enemy. Military operations are accordingly a combination of offensive and defensive action, and success will lie with the combatant who can seize and retain the initiative.

Aggressive action, the assumption of the initiative, implies the power of maneuver in strategical and tactical combinations.

Strategy maneuvers the troops into the most advantageous position for battle, but strategical advantages can in general be realized only by **winning the battle,** which is their logical culmination. For success in battle the power of tactical maneuver is essential.

The immediate purpose of field fortifications is to increase the power of resistance of the troops occupying them by decreasing their exposure to the fire of the enemy and increasing the accuracy and volume of their own fire. They thus serve to hold the enemy in check and limit his power of maneuver. Furthermore, they accomplish this result with the least number of men, thereby rendering the greatest possible number available for aggressive concentration of superior forces at the critical points.

Even in a successful attack the assailant can not advance continuously. Halts will be necessary to permit of the bringing up of supplies and reinforcements, to refresh the troops, to hold the enemy in check, to select new points of attack, to readjust the artillery positions, etc. The assailant at all such halts must cling with the spade to that which he has won with the rifle and bayonet. Troops can not remain stationary upon the field of battle exposed to the fire of the modern rifle, machine gun and artillery.

Fortifications therefore, while **essentially defensive** in their nature, will be extensively **employed also in the attack.** The neglect to utilize them will involve heavy losses and, if opposed to a skillful adversary, will invite defeat. On the other hand, **their excessive and indiscriminate use** limits the mobility of the troops, tends to destroy the aggressive spirit which is essential to success, and surrenders the initiative to the adversary.

Field fortifications then are a means to an end. If used indiscriminately, without due regard for the strategical and tactical requirements of the situation, they exercise a most baneful influence. **Their correct employment** for the achievement of the purpose in view calls for the highest skill of the commander.

The technical details of the works themselves are comparatively simple and readily comprehended, but their location, arrangement and adaptation to the tactical situation and to the terrain call for a high degree of skill, analogous to that required in road and railroad location.

The characteristic features of fortifications in all ages have varied with the nature of the weapons employed and with the particular tactical object in view. Structures which would provide protection against arrows and stones would be quite inadequate against modern artillery. The hasty outpost trenches of a rear guard in retreat would be quite unsuited to an army engaged in a protracted and decisive struggle. In general fortifications are designed to serve two purposes:

1. To facilitate the effective use of the weapons of the defenders; and
2. To restrict the effective use of the weapons of the attackers.

All constructions which serve either of these purposes may then be classed as field fortifications and will include the following:

(*a*) Rifle trenches for the firing line and cover trenches for supports.

(*b*) Emplacements for machine guns and artillery.

(*c*) Shelters for protection against fire, particularly shrapnel and high explosive shells, and against weather.

(*d*) Communicating trenches between supports and firing line.

(*e*) Observing stations, dressing stations, kitchens and latrines.

(*f*) Obstacles to retard the enemy's advance and hold him under fire, including explosive mines.

(*g*) Demolitions for clearing the field of fire and restricting the tactical maneuvers of the enemy.

(*h*) Measures for concealing all works from the enemy's view.

(*i*) Mining operations or tunneling for subterranean advance against the hostile works.

(*j*) General communications, such as roads, foot paths, light railways, telegraph and telephone lines, signal stations, etc.

Most of these works must necessarily be executed by the combatant troops who are to occupy them, and **all line (combatant) officers** should be qualified to superintend their construction. **The engineers,** however, will constantly be called upon for advice and assistance as to location and details, and in the execution of some of the more difficult tasks their special training and equipment will be necessary.

Geographical, political and other conditions and strategical considerations will determine the theater of war. **The position to be occupied** and fortified will be fixed by tactical considerations. The general line to be occupied will usually be determined from a map, but the **actual location** of the trenches and accessory works can be satisfactorily made **only on the ground.**

These are certain requirements which experience indicates that a defensive position and the works executed thereon should fulfill. Many of these requirements are at variance with each other and it will never be practicable to find a single position which fulfills them all. Skill and experience are necessary to determine the requirements which are of paramount importance in any particular case. Often it will be a question simply of making the best of the locality in which the troops find themselves. Often works hastily constructed on the field of battle are later elaborated and strengthened to meet the developments in the tactical situation until the operations partake very largely of the nature of siege warfare, as is the case today on the western battle front in Europe.

The matters to be considered in selecting and organizing a position are: The mission or purpose of the command, their numbers and quality; strength, position and probable intentions of the enemy; the weapons possessed by both combatants; the nature of the terrain, facilities for maneuver or retreat; whether delaying or decisive action is contemplated; the time the position must be held; the time available for preparation; etc., etc.

The first requirement of a defensive position is that it shall be one which the enemy must attack to accomplish his mission. If he can attain his purpose without such attack, then the position is useless and the time spent in preparing it wasted.

The following are certain additional considerations to be given such weight as the particular circumstances of the case may require:

(*a*) Is it proper to take up a position, or does the situation call for advance or retreat?

(*b*) Is the position suited to the strength and armament of the force which is to occupy it?

(*c*) Is the position to be held indefinitely? If not, for how long a time?

(*d*) What are the strength and intentions of the enemy? What weapons has he? Is he provided with means for aerial reconnaissance?

(*e*) Are there good positions with clear view and field of fire for both infantry and artillery? Is there a good field of fire at all ranges? If not, which is more important, a near or distant field of fire?

(*f*) What are the facilities for advance or retreat from the position.

(*g*) Are the flanks of the position naturally secure? If not, what expedients may be adopted to secure them?

(*h*) Are the communications within the position good?

(*i*) Is there cover for supports and reserves?

(*j*) Does the terrain present natural features adaptable to defense, or will great labor be required?

(*k*) Is the ground in front such as to facilitate the enemy's attack? Are there natural obstacles to his advance? Are any artificial obstacles required?

(*i*) Is the ground in rear favorable for counter-attack in case the enemy should penetrate the first line of works?

(*m*) Is the position naturally concealed from view, including view by aerial scouts? If not, what artifical means of concealment are possible?

(*n*) How much time is available for the preparation of the position? How much time will each item of the work require, and what is the order of relative importance? How should the labor and tools be distributed to produce the best results?

These and many other important questions must be considered. As has been stated, a single position giving a favorable reply to all these questions will never be found. Any position must be a **compromise between advantages and disadvantages.**

Success in battle is determined by **fire superiority,** without which the assailant can not advance and the defender can not hold his ground. Field fortifications increase the fire effect of the troops occupying them and decrease the fire effect of the enemy. They are designed to afford the maximum protection and concealment while still permitting the unrestricted use of the defender's weapons.

The shelter best fulfilling these requirements is the simple rifle trench from which the soldier may deliver fire in a comfortable standing position over a low earth parapet or through a

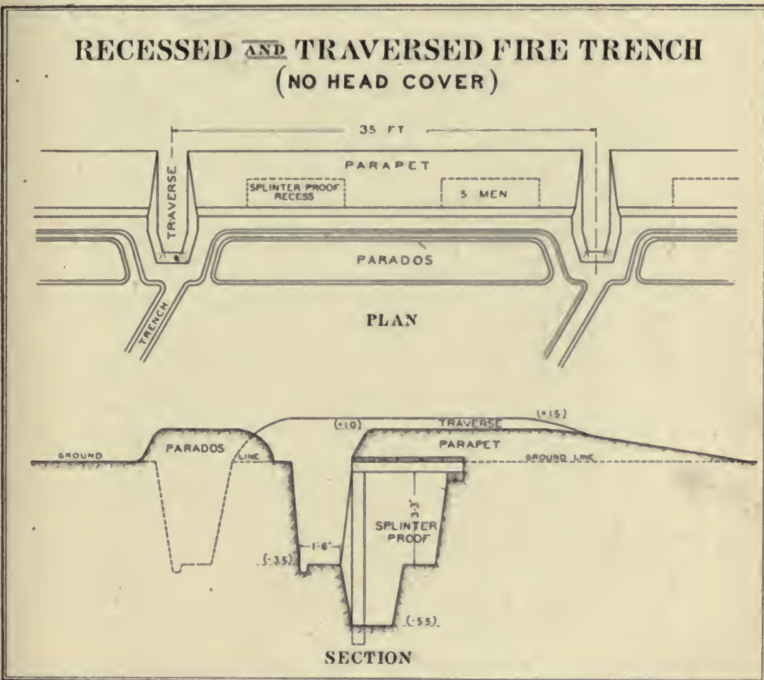


FIG. 29.

loophole in the parapet. Such rifle trenches are accordingly the principal feature of field fortifications (Figs. 29, 30, 32 and 33).

The parapet is made sufficiently thick to resist penetration by rifle bullets or shrapnel, which requires about 3 ft. of ordinary earth. The parapet should be sufficiently high to afford a view of the foreground but in order to be inconspicuous it should be no higher than necessary for this purpose. Ordinarily its height will be from 9 to 18 in. above the surface of the ground, unless excavation is very difficult in which case a shallower trench and a higher parapet may be used. Such a trench affords no adequate protection against **direct hits by high-explosive shell,**

FIG. 30.—Simple rifle trench with sand-bag and hurdle revetment and splinter-proof shelters under parapet.

which would destroy the parapet and kill the man behind it. Such shells will also penetrate and demolish any shelter which it is practicable to construct in the field. The only protection against the fire of large caliber guns which troops in field works

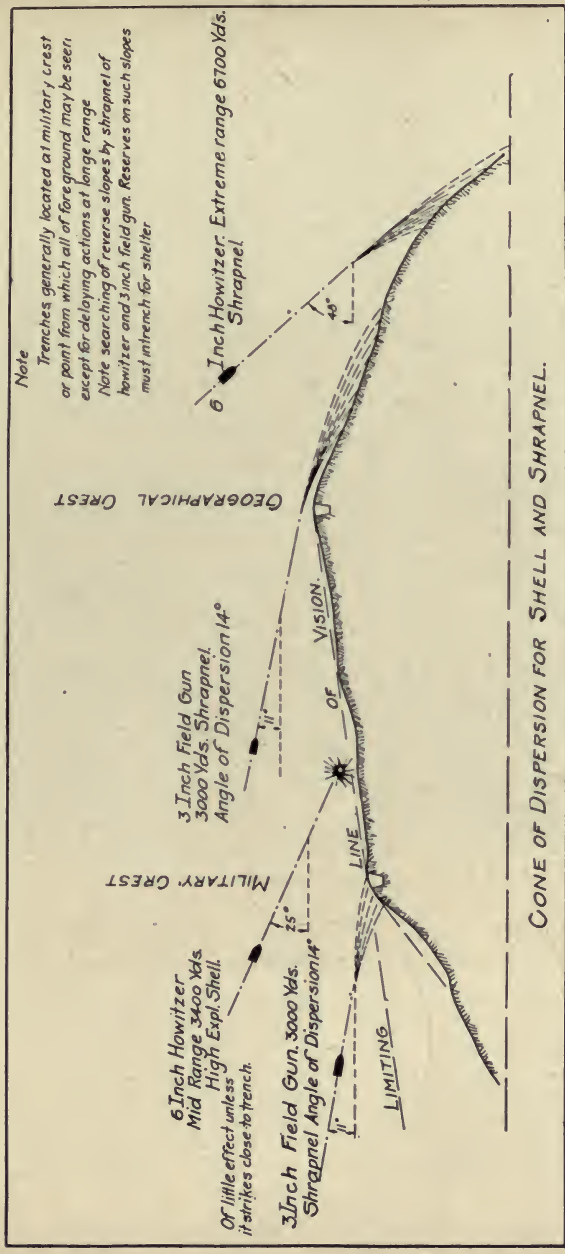

Note
Trenches generally located at military crest or point from which all of foreground may be seen except for delaying actions at longe range
Note searching of reverse slopes by shrapnel of howitzer and 3 inch field gun. Reserves on such slopes must intrench for shelter
6 Inch Howitzer. Extreme range 6700 Yds. Shrapnel
40°
GEOGRAPHICAL CREST
3 Inch Field Gun 3000 Yds. Shrapnel. Angle of Dispersion 14°
11°
MILITARY CREST
25°
6 Inch Howitzer Mid Range 3400 Yds. High Expl. Shell.
Of little effect unless it strikes close to trench.
3 Inch Field Gun. 3000 Yds. Shrapnel Angle of Dispersion 14°
11°
LIMITING LINE OF VISION
CONE OF DISPERSION FOR SHELL AND SHRAPNEL.

FIG. 31.

enjoy is the improbability of direct hits. This probability is so small that under battle conditions it has been found that the destruction of trenches by shell fire requires an expenditure of ammunition out of proportion to the results obtained. It is therefore seldom attempted. **The attack of such trenches** will be by means of showers of **shrapnel and rifle bullets** (Fig. 31). While the actual physical effect of such fire in killed and wounded

FIG. 32.—Rifle trench with head cover (loopholes) and traverses.

may not always be great, it may force the defenders to keep their heads down below the parapet and prevent reinforcements from coming up, and this will diminish the volume and accuracy of their fire and may permit the attacking infantry to advance against the trenches.

To further decrease the vulnerability of the defenders the parapet may be provided with **head cover** by placing in the parapet loopholes of plank, sand bags, etc. (Figs. 32 and 33). This allows the occupants to deliver fire without exposing their heads and shoulders above the crest of the parapet. **Overhead cover,** con-

FIG. 33.—Rifle trench with plank loopholes and shelters under parapet. The latter is being covered with sod for concealment.

sisting of a shelf of plank covered with earth or steel plates supported by framework may also be provided. As this requires

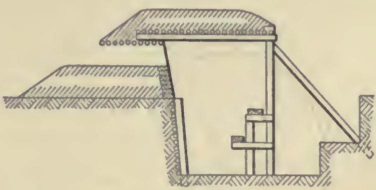


FIG. 34.—Rifle trench with overhead cover.

considerable time and labor to construct and greatly increases the visibility of the parapet as a target it is of limited application (Figs. 34 and 35). The troops in the present European war are provided with steel helmets stout enough to deflect rifle bullets and shrapnel fragments. Trenches are often provided with overhead nets to stop **grenades.**

The trenches are made very narrow with steep side slopes in order to reduce the possibility of shrapnel falling in the trench. **If the earth will not stand naturally** on a steep slope some form

FIG. 35.—Rifle trench with overhead cover of steel plates supported on frame-work.

of **revetment** must be provided. The most common forms are planks or hurdles of woven brush, sand bags, fascines, and the like (Figs. 36 and 37). Drainage must also be provided if the trenches are to be occupied during rainy weather. **If the trench can be properly graded** a continuous drain may be carried along the back of the trench and led out at the lower end (Fig. 29). Otherwise, sump holes may be provided at intervals. **Surface drains** may also be dug on the high ground above the trenches.

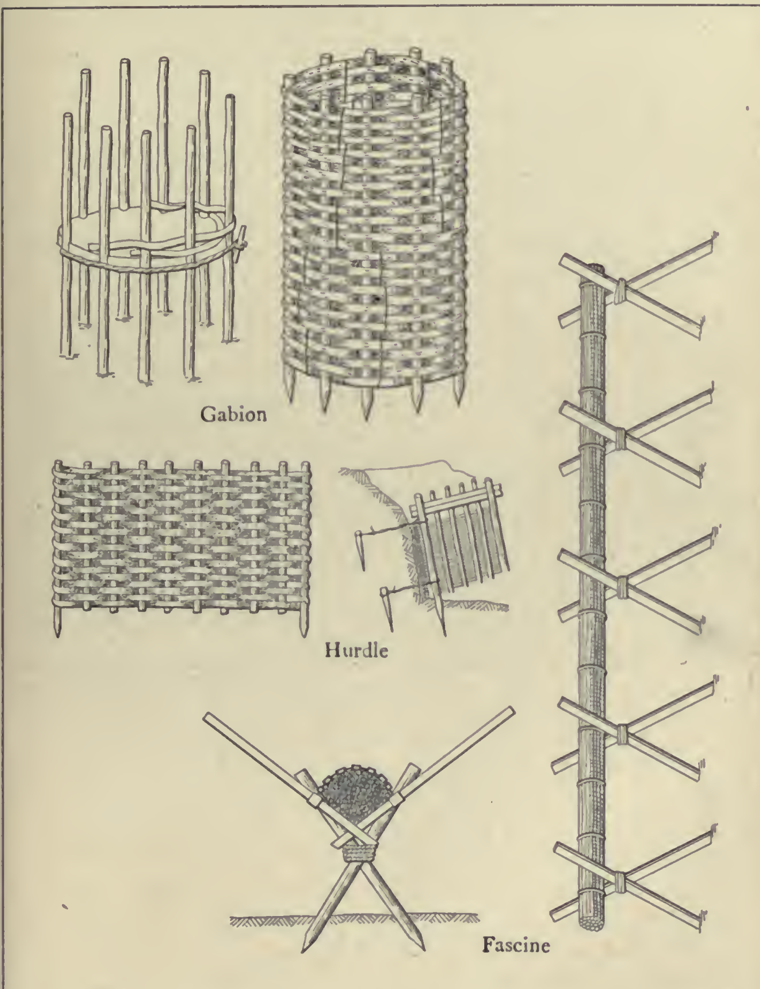


Fig. 36.—Common forms of revetment.

To permit the movement of men along the trench it may be widened and deepened at the rear, or a separate trench parallel to and immediately in rear of the fire trench may be provided (Figs. 30 and 38).

In order to protect the occupants from oblique or enfilade fire and to localize the effect of shells bursting in the trench, **banks of earth perpendicular to the parapet** and of equal or somewhat greater height may be placed at intervals. These are called **traverses** (Figs. 29 and 32). They should be thick enough to resist penetration by rifle bullets and, in order to take up as little room

Fig. 37.—Common forms of revetment. Plank, turf, sand-bags, gabions and logs.

as possible, their sides should be steep, and revetted if necessary. They are placed usually at intervals of one or two squads (8 to 16 men) and communicating trenches are dug around them, either in front or in rear.

Bomb-proof shelters are often provided in the fire trenches for the supports or for sheltering the occupants when not actually firing. These consist generally of excavations under the parapet, open to the rear. If provided with a sufficient overhead covering of earth they afford complete protection except from direct hits by large shells and grenades or shells bursting in the trench. They are provided with a roof of poles or planking. The roof may be placed on the ground and the earth excavated from beneath and thrown on top. A seat should be placed at the front and the headroom should be at least sufficient for a comfortable sitting posture (Figs. 29, 30, 33 and 39).

Concealment from the enemy's view, both before and during combat, is a most important element of protection from hostile fire. The freshly turned earth of a parapet is exceedingly conspicuous, forms an excellent target unless concealed, and considerable labor and skill may well be employed to render the works inconspicuous. The trenches should be kept off the sky line. If necessary to place them on a crest they may be concealed by shrubbery or brush placed behind them. The obstacles in front of the trenches must be inconspicuous. The first requirement for concealment is that the works should be blended with the existing natural and artificial features of the terrain. The parapets should be low and all sharp angles, either vertical or horizontal should be avoided. If built on the turf this may be cut in strips, rolled to the front and rolled back over the parapet when the latter is completed, thus concealing the fresh earth. The parapet may be covered with leaves or shrubs naturally disposed and its ends should be graded gently into the natural ground. The parapet should be sufficiently high, however, to conceal the rear lip of the trench. Loopholes in particular are conspicuous and should be concealed by a shrub or branch, which will ordinarily not interfere with fire through the hole. A low, thin hedge will completely conceal a trench immediately behind it without interfering with fire. Works placed just inside the edge of a wood are very difficult to distinguish, but if the edge of the wood be sharply defined it will itself afford excellent ranging points for the hostile fire. Diversified ground, ravines and ridges, standing crops, scattered trees, hedges, fences, etc., lend themselves to the concealment of the works and should be utilized to the utmost. Skill in this particular branch of landscape gardening will produce remarkable results and, under favorable conditions, trenches may be rendered indistinguishable even at a distance of 100 ft. If opportunity is afforded the works should be examined from the front, the enemy's point of view, when the best location, the necessity for concealment and the measures that should be adopted will become apparent. The highest expression of the art of field fortification consists in utilizing to the best advantage the existing natural and cultural features of the terrain, both to increase the effectiveness of the works, and to insure that concealment which is so important an element of security.

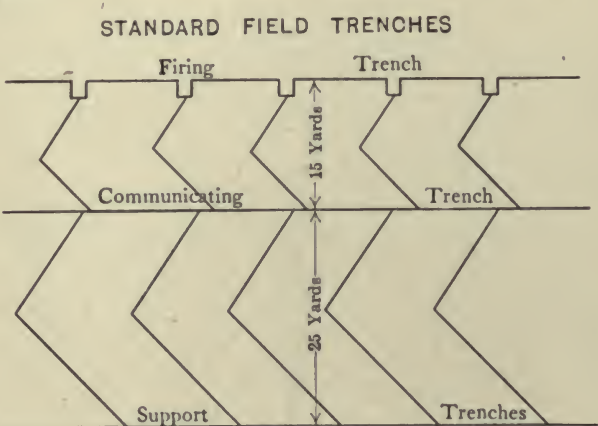


FIG. 38.—Standard field trenches. showing communications between firing line and supports.

The supports for the firing line should be placed as close to the latter as the requirements of easy concealment and protection from the enemy's fire will allow. **Natural cover,** if available within a reasonable distance, is to be preferred, both because of superior concealment and the lesser amount of labor required in its adaptation. Natural shelter also possesses the great advantage that it does not ordinarily restrict the tactical mobility of the troops to the same extent as cramped and confined artificial shelters, difficult of ingress and egress. Accordingly, while the immediate supports of the firing line must often of necessity be immobilized in artificial shelters, for the mobile reserves who must be ready for prompt concentration at the critical points, natural shelter well in rear of the firing line will almost invariably be sought.

Fig. 39.—Shelter under parapet in construction. Timber frame and covering of sand-bags on plank.

A covering ridge just back of a firing line may afford excellent natural cover, or may be artificially prepared with little labor, but in the absence of some such natural feature, artificial cover must be provided. This will usually consist of trenches in rear of the firing line. As such trenches are not required to deliver fire, more complete protection to the occupants is possible than in the fire trenches. The trenches are usually made very deep and comparatively narrow and may be roofed over or have bomb-proof chambers leading out from them. In a position which is occupied for some time these chambers may be developed into elaborate subterranean barracks, with planked ceilings supported by columns, drainage, water supply, artificial

FIG. 40.—Second line of defense showing simple traversed trench and communicating trench zig-zag to front.

light and heat, etc. In this manner hasty field fortifications are gradually developed into elaborate siege works.

Communicating trenches must ordinarily be provided to allow of a safe passage between the support shelters and the firing line (Figs. 38 and 40). As these trenches will be occupied only for a few seconds while passing to and fro, simple concealment from view will often be sufficient. The trenches, however, should usually approach a firing line in a direction oblique to the enemy's fire, that they may not be subject to enfilade, or they may zigzag to the front. The parapet is placed on the exposed side. If the location of these trenches is such as to render them conspicu-

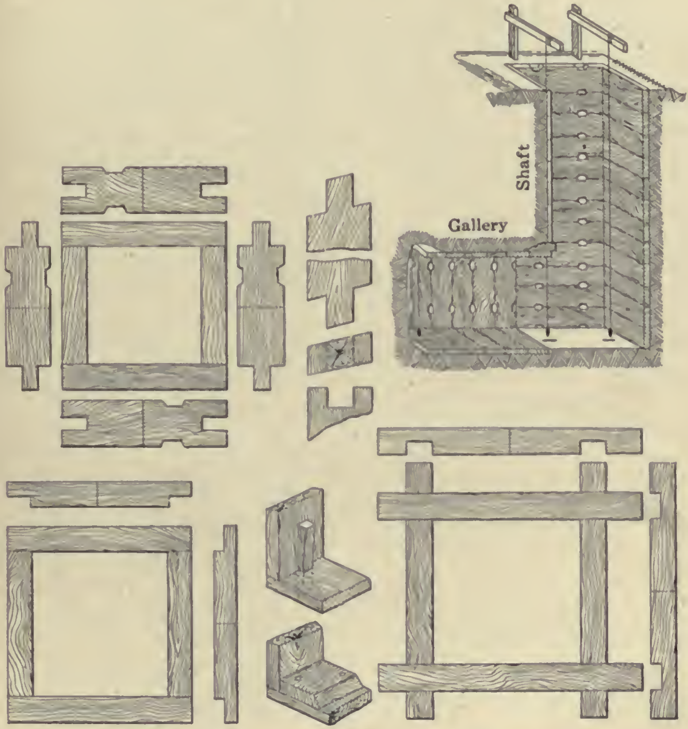


FIG. 41.—Military mining. The linings are carried in stock.

ous and subject to fire, they may be roofed over or a **subterranean gallery** may be substituted for an open trench.

Subterranean attack has long been characteristic of siege operations and may also be an important feature of modern trench warfare. It is conducted by sinking shafts and driving sub-

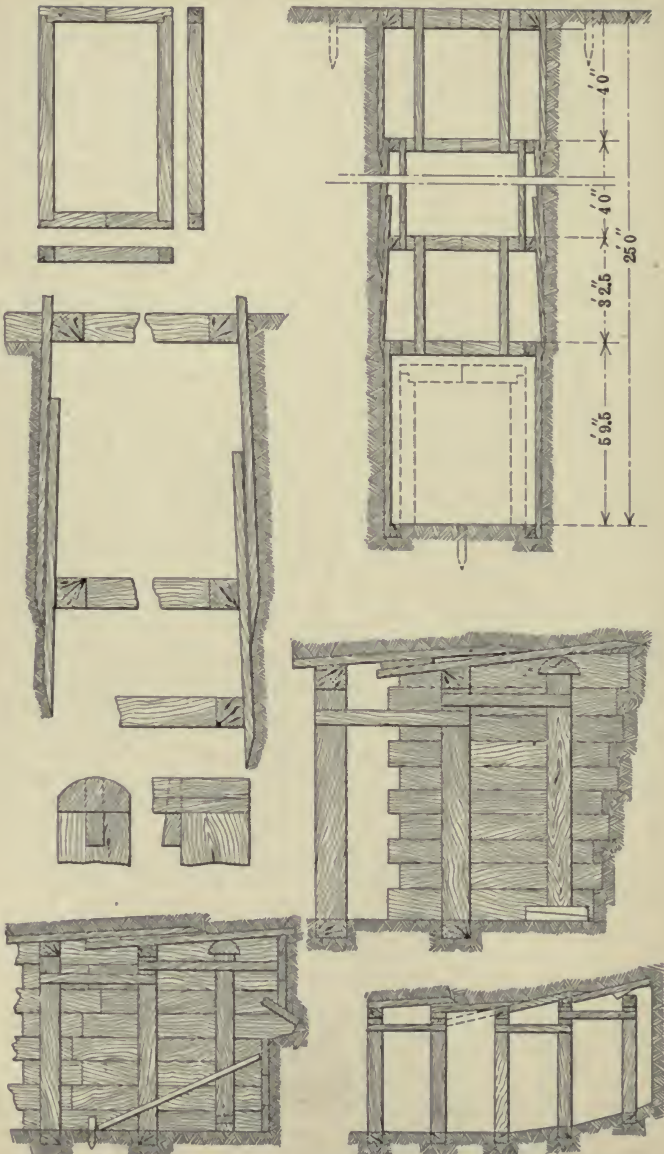


FIG. 42.—Military mining. Linings for shafts and galleries.

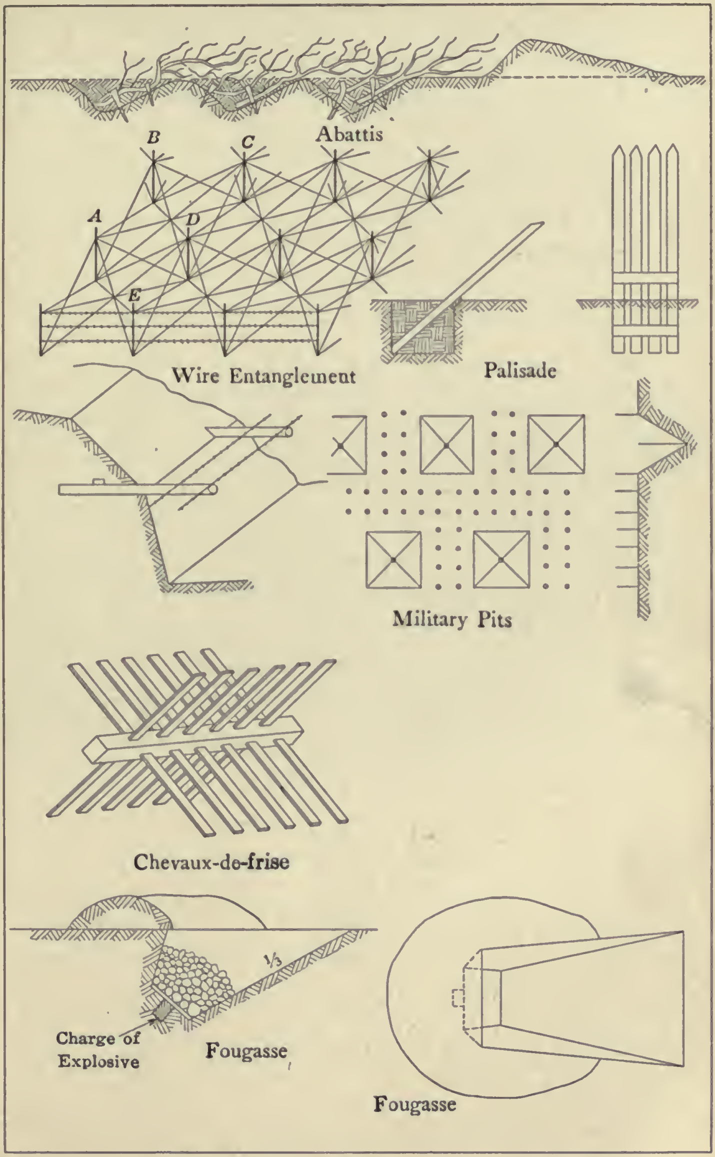


FIG. 43.—Types of military obstacles.

terranean galleries toward the enemy's works. At the end of the tunnel a large charge of explosive is set off, destroying a section of the enemy's line of intrenchments (Fig. 48). In the confusion following the explosion an assault overground is made on the hostile works. Protection against this mode of warfare is had by means of "listening galleries" driven forward from the intrenchments. By means of these the enemy's subterranean operations may be detected and measures taken to frustrate them. The excavation is made by hand with specially constructed tools, by the use of light charges of explosives or by

Fig. 44.—Barbed wire entanglement. The soldiers are cutting the wire with shears.

boring machines operated by electricity or compressed air. Small trams may be used to remove the excavated material and in long galleries artificial light and ventilation will be required. The galleries are lined with wood sheathing as the excavation progresses (Figs. 41 and 42).

If opportunity allows, **the foreground of the works** will be prepared with a view to improving the field of fire and embarrassing the movements of the enemy. Trees, buildings and other features which obstruct fire are removed, roads and bridges demolished, ranges to important points measured, etc. In this work explosives are liberally employed to save time and labor. Fire should be used sparingly as it renders the locality conspicuous both during and after the conflagration. **Obstacles of various kinds** are placed in the foreground to retard the enemy's movements and hold him under the fire of the defense (Fig. 43). Ravines which might permit concealed approach may be choked by felling trees in them. Low land may be inundated by means of dams in the streams. All obstacles should be such as to retard movement without affording cover from fire. The most

Fig. 45.—Abbatis.

effective obstacle is a belt of wire, preferably of barbed wire, strung on posts or other support. This is known as a wire entanglement and is difficult to remove or destroy by explosives (Fig. 44). It may be effectively concealed in high grass or standing crops. It should usually be placed close in front of the trenches in order to prevent its removal by the enemy and to hold him at the point where the defender's fire is most effective. Other favorite forms of obstacles are abattis or slashings of trees with barbed wire interlaced, palisades or picket fences, pits covered with brush, wire fences, chevaux-de-frise, military explosive mines with charges of broken stone, and the like (Figs. 45, 46, 47 and 48). As with the trenches, great pains should be taken to conceal these obstacles from the enemy's view, especially as they may disclose the location of the trenches in rear. Accordingly they should be placed in the zone where the defenders' fire is most effective since this renders the obstacles most effective and also makes it difficult for the enemy to remove or destroy them. In the presence of the enemy obstacles must generally be placed and repaired under cover of darkness.

As the best protection against hostile fire is concealment from view, night attacks are of common occurrence in trench warfare,

FIG. 46.—Chevaux-de-frise and wire entanglement.

and to guard against these **artificial illumination of the battlefield** by night is essential. **Flares or torches** may be used to illuminate the enemy's movements, or as warning signals. Bonfires may also have a limited application. They are often used to mark fords over streams, or to indicate areas where aviators may make a landing. Such illuminations, should if practicable, be screened on the side toward the defense.

Searchlights are often placed on the line of the fire trenches, but generally will occupy some commanding point, such as

FIG. 47.—Fougasse or small land mine exploding.

FIG. 48.—Land mine—200 lbs. of dynamite.

a ridge or hillock in rear of the line. Arrangements should be made for moving them occasionally from place to place since, if fixed in one position, they are liable to be reached by hostile fire. Rockets or bombs may be used for signalling and illuminating. One type of illuminating rocket is provided with a parachute which will sustain the light as long as forty seconds. Aeroplanes and balloons may be fitted with searchlights, or may drop illuminating bombs. Searchlights for use with a mobile army in the field must be rugged, and of such size and construction that they are readily transportable. The source of power for the field searchlight must also be readily transportable, otherwise its use on the battlefield might seriously encumber its operators. In European countries various types of field searchlights have been developed. Some of these are mounted on motor trucks, and some are designed for animal traction. Ordinarily some method is necessary for raising the light so as to increase its effectiveness. Several types of collapsible or telescoping towers are in use. If not raised considerably above the ground, searchlights cast long shadows and illuminate the immediate foreground to an undesirable extent. **The current required for operating the searchlights** may be supplied by a gas engine connected to a suitable generator. In many cases the engine driving the motor truck is made to furnish power for the searchlight. Storage batteries or dry cells may be used where suitable. Steam engines can be connected to proper generators, but a considerable time is necessary before the plant can commence to furnish power. Smoke from a steam plant is also objectionable, as it might disclose the location of the plant. In addition to electricity, resort may be had to acetylene or other suitable gas for the source of light.

Machine guns are employed in the fire trenches or in specially prepared emplacements in the intervals. They are extensively used to support the line at localities where infantry fire is restricted. **Artillery is usually placed** behind the line of infantry defense, natural cover being utilized as far as possible (Fig. 49).

The numerous and infinitely various works included under the term "field fortifications" will usually be executed under the most trying conditions. Frequently they must be constructed actually under hostile fire. **The details of the works** are therefore necessarily simple, but this very simplicity is the highest expression of the skill of the designer, as there is a very great tendency to over-elaboration. It is to be borne in mind that the works must ordinarily be constructed by the troops which are to occupy them and that of the average untrained man little

Fig. 49.—Emplacement for machine or field gun.

more than ordinary earth excavation can be demanded. The works therefore must be designed for rapid construction by **unskilled labor with simple tools** and the materials of nature. These conditions and the experience derived from meeting them have resulted in the development of certain type plans. These plans are by no means rigid but must be infinitely varied to meet the actual conditions, such as terrain, nature of soil, tools and materials, time available for construction, etc. Each situation is unprecedented and calls for new measures adapted to the circumstances. The engineer or line officer who directs the work must have a thorough knowledge derived from study and

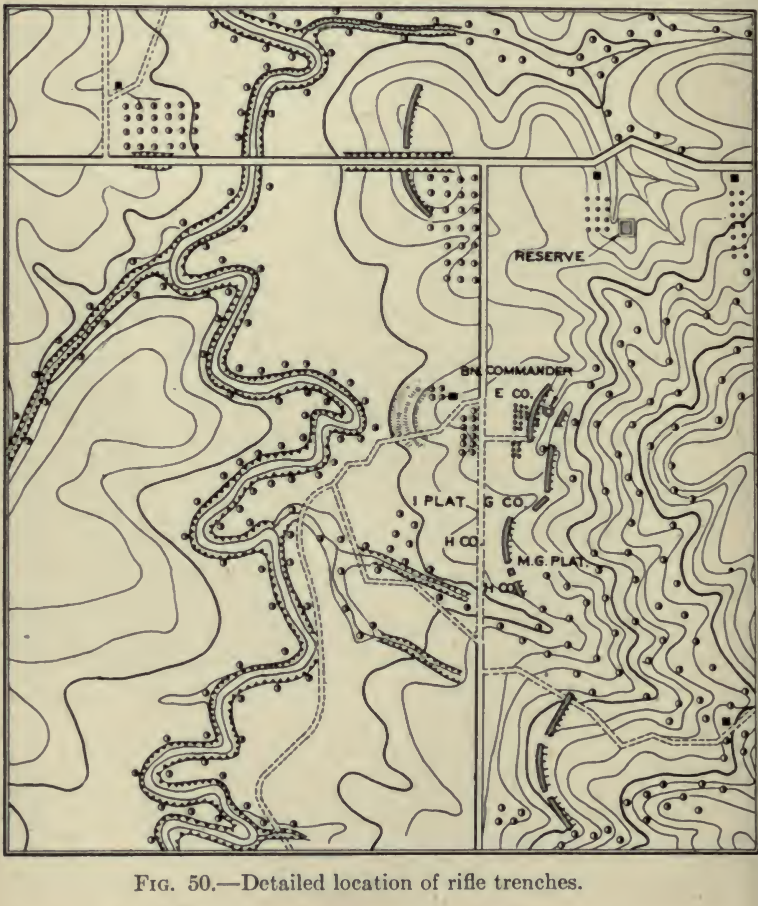


FIG. 50.—Detailed location of rifle trenches.

experience of the demands of the situation, the works that will be required, the relative importance of the different works, and the time that will be required to construct them. Without a comprehensive grasp of the situation the works will be poorly located and badly adapted to the situation, and confusion instead of system will characterize the operations. In the end, unnecessary bloodshed and loss of life, defeat and ruin of the combatant force, or national disaster will be the logical results of incompetence and inexperience. Hasty fortification is one of the highest of the fine arts whose practice demands in a superlative degree, judgment, skill and experience, and in whose field the novice and incompetent may wreak utter disaster and ruin.

This map of an actual piece of ground (Fig. 50) shows the manner in which rifle trenches are disposed to cover the ground in front with their fire. There are shown the trenches of three battalions, with the detailed dispositions of the center battalion. The enemy is approaching from the west, and it will be observed that the fire trenches in a general way occupy the convex faces of knolls or noses, with their flanks curved back or "refused" to sweep the ravines intersecting the front. The support trenches of the center battalion are also indicated—they are close in rear of the fire trenches. The trees, buildings, and other obstructions which interfere with fire are demolished. In particular the loop of the creek which protrudes into the foreground in the center of the position is an element of weakness, because this creek with the trees on its bank affords a covered or concealed approach for the enemy. Accordingly, the trees around this loop are thinned out (it is not necessary to cut them all) and the débris is thrown into the bed of the stream to obstruct it and prevent its use by the enemy. An examination of this map will indicate that these trenches are carefully disposed to cover with their fire all of the ground in their immediate front. Thus it will be observed that the fire trenches of E. Co. of the center battalion can not cover with their fire the very steep (hachured) slope in their front, immediately opposite the point of the loop in the creek. But this ground is effectively covered by the machine gun platoon (M. G. Plat.), by part of H. Co., and by the fire of the southernmost trench of the next battalion to the north. Similarly it will be observed that the trenches of the center and left (southernmost) battalion, are disposed to sweep the ravine between their positions, after it has been opened up somewhat by thinning out the trees and underbrush. The trenches of the northernmost (right) battalion enfilade or sweep the two branches of the creek in the foreground of the battalion's position. Here the trees should be thinned out to make the fire effective.

SIEGE OPERATIONS

Siege operations have been frequent in warfare since the dawn of history, in fact they antedate the invention of firearms, and were conducted in the days when the only weapons were bows and arrows, stones hurled by catapults, battering rams, etc. They were formerly distinguished from operations in the open field by the **extreme formality** which characterized the procedure of both combatants. **The increasing power of modern firearms** has tended toward the obliteration of the sharp distinction between siege and field operations. On the one hand we find permanently fortified places making extensive use of detached forts and hastily constructed field works as accessories to the main defense. On the other hand we see that the intensity of the fire of modern ordnance has forced troops operating in the field to resort to many methods formerly regarded as characteristic of siege warfare.

Important localities whose strategical value can be foreseen are still fortified, however, in times of peace. **Such defensive works** are very elaborate and of great strength and they are provided with every conceivable device and facility for resisting attack. An assault upon them has little prospect of success unless the works have been at least partially demolished, inasmuch as they present great physical obstacles and afford such thorough shelter to the defenders that it is difficult to shake their morale or diminish the effectiveness of their fire by means of rifles, machine guns or light field guns. The defenders will also be provided with ordnance of the most powerful types, they will be intimately acquainted with the foreground, which is specially prepared in advance to embarrass the attack, and they will possess large supplies of ammunition and excellent facilities for its storage and use. The fire of the defenders and their protection will therefore be more effective than is possible with less formal preparation.

FIG. 51.—Bringing up heavy artillery for the attack of a fortress.

Such fortifications must generally be thoroughly demolished before their defenders can be dislodged, and for this purpose **guns of large caliber,** hurling great charges of explosive are required, coupled often with extensive mining operations such as have been described.

The first step in the reduction of such a fortress, which should be carried out if practicable, will be to cut off its supply and reinforcement as well as its communication with the outside world, by surrounding the place with a line of troops. This is called the **line of investment.** It should generally be drawn as close to the fortress as the effectiveness of the defender's fire will permit. It is not necessarily continuous, but must usually be fortified. The investing troops may have to resist attack from more than one direction, inasmuch as the enemy may endeavor to break the investment by sorties of the garrison of the fortress, or by the attack of a field army operating in conjunction with the garrison. If the civil population has not been previously withdrawn they are compelled by the besieger to remain in the fortress in order the more rapidly to exhaust its food supplies.

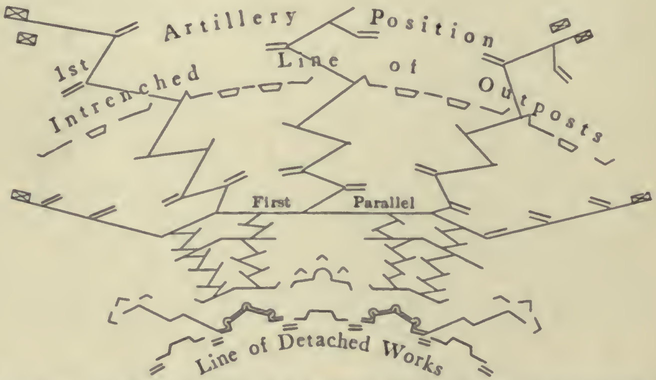
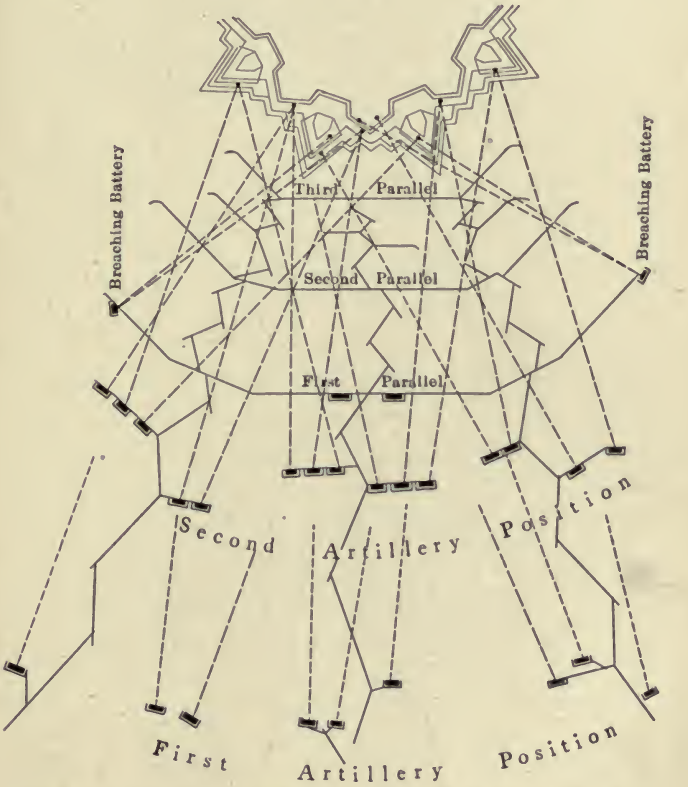


FIG. 52*a*.—Formal attack of a fortress by parallels and approaches.

The investment having been completed or found impracticable, one or more points of the fortress are **selected for the formal attack.** Or if the attacker is well supplied with heavy ordnance the works may be generally demolished and rendered untenable by a vigorous bombardment.

The points selected for attack will be those where the fortifications appear to be weakest, where the attacker's fire may be most easily concentrated, where the foreground is most favorable for his operations, where he is least apt to be interfered with by sorties or attacks from the outside, or where the consequences of success will be most disastrous to the enemy, etc., etc.

The heavy guns are then emplaced and the bombardment commenced (Fig. 51). When the defender's artillery has been



Note: Guns of batteries of the first artillery position whose lines of fire (dotted) nearly coincide with those of batteries of the second position are moved forward and mounted in the 2d artillery position.

FIG. 52*b*.—Formal attack of a fortress by parallels and approaches.

brought under control an attempt is made to break out an infantry trench as close as practicable to the fortress. This is called the "**first parallel.**" Zigzag approaches are pushed forward from the first parallel and a second parallel is broken out. To avoid as far as possible the enemy's fire this work is usually done at night—all in one night if practicable. **Successive parallels** are thus established and pushed as close to the enemy's works as his fire will permit (Figs. 52*a* and *b*). Meantime the operations are covered and the fortress damaged as much as possible by a practically continuous bombardment. From the last parallel **mines are driven forward** to demolish the works. The enemy will oppose these operations with fire, by sorties of the garrison and by **countermining operations** against the besieger's works. A breach in the fortress having been effected by bombardment and by mining, the besieger delivers an assault from the last parallel, supported by the fire of his artillery.

The various means for reducing a fortress, therefore are:

(*a*) Starvation as to ammunition, food supplies, etc.

(*b*) Demolition of the works by the fire of large caliber guns and by mining.

(*c*) Assault of the works from a trench or "parallel" established as close as practicable.

These methods may be employed singly or in combination, depending upon the strategical situation, the purpose in view and the circumstances of the case. Successful assault will usually, however, be impracticable without a previous bombardment.

CHAPTER VII

MILITARY DEMOLITIONS

It has been frequently remarked that war is a game of destruction, and demolition of material objects is indeed always an im-

FIG. 53.—Ponton equipage used to replace ruined bridge span. (German ponton equipage.)

portant accessory of tactical operations. It serves to hamper the movements of the enemy, to frustrate his plans and, by the removal of obstacles, it facilitates the operations of our own forces. **Wanton destruction,** however, especially of objects which have permanent and intrinsic value aside from possible military uses, will never be justifiable. Demolition on a large scale (except in emergency) should not ordinarily be permitted without the express order of a responsible commander, as otherwise military expediency may degenerate into vandalism. Also the **demolitions should be carried no farther** than military necessity demands. Ill-timed or premature destruction may involve very unfortunate consequences, and hardship may not be imposed on the inoffensive civil population except where necessarily incident to the successful prosecution of military operations.

As in all the operations of war so in military demolition there is demanded adequate results in the minimum of time. Demolition is the particular function of the engineer troops, but as it may be required at any time in any part of the theater of war, **all troops are now equipped** with demolition outfits. These outfits must necessarily be simple, light and portable while capable at the same time of producing powerful effects. The means of demolition best adapted to military requirements are **fire and explosives.** The former requires no equipment, the latter provides a powerful instrument of light weight.

Demolitions are frequently accomplished by the fire of **high-explosive shells** from large guns. Indeed, for the destruction of hostile fortifications and obstacles protected by the hostile fire, this will often be the only practicable means. It is, however, always expensive and often uncertain and inapplicable. Where it is possible to judiciously place charges of explosive, greater, more certain and more prompt results can usually be obtained.

The advances made in recent years in the manufacture of high explosives have placed a powerful weapon in the hands of the military. But knowledge and experience in the effective practical use of explosives is not common and it is very important that all officers, and especially engineer officers, should be fully instructed in practical demolition.

An explosive for military demolitions should be:

(*a*) Stable for long periods.
(*b*) Unaffected by ordinary variations of moisture and temperature.
(*c*) Not unduly sensitive to shock in handling, transportation, etc.
(*d*) Not unduly difficult to detonate.
(*e*) Quick enough to give good results even when unconfined.
(*f*) Convenient in form and consistency for transportation and use under field conditions.

These requirements call for a high explosive of medium strength, solid in consistency, and put up in damp-proof packages of standard size. **A number of commercial explosives** meet these requirements fairly well, and none is invariably preferred to the exclusion of all others. It will be a question usually as to which can be most readily obtained in sufficient quantity. Amongst these explosives are gun-cotton, nitro-glycerine, dynamite, trinitrotoluol, melinite, lyddite, shimose, jovite, the picrates, fulminates, Sprengel safety mixtures, gunpowder. Dynamite is the most common commercial explosive in this country and is well adapted to military uses. Nitro-glycerine is dangerous in handling and transportation because of its liquid form. **The fulminates,** in particular, mercury fulminate, are especially useful as **detonators for other explosives** because of the abruptness and violence of their action. They are accordingly extensively used for caps, primers, etc.

Explosion is produced by detonation, for which purpose a small **cap or primer of fulminate** is inserted in the charge. The cap may be fired by means of a powder fuse or by electricity. The latter is the preferred method, but requires a magneto-electric exploder and lead wires. If these are not available the fulminate may be ignited by means of a powder fuse. **Two classes of fuse** are employed known as time and instantaneous. They are distinguished by the color of their wrappings. Time fuse burns at the rate of about 3 ft. per minute; instantaneous fuse, 120 ft. per second or more. Caps and fuse must be kept away from other explosives.

Charges should be tamped in some manner whenever this is practicable, as their effect is thus greatly increased. Timbers should be bored to receive the charge when practicable. Charges placed to destroy concrete, steel, etc., should be tamped with earth or mud. If tamping is impracticable the charges must be increased. Skill in placing the charge will greatly increase its effect. Several small charges judiciously distributed will often produce better results than one large charge, but care must be taken to insure simultaneous detonation.

Fig. 54.—Railroad track cut by dynamite.

In the case of an important demolition **a reconnaissance or examination** should, if practicable, be made to determine the extent of the destruction required and the easiest, surest and most expeditious manner of accomplishing it with the men and equipment available. The damage inflicted should be sufficient for the purpose in view and no more. Thus, **if the purpose is merely to delay** for a short period the use of a certain bridge it may be sufficient to remove the deck instead of destroying the trusses. A telegraph line may be temporarily interrupted by cutting the wires, but for complete demolition the poles should be cut down and burned.

A structure that is to be demolished should be attacked at **its weakest point,** or the point where the least time and effort in the way of demolition will require the greatest time and effort to repair the damage. Thus in the case of railroads, which are frequently attacked, it is easier to demolish a bridge than to tear up track, but it is much more difficult to repair the damage in

FIG. 55.—Rail cut by 5 oz. of gun-cotton.

the former case. It is as easy to remove a rail on a curve as on a tangent, but it takes more time to prepare and place a curved rail.

The proper charges of explosives to accomplish certain results have been determined by experiment and are given in the manuals. They serve as a useful guide but can not entirely take the place of experience and good sense.

The following notes will indicate the methods employed in some of the important military demolitions.

All timber structures may be destroyed by fire. For rapid work they may be sprinkled with coal oil, tar, or other inflammable liquid before ignition. **Framed structures** of wood or steel may be destroyed by attacking the weakest members of the framing. Thus in a truss bridge the chords may be cut at their thinnest points. **Bridges** are most effectively demolished

Fig. 56.—Machine employed by the Russians for tearing up roads.

by overthrowing their piers or abutments, which wrecks the entire structure (Fig. 53). The most vulnerable points of roads and railroads are the important bridges or viaducts. **Railroads** may also be attacked at culverts and tunnels. If these vulnerable points can not be reached, railroads may be interrupted by removing rails or cutting them with explosives, preferably on curves (Figs. 54 and 55). A fire is made of the ties, the rails placed therein and twisted while hot. An entire section of track may be removed by opening the joints at each end, loosening the ballast and then overturning the section. It is best to select an embankment and throw the loosened section down the slope. Railroads may be crippled by removing or wrecking the rolling stock, especially locomotives, by demolishing switches and water tanks. It is generally better to wreck the road at several points rather than to concentrate the work of destruction in one locality.

FIG. 57.—Tree cut by necklace of 2½ lbs. of dynamite.

Highways are very difficult to destroy, but the passage of vehicles may be interrupted by digging trenches across them, by firing land mines in the surface, or filling deep cuts with débris (Fig. 56). **Buildings** may be demolished by closing all openings and firing a large charge in a central position. **Telegraph lines** may be interrupted by cutting the wires, but for complete demolition the poles should be cut down and burned, which also destroys the cross arms and insulators. At stations the instruments are removed or demolished and the records seized. **Woods** are rendered useless as cover by fire or by cutting down the trees with tools or explosives (Fig. 57) lopping off the branches and throwing them into ravines. The trunks may be left on the ground and it is neither necessary nor practicable to remove the stumps, as it takes too much time. **Masonry arches** may be attacked by explosives at the haunches or crown. In a multiple arch bridge the destruction of a pier involves the two adjacent arches. **Locks** are rendered useless by destroying the gates or filling valves. **Supplies and materials** of all kinds are ordinarily destroyed by fire, after sprinkling them with inflammable liquid, or mixing inflammable and non-inflammable materials.

Obstacles placed in front of trenches are very difficult to destroy because they are deliberately constructed with that end in view and are under the fire of the defenders of the trenches. They are often demolished by shells and grenades, but such methods are slow, expensive and unsatisfactory. Wire entanglements are the most effective of all obstacles and the most difficult to destroy. They may be cut with nippers (Fig. 44) under cover of darkness or behind a steel shield. The process will usually be accompanied by heavy loss of life. Often it will be better to bridge over the obstacle with bundles of brush, hurdles, planks, sections of board-walk specially prepared, etc.

The use of explosives in attacking the enemy's works has been noted under "Field Fortifications."

CHAPTER VIII

MILITARY RECONNAISSANCE, SKETCHING AND SURVEYING

Maps of and information concerning the theater of war have always been prime requisites to the successful conduct of military operations. In these times, when the combatant forces are numbered by millions, when the theater of war may embrace an entire continent, and when troops may be transported hundreds of miles in a single day, the need of complete and accurate maps and information is of far greater importance than in the past when military operations were more restricted as to numbers engaged and area covered. It will be evident that the commander can not now view the entire field of conflict nor follow the progress of events except as portrayed on a map. **The modern game of war** then is played upon a map (Fig. 58). On a table in his tent or office the strategist records and watches the ever-changing situation and plans the movements of troops many miles away. In the conduct of war the commanders are dependent on their maps, and errors in the maps have often worked great mischief. McClellan's advance on Richmond in the Civil War met its first serious check at the lines on the Warwick River. McClellan's maps showed the stream parallel to his line of advance, and he regarded it as no obstacle. As a matter of fact the stream ran across the Peninsula and was found to be strongly fortified by the Confederates, greatly to McClellan's surprise and discomfiture. **The simplest scouting expedition** or reconnaissance requires a map for its rapid and successful prosecution, and its report to be intelligent must be accompanied by a map or sketch. Each outpost, each camp, each march is made by aid of and recorded and reported on a map. Each section of a line of defense must be mapped, the enemy's dispositions, movements and works are reported by means of maps and sketches. It is therefore absolutely essential that all officers from the highest to the lowest **should be able to read a map** and also to make one. **The duty of mapping** will fall especially upon the engineers. It is incumbent upon them to collect, amplify and bring up to date all existing maps and to arrange for

FIG. 58.—The modern game of war is played on a map.

their reproduction and distribution. And the lion's share of the mapping to be done during the course of the campaign will fall to their lot. The engineer officer must be able to make a map on foot, from an automobile, an aeroplane, or on the back of a horse. He must be able to sit on a hill and map the country in front of him, estimating the distances and sensing the topographical features which he can not see.

Accurate maps require much time and skill for their preparation. **If they are not available in advance** of hostilities the army must prepare its own maps of the theater of operations under war conditions. This will delay and hamper their operations, both because time will be required to prepare the maps, and because maps produced under such conditions must necessarily be rather crude and inaccurate. Accordingly the preparation or collection in time of peace of accurate maps, suitable for military use, of all possible theaters of war is an essential part of any scheme of national defense. Commanders have frequently been compelled to conduct campaigns without good maps prepared in advance, but it is certain that they were thus greatly handicapped.

There is much of our own country which has not as yet been accurately surveyed, and of Mexico, Central and South America, and the Orient, we possess no satisfactory maps. The best available maps for military purposes are those of the U. S. Geological Survey. In time, this survey will cover the entire country and will form an important item of our scheme of preparedness, but at present much remains to be done.

The scale of the maps is a matter of great importance, and for military uses maps on various scales will be required. For strategical operations over a considerable area small scale maps will be needed. These of course can not exhibit topography in detail, but only the more important strategical features, such as rivers, mountains, main highways and railroads, important cities, fortifications, etc. Useful scales for strategical purposes vary from about ½ in. to the mile to 10 miles to 50 miles to the inch. If such maps are not available in suitable form at the outbreak of hostilities they must be prepared by a compilation of miscellaneous and often discordant data. Errors in the important distances may be, to some extent, eliminated by astronomical observations in the field. For tactical purposes maps must be on a scale sufficiently large to portray topographical details, yet not too large for convenient use in the field. Experience indicates that a scale of 1 in. to the mile fulfills these requirements. The

Geological Survey maps are on a scale of 1:62,500, which is approximately 1 in. to the mile (12 × 5,260 = 63,360). The map executed by the military sketcher in the field for use in conjunction with the 1 in. maps will vary from 1 to 3 in. to the mile for road sketches, and from 3 to 6 in. to the mile for position or area sketches.

It is certain that in any military operations in which the United States may engage, **extensive surveying and mapping,** both on a small and on a large scale will be required subsequent to the outbreak of hostilities. Even if maps are available in advance they will often be on too small a scale to meet all tactical requirements, they will not portray all features of military importance and will not be up to date. When the surveys can be executed under cover of the first-line troops the methods for mapping will be based upon those employed in time of peace, except that refinements and hair splitting accuracy will be relegated to the background and speed will become paramount —as in all military engineering. The control will be established by astronomy, triangulation, traverse and extensive leveling. The filling in will be done chiefly by the methods of individual military sketching. **On such surveys** many of the great number of civilian surveyors in the United States may be usefully employed, if under the direction of engineer officers who appreciate military requirements and understand military methods.

In survey work executed with the fighting forces at the front quick results will invariably be demanded, and must generally be obtained with such simple instruments as can be conveniently carried on the person of the topographer, or with no instrument at all. These conditions have resulted in the adoption of instruments and methods which are characteristically military. While a number of methods are employed that most commonly used is a crude and hasty **adaptation of the plane table method** of surveying in which the skill and experience of the topographer must compensate for the lack of time and accurate instruments.

The military plane table consists of a small board, 12 in. × 14 in. in size or less, which is held against the body of the sketcher or mounted on a light portable tripod (Figs. 59 and 62). The board is leveled by eye or by a small spirit level placed on the board or attached to one of its edges. It is oriented by means of a compass, which may be in a separate case, or may consist merely of a declinator attached to the edge of the board. The alidade is a small flat ruler with folding sights, or more commonly, a simple

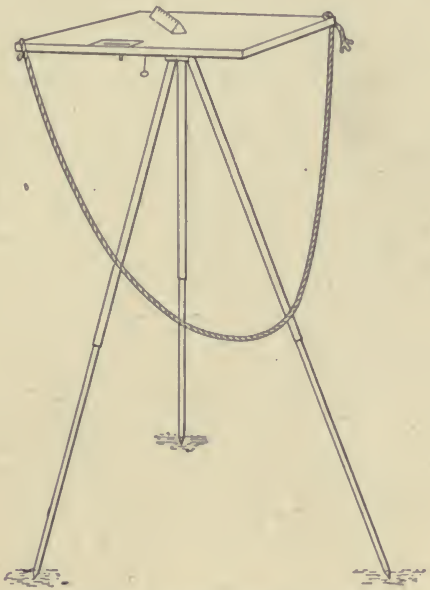


FIG. 59.—Military plane-table or sketching board, with attached needle or declinator, three cornered ruler and tripod.

three-cornered piece of wood, the sights being taken along its upper edge. **The horizontal position of points** is determined by intersection and resection, by laying off the directions and measuring the distances, etc. **Distances are measured** usually by pacing and counting with a "tally" (Fig. 60) also by a speedometer, or an odometer on the wheel of a vehicle, by the "walks" of a horse, or by time at a known gait, either afoot, in a vehicle, or on horseback. In some cases, especially in "place sketching," where the sketcher can not occupy the ground he is to map, distance may be determined by some form of simple range finder, by angles measured with a pocket sextant (Fig. 60) or compass from the ends of a known base (intersection) and for short distances by estimation. The sketcher will construct the necessary scales of paces, wheel revolutions, or time. If the

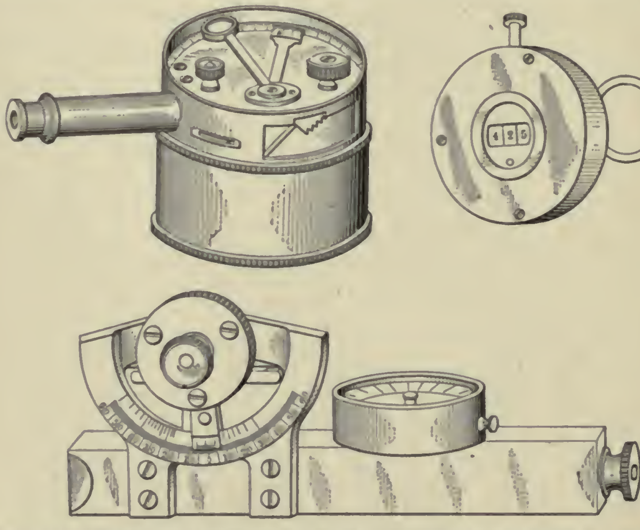


Fig. 60.—Some instruments employed in military sketching. Pocket sextant, pace-tally and clinometer.

length of his own stride or the gait of his horse has not been determined, this will be done by several pacings of a known distance on average ground. The scales are laid out on paper and pasted to the edges of the alidade. **Horizontal angles** are laid off by compass or alidade sights or in some cases measured with a pocket sextant and laid off with a protractor.

Absolute elevations are determined with a small pocket aneroid. Slopes are measured by sighting along an edge of the sketching board, held in a vertical plane, and reading the slope by means of a plumb line and graduations on the lower edge of the board (Fig. 61). They may also be measured by a simple hand clinometer, such as the Abney, with which very close results are obtained by a skilled operator (Fig. 60). The sketcher will be provided with a set of scales of "map distances." A **"map distance"** is the horizontal map interval between contours.

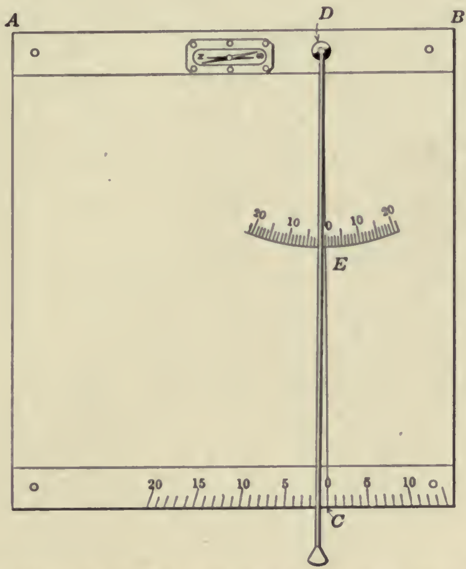


Fig. 61.—Measuring vertical angles or slopes with sketching board.

It varies with the scale of the map, the vertical interval between contours, and the slope of the ground. As the first two are fixed the map distance varies with the slope, and the scales indicate the map distances or horizontal intervals between contours for various slopes. **Having measured a slope** the number and position of the **contour points** is determined by applying the map distance scale for that slope, no computation being necessary. If the slope is not uniform the contour points are adjusted by eye, but their number is fixed by the scale.

FIG. 62.—Military sketching (mapping) equipment in case. Sketching board with declinator, scales of map distances, slope scale and paper clamps; tripod; prismatic compass; clinometer; stop-watch; alidade; pads, pencils, etc.

Elevations thus determined may be checked with hand level (or the clinometer set for zero slope) and aneroid barometer.

In order to facilitate the reading of maps those in our service are constructed on what is known as **the normal system.** In this system the V.I. between contours varies inversely as the scale or representative fraction. Thus for a map whose scale is 1 in. = 1 mile, the V.I. is 60 ft. for a map whose scale is 3 in. = 1 mile, the V.I. is 20 ft. Accordingly, a certain map distance corresponds to a certain ground slope, whatever the scale of the map, which greatly facilitates the interpretation of ground forms as portrayed on maps of various scales.

The method of procedure in making such maps is to determine as accurately as practicable, by the methods above described, the true horizontal position and elevation of a **number of critical points** in the terrain and then, using these as a skeleton or control, to fill in the intervening topography by eye. The speed with which such a map can be made and its accuracy when completed will depend very largely on the skill of the sketcher in selecting and locating the critical and prominent points of the terrain which will be of use to him, in selecting stations affording good views of as large areas as possible, and in estimating intermediate distances and slopes and interpreting ground forms. **The valley or stream lines** and the hills and ridges form **the natural skeleton** for a topographical sketch. If the position of the stream lines and two or more elevations on same be determined, together with the position and height of the adjacent knolls and ridges, the topography is readily sketched in by eye. If the sketcher has skillfully selected and determined the controlling elevations and distances the chance of cumulative errors is greatly reduced and the sketched in topography may compare favorably in accuracy with a painstaking instrumental survey. Skill in such work is attained only by practice. The greater the skill the smaller the number of controlling points that will be required. If the sketcher is a proved adept at estimating slopes and distances he can dispense with many of the careful measurements which the novice would be forced to make.

Care should be taken to avoid cluttering the map with details, but it must nevertheless **exhibit all features** that are of military importance. **The conventional signs employed** are few and simple (Fig. 63). Extensive wooded or cultivated areas may be designated by tracing their outline and noting the nature of the growth, as—"shocked corn," "standing wheat," "open wood,"

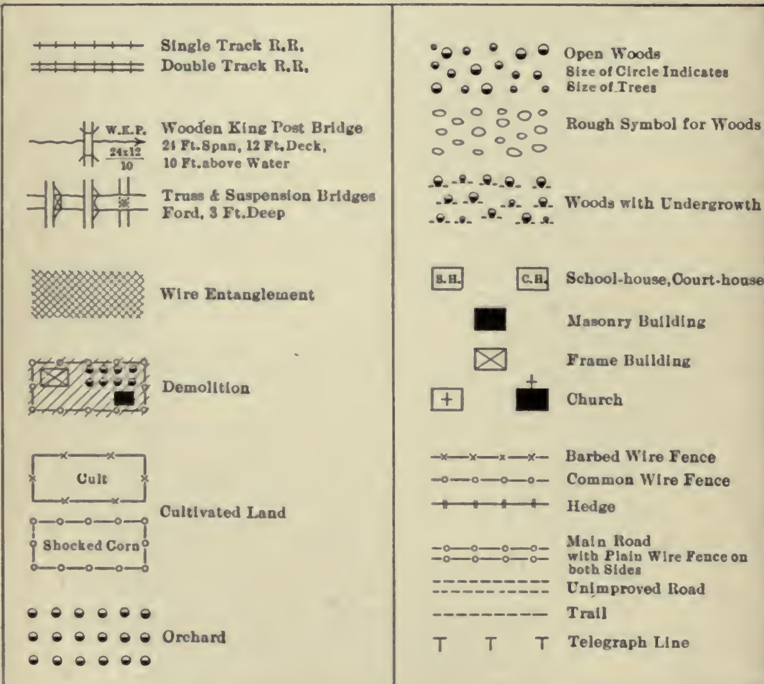
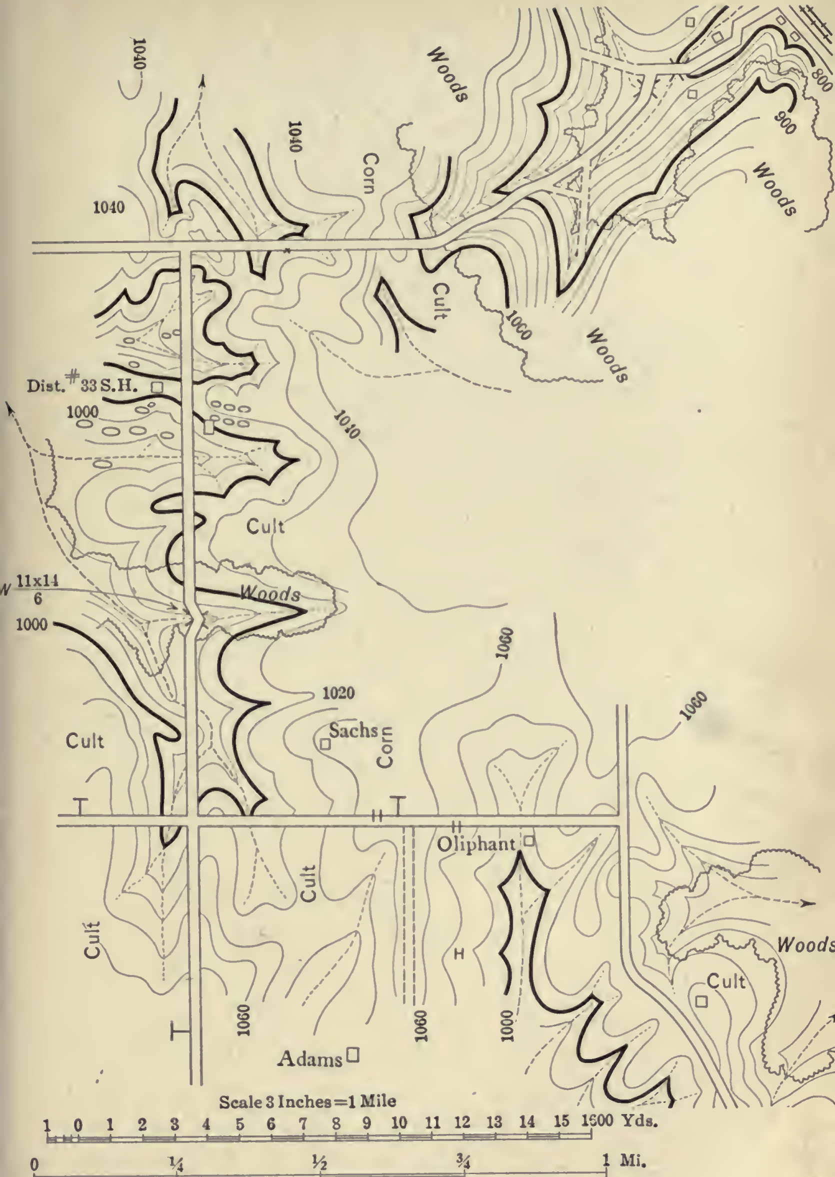


FIG. 63.—Conventional signs employed in military sketching.

etc. **Notes should describe** the nature of roads, as—"good macadam, 16 ft.," "good earth, 12 ft., ditches," etc. The span, width of deck, height, material and practicable load of bridges is indicated by notes. Buildings are never drawn to scale, but the size and construction of important buildings may



(123) Fig. 64.—Road sketch executed by military methods.

Scale 4 Inches = 1 Mile. V. I. 15 Feet

FIG. 65.—Position sketch executed by military methods.

be indicated by a note. Fords are designated by noting width, depth and velocity of stream, nature of approaches and bottom. The names of railroads, gauge, number of tracks, location and capacity of stations, sidings, water tanks, the rolling stock available, etc., are noted, as also the names and distances of adjacent stations in both directions, the vulnerable points of the road, such as large bridges, tunnels, etc. Telegraph and telephone lines are of special importance, the adjacent towns to which they

FIG. 66.—Military sketchers with equipment.

lead should be ascertained by inquiry. Streams which are to be used for water supply may be roughly gauged. Ground suitable for camp sites or defensive positions should be noted, etc. The local resources in the way of crops, animals, foodstuffs, tools, machinery, etc., should be ascertained approximately. Towns are described by giving their populations, nature of industries, stock and output of mills and factories, important buildings, railroads, telegraph and telephone communications, etc. There is hardly a local feature which may not be of importance from a military point of view. The reconnaissance will generally be for the purpose of investigating certain particular conditions, but even under such instructions very important matters outside of the instructions should be reported. The officer charged with such duty must have his powers of observation and acquisitiveness developed to a high degree.

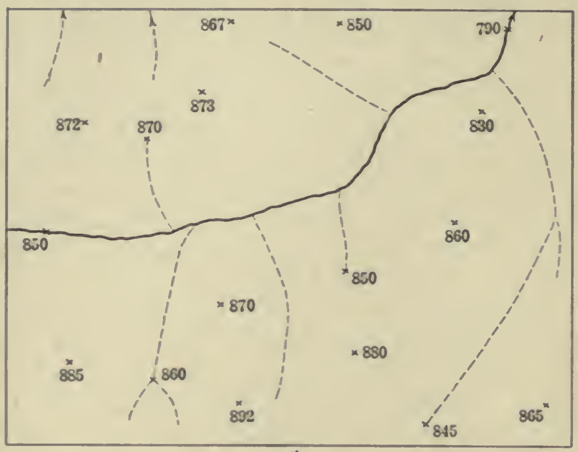
By the methods herein outlined a competent sketcher may map ten or more miles of road per day, sketching in also the topography on each side which is visible from the road. **In sketching an area** he may cover from ½ to 2 sq. miles in a day, depending upon his skill and the nature of the terrain (Figs. 64 and 65). **Where an extensive area is to be surveyed** the work is divided into a number of small areas, with natural or artificial lines of division, which are mapped simultaneously (Fig. 66). A number of these areas will be in charge of a principal sketcher whose duty is to distribute his subordinates, fixing the limits assigned to each. He makes certain that each individual sketcher connects with his neighbor on either flank by having one or more points in common, without overlapping or duplicating work further than is necessary to join the two sketches in one. He carries an aneroid barometer with which he gives each sketcher the elevation of his starting point. He may be accompanied by an assistant who measures the distances and sketches the important features along the base line from which the area sketchers start. This is used later to combine and coördinate the individual sketches. These are turned in simultaneously and are pieced together and retraced or otherwise prepared for reproduction. As the sketches are usually made on translucent vellum they may be printed directly.

Mapping operations on a large scale will ordinarily involve **the correction, amplification, compilation and reproduction of maps,** and this duty will fall to the Engineer Department. So far as possible it should be done in the office, away from the haste and confusion of the field. But much of this work must necessarily be done in the field, especially reproduction. **Actinic**

printing processes are often too slow for satisfactory reproduction in the field. If blueprinting is employed the rate of reproduction may be greatly increased by using brown print (maduro) negatives, from each of which blueprints may be produced as rapidly as from the original tracing. **The hectograph** is also useful for reproducing small sketches. It is light, portable and simple in operation, more rapid than blueprinting, and has a further advantage in that maps in several colors may be produced in one operation. **The best field method** now generally employed is **lithography,** or rather zincography, since the excessive weight of litho stones renders them inconvenient for rapid transportation. The engineer troops are accordingly supplied with an efficient and portable outfit for map compilation and reproduction, including drafting, photographic, actinic printing and lithographic (zinc) apparatus. This is one of the most important items of their equipment.

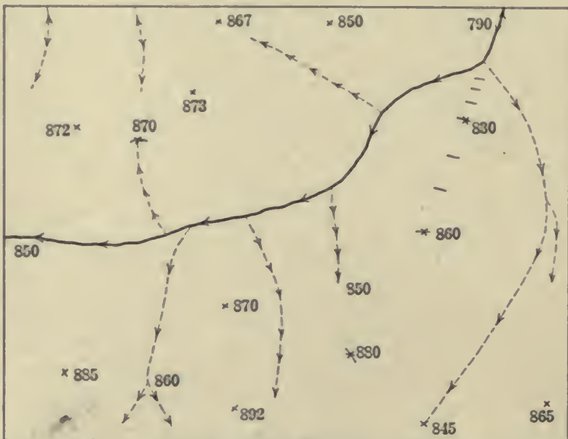
Fig. 67 indicates the manner in which a piece of ground is contoured by the methods of rapid military sketching hereinbefore outlined. For the sake of simplicity such features as buildings, fences, trees, etc., are omitted, although these would, of course, appear on a complete sketch and, moreover, are important as references and control in plotting the critical points of the terrain. In Fig. *A* the sketcher has determined and placed upon his sheet the drainage lines of the area with a number of elevations on each. He has also determined and plotted the horizontal positions and elevations of the tops of hills and the crests of ridges and of the points where there is a marked change in slope, as at 830 in the northeast portion of the area. This data constitutes the control or skeleton of his sketch, and if the work has been carefully done and no critical points omitted it will be possible to make a fairly accurate contoured map of the area without any additional information and without again seeing the ground.

It was observed that the slopes of the stream beds were fairly uniform, that is to say, in this case there were no waterfalls.



A

Arrow heads show direction of water flow.



B

Arrow heads (except those appearing also on *A*) are points where contours cross streams or dry runs.

FIG. 67*a*.—The evolution of a military contoured sketch.

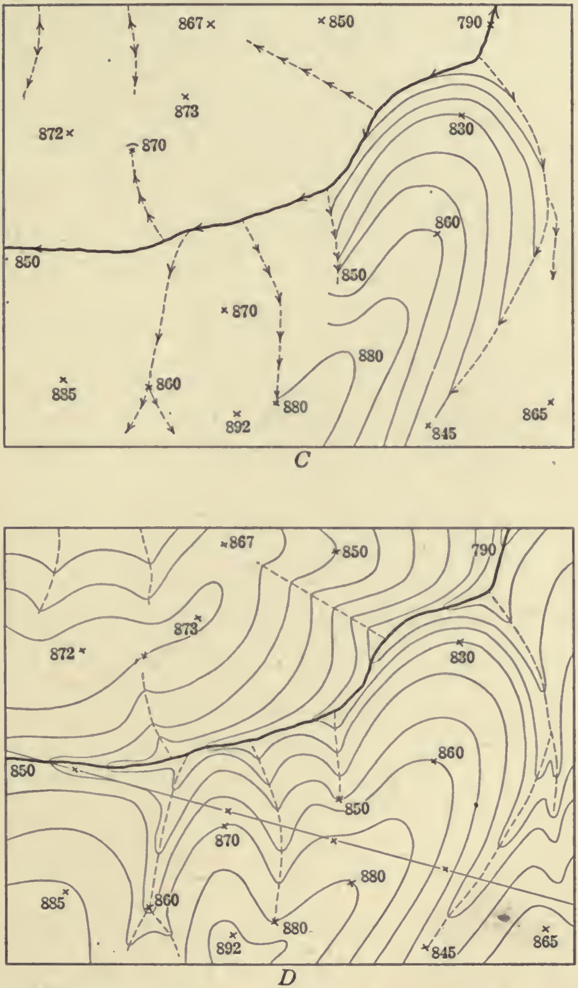


FIG. 67b.—The evolution of a military contoured sketch.

In Fig. *B* the sketcher has placed the contour points on the drainage lines. These may be spaced uniformly or the stream beds may be made slightly steeper at their upper ends, as will usually be the case. The sketcher also places the contour points on the axis of the ridge in the eastern part of the area. As the plotted elevations indicate a change of slope from quite steep at the bottom to a gentle slope higher up, the contour points are spaced accordingly. He now sketches in the contours, on the controlling points thus determined, Fig. *C*. By similar procedure the balance of the area is filled in and Fig. *D* presents the complete sketch.

In practice the contours would usually be sketched on the ground or "in sight of the facts." Thus, in placing the contours shown in Fig. *C*, the sketcher might stand at 860 where he could see the drainage lines on all sides. By thus viewing the terrain the sketcher would note the small details of the ground forms and portray them on his sketch. Thus, the small fold or drainage line beginning at 850 near the center of the area could be sketched in quite accurately by eye, even if it had not previously been included in the skeleton, as shown in Fig. *A*. For purposes of instruction, however, the sketchers are required to prepare Fig. *A* in the field and then to fill in the contours without viewing the terrain. This gives them excellent instruction in portraying ground forms and by comparing their sketches thus prepared with a more accurate map of the same area they will note the faults they have committed, and especially the critical points which they have failed to perceive and locate in the field.

MAP READING

While not every officer and non-commissioned officer will be called upon to make maps and sketches, all, from the highest to the lowest, will frequently have to **read and interpret** them. An officer who is not an adept in map reading will be at a great disadvantage in the exercise of independent command. The map should convey to his mind a fairly accurate picture of the actual ground, and he should be able to rapidly and accurately obtain any information which the map can furnish. Such facility is acquired only by long practice. To locate one's position on a map, to orient it, to determine the difference of elevation or the distance between two points are apparently simple matters, but if it is a question of moving troops there are many other considerations. What are the widths, character and condition of the roads? What grades will be encountered? At what average speed can a wagon train move? Is the road open or shady? Can it be easily observed from adjacent heights, or possibly fired upon? What towns lie upon it? Is there a telegraph line alongside? Are there bridges over the streams? If so, are they in good condition and amply strong to carry the loads accompanying the army? If not, how long will it take the engineers to fix them? Are there fords nearby? What are the depths of water? What effect do floods have? Is a certain locality suitable as a camp site for a certain body of troops? How about the water supply? Is there shade? Is the drainage satisfactory? Is fuel available? How should the various organizations be disposed? Is the locality defensible? Where should the outpost line be placed and how many men will be required to cover it? If a defensive position is to be taken to cover some important point or some movement of troops, where is the best general line for occupation? Can the enemy avoid it or must he attack? Is there natural cover available? How about the roads and other communications? Are there good observing stations and sites for the artillery? Is the field of fire satisfactory? What natural obstacles exist? How about the facilities for retreat or withdrawal? Are the flanks secure? What materials for construction will probably be available? Can civilian labor be secured—if so—to what extent? These and many similar questions must be tentatively answered from maps, sketches and reports of reconnoitering parties, but it is to be remarked that the final dispositions will almost invariably be made upon the ground itself, for the best map can not answer all questions that arise.

One interesting problem that is often encountered in military operations is that of **visibility,** a question as to whether a certain point or area is visible from a certain other point. Such a problem can seldom be solved with great precision on a map, but an approximate solution will often be required. Thus, in the case of a movement of troops, is the road along which they will march visible from certain commanding points in the vicinity? If so, what parts of the road? If it is desired to conceal the movement from the enemy, as will usually be the case, such observation points should be determined and either avoided or occupied in advance in order to prevent the enemy from doing so. Artillery requires observing stations from which its field of fire can be observed. It is necessary to select these positions, to ascertain the areas visible from each, to determine whether observation towers are needed and, if so, how high they must be, etc.

The solution of visibility problems involves the construction of profiles (Fig. 68). As this is a tedious process short cuts are usually employed. One who is proficient in map reading can solve the less critical problems at a glance. If there be intervening ridges it is often necessary to fix the height of the line of sight at such ridges. Visibility problems may be solved by proportion and by the use of the slide rule. The following rough method will also be found useful in many cases. A red rubber band is graduated in tens and hundreds on any scale. The tens are numbered, the hundreds are not. Now suppose, for example, that the elevation of the point of sight is 410 and that of the point to be observed 290. Stretch the rubber band so that the first 90 falls on the point to be observed and the second 10 following on the point of sight. Then the elevation of the line of sight where it crosses the intervening ridge is read on the band. If this is greater than the ground elevation as shown by the contours, the two points are mutually visible, each from each. Of course if there are trees growing on the ridge it is necessary to

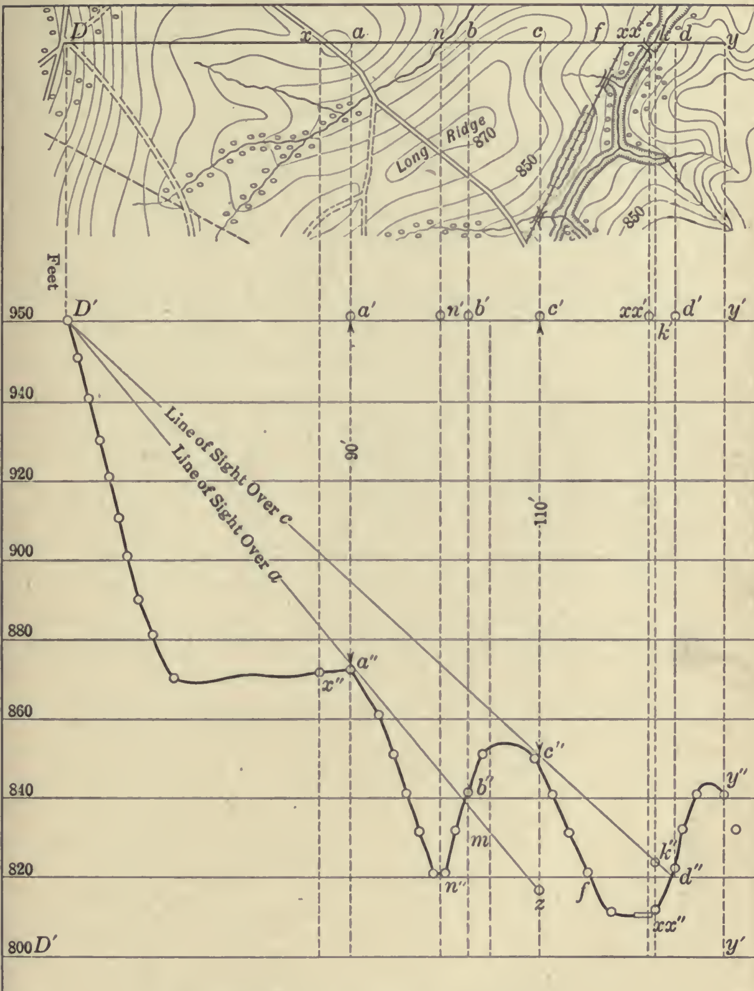


FIG. 68.—The construction of a profile.

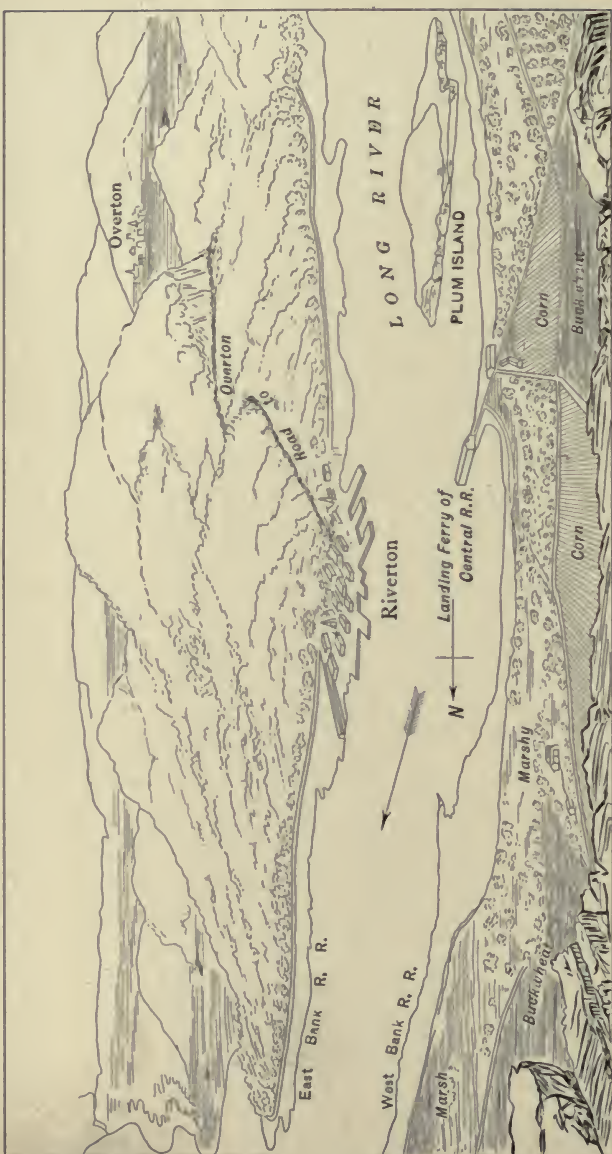


FIG. 69.—Military landscape sketch.

make allowance for these. To determine what area is visible from a given point, draw a number of radial lines from the point. An inspection of the map will usually determine the intervening ridges or hills which will limit the visibility. Mark the critical points on each line of sight. Now stretch the rubber band so that the proper elevations fall on the point of sight and an intercepting point, look along the band and find the point where the graduation on the band coincides with the elevation on the map. This will be the point where the line of sight strikes the ground. Look back along the band and make certain that at all points between the point of sight and the assumed intercepting point the line of sight is above the ground. By joining the points thus determined with broken lines the approximate boundaries of the visible and invisible areas are determined. The invisible areas should be shaded.

Photography is of little practical use for map making for military purposes except in the case of photographs taken from a balloon or aeroplane at a considerable height, which are in effect a form of map. But photographs are a valuable accessory to maps in giving a clearer appreciation of the terrain as it appears to the eye. They are of great value for showing the construction and condition of bridges, wharves, buildings, etc. **Landscape sketches** are usually of more value than photographs, inasmuch as they give special prominence to the important features of the terrain, omitting the mass of details which obscure the critical points (Fig. 69).

Acknowledgment.—Most of the figures accompanying this chapter are taken from "Military Topography," by Major C. O. Sherrill, Corps of Engineers, U. S. Army, the leading American work on this subject.

CHAPTER IX

MILITARY SANITATION

A sound physique and rugged health are essential prerequisites of military training and military service. **The fighting efficiency of the troops** is directly dependent upon the maintenance of their health, which is accordingly of prime importance, not only from a humanitarian but more particularly from a purely tactical point of view. **The history of the past wars** shows that the losses of armies due to sickness have far exceeded those of battle. **Camp epidemics** have decided the issue of war, the fate of nations and the progress of civilization. Sanitation may be regarded then as coördinate with strategy and tactics in the conduct of war.

Sanitation is the particular field of the medical department but its success in this field is contingent upon the obedience and intelligent coöperation of all officers and men of all arms. **The sanitary functions of the engineers** are distinctly subordinate to those of the medical department, and consist in executing the more important engineering operations demanded by sanitary requirements. These operations are similar to those of the civil sanitary engineer, but like other works of military engineering, are generally less formal and more in the nature of makeshifts. Such operations will be required wherever troops are assembled, in concentration and training camps, in the trenches and on the march.

On the battlefield, in the presence of the enemy, efficient sanitation will be difficult enough, and remarkable are the makeshifts by which it is effected. But it is not here alone that sickness and pestilence will exercise their baneful influence. The volunteer army must be mobilized and receive its final training at the great camps that will be established for that purpose in various parts of the country. **The general location of these camps** will be determined by strategical considerations, but in the selection of the actual sites tactical requirements will have no weight and the camps should be located with a view to **efficient sanitation.** This has not always been done. The raw levies, uninstructed in outdoor personal hygiene and sanitation, have often been assembled in great numbers in unsanitary localities and sickness and camp epidemics have been the logical results. The sites for these concentration camps should be carefully selected in time of peace, taking into consideration the strategical and sanitary requirements. While it will not always be practicable to reserve large areas exclusively for this purpose, and to provide in advance the communications, drainage, water supply, etc,, yet plans should be made by which the sites can be rendered promptly available when needed. **The necessary sanitary measures** should then be planned in time of peace and carried out before the arrival of the troops. Subsequent to the arrival of the troops their **instruction in personal hygiene** and the rudiments of military sanitation will be not less important than their instruction along other lines.

The most important engineering operations in connection with sanitation are **water supply, drainage and sewage disposal.** Other vital engineering requirements of the sanitarian, such as transportation, the construction of hospitals, depots, etc., are neither distinctly military nor distinctly sanitary. If the military engineer is to render intelligent aid to the sanitarian he must be well versed in the principles and methods of civil sanitation and capable of adapting these to military needs, often under trying circumstances.

At any site which troops are to occupy for a considerable time efficient sanitary measures will be necessary for the preservation of their health and morale. This will apply as well to defensive positions on the battlefield as to camps at some distance from the theater of actual conflict. **A site naturally healthy** should be selected for occupation whenever conditions permit. The site should be well drained and open to sun and air. High ground with a sandy or gravelly soil or good firm turf is to be preferred. In warm weather an open wood affords protection from the heat while permitting the circulation of air. In cold weather a southern exposure with a hill or wood to give protection from the prevailing wind is desirable. Strategical and tactical considerations are usually paramount, but the most healthful site which these considerations permit should always be selected. In the selection of the site the engineer will of course be called in consultation. Above all, **an ample supply of good water** must be available, since impure water is the most effective means of transmission of some of the most usual and dangerous of camp epidemics, including typhoid fever, dysentery and cholera. Drainage should be efficient, and measures adopted for disposing of sewage and kitchen waste. When **flies and mosquitoes** are plentiful special measures may be taken to abate such nuisance and danger as their presence entails. The most important duty of the military sanitarian is not to cure sickness but to prevent it.

For the permanent concentration camps one of the approved civil methods of water supply may be adopted. If the camp be near a large city having a good water supply the latter may be used, at least for drinking and cooking purposes, the use of water by the civil population being curtailed if necessary. **The amount of water** to be supplied is indicated by the experience of civil communities. Many civil uses of water may, however, be greatly limited or entirely dispensed with. These may include such items as flushing the streets, elaborate water-borne sewage systems, etc. As military discipline permits **thorough regulation of the use of water,** much of the waste characteristic of civil communities, especially where the supply is unmetered, may be eliminated. The camp may also to some extent be located and arranged with a view to facilitating the water supply. It will usually be impracticable to adopt the modern method of slow sand filtration on a large scale, unless such has been installed during peace, since the construction of the filters requires considerable time. For similar reasons **a gravity supply** is to be preferred to one which requires pumping. Nevertheless, pumping must often be resorted to, and it is to be remarked that the high pressure required for distribution over a wide area and for fire protection, etc., will seldom be necessary. A natural site where a storage reservoir of adequate capacity may be created by a hastily constructed earth dam should be sought. If its elevation is such that pumping may be avoided so much the better. A camp site near a large **river or a lake** is often advantageous, but in such case an intake and pumping plant will usually be necessary, and possibly also settling basins and tanks or distributing reservoirs. Smaller streams may be dammed, always upstream from the camp. The storage reservoirs may serve also as settling basins for plain sedimentation and **chemical coagulants and mechanical filters** may be used. Deep-driven wells are often a convenient and satisfactory source of supply. Distillation furnishes the purest possible water, but is usually impracticable on a large scale. It may often be advantageously employed to furnish drinking water for small commands. **The most common method** of providing potable water for military uses is by boiling, preceded by sedimentation where necessary. Boiling for five minutes will destroy the germs of typhoid or enteric fever and of cholera. Boiling for fifteen minutes will destroy all pathogenic germs. Stationary and portable boilers are employed. The method has the disadvantage that it requires fuel and is slow. For these reasons many experiments have been made to devise a form of mechanical filter suitable for military uses. No entirely satisfactory device has ever been produced. In their operations on the western battle front in Europe the French, after having experimented with many types of filters, all of which were unsatisfactory, have adopted purification by the use of sodium hypochlorite. The purified water is distributed to the troops in wheeled tanks, and this method is said to be satisfactory. While it would often be practicable to pipe the supply of drinking water, the waste would probably be much greater than where it is delivered in tanks. **Water for bathing** purposes, as it need not be purified and often not even clarified, may be advantageously distributed by piping. Wooden stave tanks and gas engine pumping plants, as they are easily transported and erected, are well adapted to military uses.

On the march and in temporary camps some **dry sewage** method must usually be adopted. The simplest scheme of this kind is a pit or trench, preferably one enclosed or sheltered by a screen and, if necessary, provided with a cover such as a tent or a thatch on poles. Earth and lime are employed for covering and deodorizing and if flies are abundant the pit may be screened. Such pits with their shelters are known as **latrines.** When a camp is occupied for any considerable length of time the latrine method is objectionable. A more sanitary arrangement is **incineration.** There are many forms of incinerators, one especially adapted to military uses being a furnace and latrine combined, the whole mounted on wheels for transport. On the battlefield latrines will be employed in the trenches, but if these are to be occupied for some time the **pail system** should be employed, the contents of the pails being removed for incineration back of the line. Another expedient would be water closets and **cesspools,** but as the latter are now almost universally condemned **septic tanks** will be preferable and often not much more difficult to provide. Incineration is the most sanitary method of disposing of **kitchen waste.**

In concentration camps more elaborate measures are practicable which, as in the case of water supply, may sometimes be carried out, or at least planned in advance of the outbreak of hostilities. These may include the most approved modern methods of sewage disposal.

Military sanitation bears the same relation to civil sanitation that other lines of military engineering bear to the corresponding lines of civil work. That is to say, it is a more or less hasty and makeshift adaptation of civil methods to military needs. To achieve success under the difficulties which will be encountered in war time the military engineer should be acquainted with the theory and practice of civil sanitary engineering and capable of adapting them to military needs.

CHAPTER X

THE MOBILIZATION OF MATERIAL RESOURCES

The modern theory of war, as we have seen, contemplates in its highest development not only the universal training of the personnel, but the complete mobilization of the material resources of the nation. An army numbering millions requires in its operations vast quantities of supplies of all kinds. Unless these supplies are forthcoming as needed the nation's defenders, however intelligently organized and splendidly trained, will be unable to successfully oppose the fully equipped troops they will be called upon to meet in the event of war with a foreign power. Such has been the situation of more than one of the nations in the present war.

The supplies necessary are not limited to weapons, ammunition, foodstuffs and clothing, but include the great bulk of the products of our farms, mines, forests and factories. There is also demanded the service of our **transportation systems** by land and water. Our material resources exceed those of any other nation and are ample for the prosecution of a great and protracted conflict. They are at present, however, very poorly organized from the point of view of military necessity. This is plainly indicated by the lack of system, the delays and extravagance which are attending the furnishing of munitions of war to the European nations. Europe has paid for our inefficiency, but the experience acquired by our manufacturers and their agents will be of undoubted benefit to our own defensive policy.

In mobilizing our material resources it is necessary first to **ascertain our probable needs** in the event of war. We should then investigate and **make record of the sources** from which these needs may be supplied, and finally execute all possible preliminary measures necessary to **stimulate production.** The problem is a vast one, second in importance only to the training of personnel. We can here consider but a few of its most salient features under the three general heads, to wit:

(*a*) Probable needs.
(*b*) Investigation of sources of supply.
(*c*) Stimulative measures.

The material required for the conduct of war may be classified under two heads:

1. Commercial materials, tools or appliances, that is to say, those which are manufactured and used in large quantities in times of peace: and

2. Materials or equipment which are peculiar to warfare and not ordinarily manufactured at all, or to a limited extent only, for commercial purposes, and which can not, therefore, be readily obtained on short notice.

The line of demarcation between the two classes is not definitely fixed. Examples of the first class would be axes, barbed wire, automobiles, shoes, anesthetics, dynamite; of the second class, military rifles, portable intrenching tools, haversacks, ponton boats.

In the event of war the regular and volunteer forces would be called at once to the colors and sent to the front as rapidly as they could be equipped and trained (in the case of volunteers). In order that these troops may be promptly equipped for duty it will be necessary to keep on hand in time of peace a **reserve of material,** especially of the second class. This reserve should obviously be no larger than necessary—it will be great enough in any case. Its storage and care will be expensive, some of it will become obsolete from time to time, and some will deteriorate and become useless in storage—all of it will represent an investment paying no direct return except in case of war. **The amount of each item** of this reserve will depend, first, on the requirements of war and, second, on the predetermined rate of production and delivery subsequent to the outbreak of war.

The plans of the general staff will contemplate certain contingencies, and the enrollment, training and equipment of successive levies of men to meet these contingencies. **Measures for the mobilization** of the material resources should be based upon the greatest probable requirements, but should look further to the possible ultimate utilization of all our resources. A consideration of these probable requirements will indicate what will be needed at the outbreak of war and the rate of production that must be maintained thereafter, if military operations are not to be delayed or hampered by lack of equipment and supplies. Supplies for military purposes can be more readily, quickly and cheaply obtained the more nearly they **conform to commercial types and standards.** Hence, as far as practicable, they should be identical with or similar to the products of peace time. Many of them, of course, must be specially adapted to military needs.

Having tabulated these materials the next step is an investigation of the sources of supply. Or, to avoid delay, the two investigations may be prosecuted simultaneously. **All existing supplies** which can be **commandeered** in case of need without undue hardship to the civil population, such as automobiles and animals, should be located and recorded. **Every manufactory in the land,** both large and small, should then be investigated to ascertain what material it could produce for military purposes under war conditions. The somewhat modified requirements of the civil population during the war must, of course, also be considered and provided for. This material would not in all cases be limited to the regular output of the factory. We should consider not only what the factory does ordinarily produce but what it might reasonably be counted upon to produce with due regard to efficiency and economy. **It will be necessary also** to ascertain the time that would be required to equip the plant and train the operatives to produce a different line of products. The average American industrial plant can not change in a day, a week, or even a month from its regular output to a new line, unless careful and intelligent preparation be made in advance. Without such preparedness it might be a year before the plant would be operating in an efficient and economical manner in the production of munitions, and then perhaps **it might be too late.** This consideration is regarded as of vital importance to the national defense.

One of the most important features, therefore, of the mobilization of resources is a study of the stimulative measures that may be planned in advance to increase the rate of output. There will be many such measures and they must be carefully thought out. The writer undertakes to direct attention to but a few of these. To begin, as has been pointed out, military supplies should, as far as practicable, conform to established standards. **The plans and specifications** of these materials should be submitted to the scrutiny of manufacturers. They will thus be able to point out many modifications which will cheapen and speed up the output without seriously affecting the military value of the product. So far as possible, the manufacturers should specialize along their regular lines. The revised plans and specifications should be placed with the manufacturers for study as to measures necessary for rapid production.

Experimental samples of each class of supplies should be produced. This would indicate the methods to be followed in manufacture and the tools and machines that would be required in addition to the regular equipment of the factory. These models and samples, with **detailed instructions** as to methods of fabrication, should then be placed with important factories or groups of factories. **All special tools,** machines, gauges and patterns that would be needed should be devised. An ample reserve of these accessories should be kept on hand by the government and also placed in the factories themselves, and necessary arrangements made to augment the supply, to the end that at the outbreak of war all factories from which material would be demanded might be properly and quickly equipped to produce this material.

The assistance of the manufacturers themselves will be most helpful. Organizations of manufacturers to assist in the investigation and lining out of plans have been suggested. A thoughtful and interesting study along these lines was presented in a pamphlet recently published by Mr. Martin J. Gillen, President of the Mitchell Wagon Co.

It should be remembered that many of our most important manufactories lie **close to the Atlantic Seaboard** and might be subject to capture in case of invasion. Due allowance should be made for this fact, unfortunate from a military point of view, and corresponding reliance placed upon manufactories farther in the interior of the country which might better hope to enjoy immunity from hostile interference.

Having determined the probable rate of output, a reasonable allowance should be made for a possible increase in demand and for the possible effect of the emergencies of war time on the predetermined rate of output of industrial plants.

The mobilization of our industrial personnel would be a necessary and important feature of this general scheme. During the war, the demands of the civil population would be greatly modified and production along certain lines would be much diminished. Certain factories, very many in the aggregate, could be devoted exclusively to the production of munitions of war, and should make preparation in advance, so far as practicable, to take up this work. **A readjustment of the industrial personnel** would be required to meet war conditions. Many workmen would be thrown out of employment by diminished demand for certain commodities and would be available for transfer elsewhere. Many also would be drawn for service in the volunteer army. There are certain industrial operations in which women are nearly if not quite as efficient as men. The field of their usefulness should be investigated with a view to releasing many men from industry to serve with the army. In this manner the women could perform a duty quite as necessary and important as actual service in the field.

The question of resources is not limited to the supply of munitions of war. The government must look also to **the needs of**

the civil population during war time. For a nation which has not been self-sustaining during peace (and none of the civilized nations is entirely so) and finds its outside sources of supply cut off by war, the problem may be a serious one. The United States can be entirely self-supporting. We can produce within our own borders all of the necessaries of life and all the munitions of war, and this is an important element in our potential strength. Nevertheless the transition from the conditions of peace to those of war will be a tremendous wrench and the suffering amongst certain elements of our population, even in localities not directly touched by war, will be great. **Many of the industries** which supply the things that make life worth living without being absolutely necessary to its mere maintenance, or those producing for export or relying on imports would be paralyzed by the cessation of demand for their products or the impossibility of marketing their wares or obtaining their materials. Their employees would be thrown out of work and would have to be otherwise provided for. Thus the demand for amusements, such as the theater and music, would be greatly diminished, as also the demand for luxuries in food and dress; financial operations, trading in stocks and bonds and real estate, building operations, the promotion of new industries would all be greatly curtailed; imports and exports might be absolutely shut off—our foreign purchasing and selling markets closed to us at the very time when the home markets were dull. While many of the activities would eventually revive, the hardships for a time would be very great. **Governmental aid** and governmental foresight will be necessary to maintain confidence, prevent the sudden changes in conditions, allay panics, and afford succor; all with a view to ameliorating as much as possible the hardships which war inevitably entails. As the government depends on the people, so also would the people depend on the government.

To conduct the investigations and institute the measures herein outlined, **the assistance of the engineering profession** will be absolutely necessary. Steps have already been taken by the President of the United States to enlist the aid of the great engineering societies in carrying out these investigations. As the inquiry proceeds the stimulative measures which may be advantageously employed should become apparent.

Many manufacturers and engineers with manufacturing experience may render valuable service as consulting experts to the plants engaged in the production of war munitions, and the engineering profession should make known to the government the identity of the men who are qualified to render this important service. In the event of war there would be organized in the War Department a bureau to supervise and stimulate the production and arrange for the transportation and delivery of supplies. Many engineers would be employed in such a bureau.

Manufacturers' associations and labor unions must play their part as a patriotic duty. It is very desirable that we be spared the humiliating and distressing spectacle of frequent strikes over questions of wages and hours of labor at a time when the fate of the nation is in the balance.

In the event of war the demands on our **transportation systems** will be very heavy and it is necessary that we take careful account of our stock. Many railroads and steamship lines would be taken in complete charge by the federal authorities and all would be subject to a degree of federal military control. This control must be sufficient to meet military needs but can best be exercised through the medium of our big, experienced railroad men. If any attempt is made to replace entirely the **expert personnel of the railroads** with army officers having little or no experience in railroad administration and operation, a paralysis of our transportation systems would be the logical result.

This mobilization of our resources in material and transportation must probably of necessity be based on the voluntary service which is contemplated by our military policy. Nevertheless, as the **government has the power** to institute compulsory service in case of need, so also has it the power to commandeer the output of our factories, and even to regulate the sale of the necessaries of life to the civil population.

One question not to be overlooked is that of the **prices to be paid** for war material. The prices charged the European nations by American manufacturers have, in general, been excessively high, due in large measure to our lack of knowledge of requirements and our inefficiency in a new field of industry. It is believed that our manufacturers generally would have no wish to derive excessive and unreasonable profits from the agony of the nation. And on the other hand, they should not be required to bear more than their share of the burden by being paid less than the cost of production. It is in the interest of both parties that fair and reasonable prices should be fixed upon in conference and revised from time to time to meet changed conditions. The prices should not be perfectly rigid but capable of adjustment, perhaps on a "cost plus fair profit" basis, or on some other basis which would avoid the necessity for audit of the manufacturers' accounts.

The mobilization plans and data should be kept up to date. The opening of new factories, the enlargement or discontinuance of any already listed should be noted, and allowance made for the effect of changes in industrial conditions, etc. Plans and specifications should be modified or improved where necessary to meet changed conditions or keep pace with industrial progress and invention. Schedules of prices as agreed upon or fixed by the government after investigation should be prepared, and the quota of each factory determined and assigned.

With this information as to our resources in hand, and with all practicable stimulative measures in effect the government will be able to avoid much of the delay and confusion which have in the past so frequently marred the success of military operations. It will be possible to intelligently determine the nature and amount of the reserve supplies and equipment which should be kept on hand, and the number, capacity and location of the **government munition plants** which should be maintained in time of peace. In common with the training of our personnel this mobilization of our resources in advance of the outbreak of war will cost money—not a small sum. But in the event of war the returns on the investment would be large. And as with most things that are worth having this security is worth paying for. We must divorce ourselves completely from the false hope that we can obtain something for nothing—a hope be it said, long dear to the hearts of the American people, and which has too frequently in the past been characteristic of our military policy.

In conducting the investigations as to resources and in supervising and stimulating the output, the engineering profession can render a most valuable patriotic service as intermediaries between the War and Navy Departments and the producers. The country will be greatly dependent upon the profession in this matter, since there is no other class of men, civil or military, so well qualified to perform this important duty.

Because of our vast resources we have a tendency to regard the question of supplying the sinews of war rather lightly. We are aware that the resources exist and we comfort ourselves with the hope that the supply of suitable manufactured material is a matter that will take care of itself, although we should know that such is not the fact and that intelligent preparation in advance is just as necessary as in the matter of personnel. The nation whose resources in material are limited must look with especial care to the conservation and mobilization of these resources. Because our resources are not limited we give ourselves little concern in the matter. **But are we not short-sighted** in this respect? Are we not, to use a slang expression, "overlooking our best bet?" There has been hardly a military campaign in the history of the world in which the belligerents have not been **more or less hampered by a shortage** of ammunition and supplies, either immediate or prospective. Thus in the present war, Russia on several occasions has been unable, in spite of ample personnel, to successfully oppose the German troops because of a shortage of material, and she has been compelled to forego success which might have been gained, and has been forced to sacrifice many valuable lives which might otherwise have been spared. Several of the great "drives" indulged in by various belligerents have fallen far short of a full measure of success partly because an inexhaustible supply of ammunition was not available.

Now it is true that we possess accumulated wealth and material resources exceeding those of any other nation, and our manufacturing equipment and methods are the greatest and most efficient in the world. If our advantages in these respects could be brought to bear we could furnish the materials of warfare at a rate with which no other nation could keep pace. **Should we not take advantage** of these circumstances to insure our success in case of war, and to purchase that success with the least expenditure of our most valuable possession—the lives of the nation's defenders? In other words, if a fighting man knows that he has an inherent advantage over all possible opponents in some one particular which they can not evade, is he not wise if he develops this advantage to the utmost and then conducts the combat in such a manner as to make his advantage the determining factor in the result? Superior material alone can not win battles nor compensate the lack of trained personnel. But its possession constitutes an advantage which, other things being equal, will determine the issue of the conflict.

Sir John French, late commander-in-chief of the British forces says:

"The power of defense conferred by modern weapons is the main cause for the long duration of the battles of the present day, and it is this fact which mainly accounts for such loss and waste of life. Both one and the other can, however, be shortened and lessened if attacks can be supported by a most efficient and powerful force of artillery available; but an almost unlimited supply of ammunition is necessary, and a most liberal discretionary power as to its use must be given to artillery commanders. I am confident this is the only means by which great results can be obtained with a minmuim of loss."

CHAPTER XI

HOW MAY THE ENGINEERS AND CONTRACTORS OF AMERICA PREPARE TO MEET THE MILITARY OBLIGATIONS OF CITIZENSHIP?

We have now considered our present military policy and have seen how this policy precludes that thorough preparation for war which is possible only by means of large standing armies and trained reserves. It will be apparent to the reader that the national defense relies at present chiefly upon the **patriotic willingness** of our citizens to partially prepare themselves during peace for volunteer duty in war. We have briefly reviewed some of the principal operations of military field engineering and have indicated the essential differences between military and civil practice.

In what respects are our civil engineers and contractors qualified to meet the military obligations of citizenship, and what may they do under present conditions to increase their efficiency?

There is no class of our citizens more intelligent or more patriotic than the engineering profession. But patriotism which finds its expression in tear-dimmed eyes and choked throats is of no practical value to the national defense. **The highest form of patriotism,** the only useful form, is that which recognizes the obligation of citizenship and voluntarily prepares to meet it.

The engineer officer, as we have seen, must be both a soldier and an engineer. If it be necessary for the volunteer candidate to acquire both these qualifications, a considerable period will be required for his proper training and he will not be ready to take the field at the same time as the volunteers of other arms. **Our civil engineers and contractors,** possessing in advance the technical training in construction, constitute the best material for the supply of engineer officers. Contractors may be of very great help. The hustling American contractor **possesses most of the qualifications** so necessary in the successful military engineer. He is often in these days a man with technical training, he is always used to outdoor work, he knows how to handle men and is familiar with construction plant, he has initiative and resource (otherwise he would seek a different profession), and he appreciates the importance of speed in construction work. The eye of the military appraiser turns appreciatively upon the contractor, who possesses so many of the qualifications he seeks. **Contractors' foremen,** being used to handling men and outdoor construction, will constitute excellent material for non-commissioned officers of engineers—the pioneers of the mobile army. For the rank and file of the volunteer engineer battalion we may find ample material in our great industrial organization. Of all these candidates there is none more valuable than the man who has had experience as a laborer on general contract work. He is usually handy, used to outdoor work and exposure and, to a considerable degree, is disciplined in a military sense. The contractor, his foreman and his gang are of great value as a military asset. Men with some outdoor experience will ordinarily be preferable to those whose careers have been limited to the office.

But however thorough his technical training, however extensive his experience, and however great his natural adaptability and resource, the civilian engineer has very much indeed to learn before he will be qualified to perform his military duties. He must learn his duties as a soldier, **acquire a practical knowledge of tactics,** and adapt his civil engineering knowledge to military requirements. In most instances he must divest himself of certain preconceived ideas and methods. In view of the very short time that will be allowed for intensive training after the outbreak of war before the volunteer army will be called upon to take its place in the line of battle, it is absolutely essential that some portion of this necessary training be obtained in time of peace, especially in the case of engineers. How may this be accomplished? Assuming the patriotic willingness of the engineering profession to meet the obligations of citizenship, how may they be afforded the opportunity to acquire training?

The first step manifestly is **to interest the profession** in this important matter of national defense. They must be brought to a realization of what our military policy is, the extent of its reliance upon voluntary service, and how important is the part of the engineer in any scheme of defense that is likely to be adopted by the American people. It is not only necessary to arouse this interest on the part of the profession but to maintain it, which is equally important and far more difficult. With a great war now going on in Europe there is little difficulty in interesting the people of this country in military affairs. But experience shows that our martial ardor cools very rapidly as the scenes of actual warfare recede into the past.

It will be necessary to devise some system by which those men who are willing to undergo training can be instructed in the duties of military engineering. It is too much to expect of the average civilian engineer that he would pursue a lonely course of study on a subject outside of his regular practice, one, moreover, which holds out no promise of financial return. The driving force or incentive to the pursuit of such study would be lacking, and the men would be glad to have some form of compulsion or obligation applied. Moreover, such study would produce little result except under the guidance of professional engineer officers. Also, **the study should be supplemented** by practical training in the field. To produce results then, it is apparent that this instruction must be subsidized and directed by the War Department. **The engineering societies** might advantageously act as intermediaries between the government and the individuals, chiefly in the important matter of attendance, though it is not intended to suggest that the instruction be limited to members of such societies.

Several schemes for such instruction suggest themselves. A

number of colleges and universities have, at present, courses of military instruction, and it is possible that the number of such will be increased in the not distant future. **At engineering colleges** this military instruction might readily be extended to include a course in practical military engineering, with class-room work, lectures and field instruction. The course would cover the more important duties that have been heretofore outlined. This course would be similar to that now pursued at the U. S. Military Academy, the **Federal government coöperating** with the institution in furnishing instructors and equipment. Such a course would have considerable military value and would certainly be useful also from a purely civil point of view. It could be readily inaugurated and the expense would be inconsiderable in comparison with the benefits. Schools having such departments could afford some of the tactical and technical training which the profession of military engineering demands.

The problem of effectively reaching the graduates or practicing engineers is more difficult. It might be accomplished by an application of the **"business men's camp"** experiment, such as was conducted recently at Plattsburg, N. Y., and at other places. **The greatest difficulty** in the way of success is that of attendance. This, of course, must be entirely voluntary, and is in the hands of the engineers themselves and of their employers. It is probable that many patriotic employers, if they could be made to realize the great need for and importance of such training, would pledge themselves to grant leave with pay to engineers desiring to attend the instruction. It is unfortunately true that under our present military policy we must appeal to and rely largely for success on the patriotic spirit of individual citizens. The burden is thus unequally distributed and must always be unless compulsory service is adopted. **The federal, state and municipal governments,** which employ large numbers of civilian engineers, might well set a good example in this way by making it possible for their technical employees to attend such instruction camps. If systematic attendance can be secured all other difficulties in the way of a reasonable measure of success may be overcome. To obtain the best results, Congressional action would probably be necessary. There would be many details to work out, but the scheme holds some promise of success and is at least worth an experiment. The writer is aware that from the point of view of efficiency the scheme has disadvantages in common with all other schemes based on voluntary service. But we must face conditions as we find them and do the best we can under the difficulties that exist. Rational preparedness for defense is necessary for the maintenance of peace and dignity—indeed for the assurance of our continued national existence. As our late Secretary of War has pointed out, if we wish to avoid compulsory service on the one hand and almost utter defenselessness on the other, our citizens must prove that a voluntary system based on patriotism can be relied upon to insure adequate defense, even if it does not provide the best possible defense.

Field training in military engineering has been developed to a high degree of practical efficiency in the regular army and, under the supervision of officers of the Corps of Engineers, can be readily adapted to the instruction of civilians. The government owns or may obtain the use of **tracts of land suitable for the instruction camps** in the vicinity of many large cities, such as New York, Chicago, San Francisco, St. Paul and Minneapolis, Kansas City, Washington, etc. The engineers resident in such cities could thus reach the camp at a small expense in time and money. Each camp would be in charge of several regular engineer officers with a detachment of engineer troops and the necessary equipment in the way of instruments, tools and materials.

The course of instruction should be prepared in advance and should be varied and progressive to stimulate interest while carefully avoiding ennui or unnecessary fatigue. As in the school training, previously referred to, it should be along both tactical and technical lines. The details of camp life and the operations of field engineering are essentially interesting and the course of instruction, if intelligently carried out, would leave on the students the impression of having enjoyed a profitable and pleasant vacation, and this would go far toward insuring their attendance at subsequent sessions. More advanced courses would be prepared for men in attendance at their second or third encampment. The instruction should properly be extended over several encampments. It would include camping methods, camp administration and sanitation, simple infantry drill and the manual or arms, marches, security measures in camp and on the march, battle exercises, target practice, and instruction in practical military engineering along the lines heretofore discussed. The instruction would include examinations and discussions of previously constructed works, demonstrations by the regular detachment, the actual construction of simple bridges, sections of road, trenches, obstacles, etc., the use of the ponton equipage, demolition and sketching by the students themselves, the solution of simple tactical problems, including in particular the selection and organization of a defensive position, the writing of orders, lectures, critiques and discussions. A very simple course of instruction along these general lines would require several successive encampments. Such a course would not make expert military engineers of the students, but it would afford them a practical conception of military methods, show them how much there is to be learned, and stimulate their interest in military affairs. They would undoubtedly become more valuable as a military asset than perfectly green men having no conception of the nature of military operations.

This field training could advantageously be supplemented by a **correspondence course of practical problems** in military tactics, map reading, and military engineering, accompanied by a course of reading. Reading alone would be of little value, inasmuch as we obtain no mental training when another does our thinking for us, and even the knowledge acquired is quickly forgotten. It is experience and responsibility that develop judgment, initiative and the power of decision. When a student reads a text-book on the art of war the responsibility for the facts alleged and the deductions made rests entirely upon the author. From such works the student temporarily acquires a certain amount of information, but he certainly assumes no mental responsibility and without this he receives no training. When, however, he undertakes the independent solution of a practical problem, whether in the field or at his desk, the responsibility rests upon his shoulders alone and the results he obtains are impressed upon his mind as practical experience. These principles should form the basis of the instruction in the field work and correspondence courses. Reading is indeed of value but has its greatest value in connection with original and independent effort on the part of the student.

The solution of these practical military problems, whether on a map or in the field, constitutes what is known as the applicatory method of military instruction. It is the method which is pursued by all modern armies, being properly regarded as the best substitute possible in time of peace for the actual experiences of war. Without doubt this study is one of the most stimulating and entertaining of mental activities. A brief survey of the method will therefore be of interest. The problem as stated sets forth the situation of or circumstances surrounding a certain imaginary body of troops of which the student is assumed to be the supreme or one of the subordinate commanders. The statement covers the position and strength of the friendly troops, the local conditions as to terrain, weather, etc., certain information concerning the enemy, usually more or less incomplete and inexact, the orders and instructions of higher authority, etc. From a careful consideration of all this information the commander shapes his course of action. He first determines his mission or purpose. Often this will be embodied in the orders he has received, but circumstances may arise which compel him to disregard orders which did not contemplate these circumstances. His mission must then be deduced from his knowledge of the situation as a whole and of the wishes or intention of his superior. It may demand a course of action at variance with the orders he has received and it is here that his judgment is called into play. Having determined his mission, the commander reviews the various courses open to him and comes to a decision on the course which appears to offer the greatest promise of success. This decision will require a rapid but thorough consideration of all the possibilities of the situation. He next prepares the details of a plan for carrying out his decision and finally embodies this plan in orders to his subordinates. The review or estimate of the situation, the deduction of the true mission, the arrival at a decision, and the preparation of the plan and orders constitute the solution of the problem. These interesting and instructive mental processes will be no innovation in the brain of any thinking man, inasmuch as they are characteristic, not only of military problems, but of all the serious affairs of life.

Individuals who had received training of this nature in college, or who had attended a certain stipulated number of instruction periods in camp, or both, should be given an opportunity to qualify by suitable examination for a **commission in the volunteer engineers.** Such a commission might properly carry with it a small allowance to be paid by the federal government. The possibility of obtaining such a commission would have a stimulating effect, especially amongst the younger men since, even without a money allowance, it would constitute an honorable distinction. The man who, while pursuing a civil calling, still recognizes the obligations of his citizenship and endeavors, even to a small degree, to fit himself for the discharge of those obligations, is and should be recognized as the best type of practical patriot. Such men are the real patriots on whom alone we can rely with any degree of confidence for the maintenance of the national defense. The writer believes that there are many such men amongst our engineers and contractors and that the nation would do well to afford them the necessary training, which they are ready to receive but can not obtain without assistance.

The educational schemes which have been outlined are to be regarded as tentative only. Their details have not been worked out and they are undoubtedly incomplete and perhaps faulty in many respects. The writer does not urge them as a policy to be adopted. Such a policy must be based on careful study by our governmental and military authorities, assisted by the civil profession. **But whatever policy may be adopted** for the mobilization of our resources in engineering personnel it will depend for its success on the **interest and voluntary coöperation** of the civil engineers of America. If, actuated by a spirit of practical patriotism, our engineers desire to better prepare themselves to meet the obligations of citizenship in the defense of their country, means can be found to give them a portion of the training of which they are in need.

Field signal tower, U. S. Army.

BIBLIOGRAPHY

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OFFICE OF THE CHIEF OF ENGINEERS

Washington, November 27, 1915

MILITARY READING FOR CIVILIAN ENGINEERS

By authority of the Secretary of War, and in response to frequent requests, the following suggested list of reading is published for the information of civilian engineers desiring to inform themselves on military subjects:

These references have been selected, first, with a view to giving to engineers unfamiliar with the art of war, a general survey of that subject—an understanding of which is the first essential to insure successful application of engineering knowledge and resources to military purposes; and, second, with a view to setting forth, as far as practicable, the ways in which engineering is applied to military purposes and the means provided therefor.

Both military art and military engineering are progressive, and a considerable part of the latest and most detailed information published is available only in service journals of our own and foreign armies. This is particularly true of technical details of seacoast defense (including submarine mining), of field artillery, of military aviation, and the influence of these on military engineering. It is believed, however, that the fundamentals of each subject are well covered by the references given in this list. While the list is long, the relative importance of the various works is indicated, and suitable comments on each are included, so that persons using the lists of references may be able to select those which particularly interest them.

The references under each subject are generally divided into two groups, the first containing the more essential references, and the second those suitable for persons desiring to inquire further into the subject.

NOTE.—The following abbreviations are used:
Supt. of Docs.—Superintendent of Documents, Government Printing Office, Washington, D. C.
Book Dept.—Book Department, Army Service Schools, Fort Leavenworth, Kans.

"A" MILITARY POLICY, CONDUCT OF WAR, AND MILITARY HISTORY

Group I

(1) Official Bulletin, Vol. I, No. 2, Office of the Chief of Staff, Washington, D. C. (Especially pp. 21–39,) Publisher: Army War College, Washington, D. C., Free. (An official outline of the theory under which our forces are to be organized and administered.)
(2) Military Policy of the United States.—Upton. May be obtained from Supt. of Docs.; paper 50 cents; cloth 65 cents. (A most valuable and comprehensive review of this subject.)
(3) Field Service Regulations, 1914. May be obtained from Supt. of Docs.; 60 cents. (A condensed official statement of principles, methods, and details of military operations.)
(4) Elements of Strategy.—Fiebeger. Publisher: U. S. Military Academy, West Point, N. Y. May be obtained from Book Dept.; 75 cents. (A short outline, with historical illustrations.)

Group II

(5) Conduct of War.—Von der Goltz; translated by J. T. Dickman; Hudson Publishing Co., Kansas City, Mo. May be obtained from Book Dept.; $1.70. (The standard work on this subject, covering generally the same ground as (4), but more abstractly and elaborately.)
(6) On War.—Clausewitz; translated by J. J. Graham; 3 vols.; K. Paul, Trench, Trubner & Co., 1908. May be obtained from Book Dept.; $6.60 (including postage and duty). (The greatest classic on the subject; a complete analysis of the phenomenon of war, and profound discussion of the mechanism thereof. Written early in the 19th Century, it is still the foundation of modern military theory.)
(7) American Campaigns.—M. F. Steele; 2 vols.; Publishers: Byron S.

Adams Publishing Co., Washington, D. C. May be obtained from Book Dept.; $4.50. (In addition to careful historical surveys of all the campaigns from the Colonial Wars to the Spanish American War, these lectures give extensive and valuable comments as to the military principles.)

(8) A study of Attacks on Fortified Harbors.—Rodgers; Proceedings Nos. 111, 112, and 113, U. S. Naval Institute, Annapolis, Md.

(9) Lessons of the War with Spain.—Mahan. Publishers: Little, Brown & Co., Boston, Mass. May be obtained from Book Dept.; $2.00. (Of special importance, as showing the true relation between our coast defense and our navy.)

(10) Reports of Military Observers on the Russo-Japanese War. Part III. —J. E. Kuhn. May be obtained from Supt. of Docs.; 60 cents. (In addition to an account of operations, this report contains valuable information as to fortification and siege work, organization, and equipment.)

(11) Organization and Operation of the Lines of Communications in War.—Furse, 1894. Publishers: Wm. Clowes & Sons., Ltd., London. (An old but comprehensive survey of this subject, with much historical information.)

"B" PERMANENT FORTIFICATIONS

Group I

(The references given cover chiefly the principles and general features of this subject; the *details* are mostly printed in unavailable form, either in service journals or in confidential documents. References to some of the former can be furnished, if desired.)

(12) Report of National Coast Defense (Taft) Board, 1906. May be obtained from Army War College, Washington, D. C. Free. (The official project for harbor defenses of the United States. On account of progressive obsolescence of seacoast defenses, this project has been, or is being, modified, but still sets forth clearly the fundamentals of its subject.)

Group II

(13) Lectures on Seacoast Defense.—Winslow. Publishers: U. S. Engineer School, Washington Barracks, D. C. Price 50 cents. (Much of these lectures relates to technical details, and a considerable part is now obsolete.)

(14) Permanent Fortifications.—Fiebeger, 1900; U. S. Military Academy, West Point, N. Y.; $1.00. May be obtained from Book Dept. (While rather old, this work gives a simple presentation of the fundamentals of its subject, including an historical outline. A revised edition will soon be published.)

(15) Fortification.—G. S. Clarke; Dutton & Co., New York; $4.50. May be obtained from Book Dept. (A treatise on the same lines as (14)).

(16) Principles of Land Defense.—Thuillier, 1902; Longmans, Green & Co. May be obtained from Book Dept.; $3.83. (A very valuable work, covering the principles of both field and permanent fortification.) (Probably the best single work on the subject.—P. S. B.)

"C" ORGANIZATION, EQUIPMENT, AND DUTIES OF ENGINEER TROOPS

Group I

(17) Field Service Regulations, 1914. (See "A" 3.)

(18) Tables of Organization, 1914. May be obtained from Supt. of Docs.; 25 cents. (These tables represent—subject to modification and within the limits of existing law—the approved policy of the War Department with regard to organization.)

(19) Official Bulletin, Office of the Chief of the Staff, Vol. I, No. 4 (Appendix 4.) Use of Engineer Troops. Publisher: Army War College, Washington, D. C. Free. (An official statement of the principles which should govern in the use of engineers, with practical suggestions.)

(20) Duties of Engineer Troops in a General Engagement of a Mixed Force—Burgess. Publisher: U. S. Engineer School, Washington Barracks, D. C.; 25 cents. (Obsolete in some respects, particularly organization, but excellent in general scope.)

(21) General Orders No. 6, War Department, 1915. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free. (Prescribes the training of Engineer troops.)

Group II

(22) Studies in Minor Tactics.—Army Service Schools, 1915. May be obtained from Book Dept.; 50 cents. (The principles of Minor Tactics are set forth by solution of a series of problems.)

(23) Technique of Modern Tactics.—Bond & McDonough, 1914; Banta Publishing Co., Menasha, Wis. May be obtained from Book

Dept.; $2.55. (This work covers, in a very specific way, the principles of tactics for all arms, a general knowledge of which is essential for engineers.)

(24) Operation Orders.—Von Kiesling; translation. May be obtained from Book Dept.; 50 cents. (A lucid exposition, by use of assumed cases, of the operation of highly trained troops of all arms in various phases of battle.)

(25) Engineer Unit Accountability Manual. May be obtained from Supt. of Docs.; 5 cents. (Official lists of standard equipment supplied to engineer battalions and companies.)

(26) Organization of the Bridge Equipage of the U. S. Army, 1915. (Revised edition just going to press.) (Includes description of equipage and regulations for ponton drill.)

(27) Officers' Manual.—Moss; Banta Publishing Co., Menasha, Wis.; $2.50. May be obtained from Book Dept. (Treats of routine duties of officers, customs of the service, army organization, etc.)

(28) Manual for Courts Martial. May be obtained from Supt. of Docs.; 50 cents.

"D" FIELD ENGINEERING

Military field engineering at the front differs from ordinary engineering work in the field, in being generally simpler, of a rough-and-ready character, and especially because of the limited equipment which can be taken along with the advance of an army, and because of the necessity of working in strict subordination to the military situation. In rear of the army, on the contrary, conditions are very similar to those governing ordinary engineering operations, and civilian organization is suitable, subject to directions by the higher military staff. Little attempt is made in works on military field engineering to treat of general engineering methods.)

(29) Field Fortification.—Fiebeger, 1913; John Wiley & Sons, New York. May be obtained from Book Dept.; $1.90. (In addition to technical details, this work gives valuable historical illustrations of the principles of this subject.)

(30) Field Entrenchments, Spade Work for Riflemen.—John Murray, London. May be obtained from Book Dept.; 40 cents. (A very up-to-date little work; especially on details.)

(31) Notes on Field Fortification.—Army Field Engineer School. May be obtained from Book Dept.; 30 cents.

(32) Engineer Field Manual.—Professional Papers No. 29, Corps of Engineers, U. S. Army; 3d edition, 1909, 500 pages. May be obtained from Supt. of Docs., $1.00. (A very complete official pocketbook for engineer officers in the field, containing much tabular and tech-

nical data, as well as brief outlines of principles and methods. The subjects covered are: Part I, Reconnaissance; Part II, Bridges; Part III, Roads; Part IV, Railroads; Part V, Field Fortification, and Part VI, Animal Transportation. A new revision of the manual is contemplated, but will not be ready within a year. The portion of the manual relating to Field Fortification, being somewhat obsolete, should be considered in connection with either (30) or (31) above. The portion relating to Railroads is largely superseded by (35) below.

(33) Notes on Bridges and Bridging.—Spalding. May be obtained from Book Dept. (A small pamphlet on military bridging.)

(34) Military Topography for Mobile Forces.—Sherrill, 2d Edition; Banta Publishing Co., Menasha, Wis., 1911. May be obtained from Book Dept.; $2,25. (Besides matter given in ordinary text-books on surveying, this work gives in detail the special methods of sketching developed in the army for rapid military mapping.)

(35) Military Railroads.—Connor; Professional Papers No. 32, Corps of Engineers, U. S. Army; Supt. of Docs.; 50 cents. (Intended to cover general administration of existing railroads for military purposes and the handling of railroads by military personnel in the advanced sections where railroads can not be operated by their regular civilian organizations, or where new railroads are required in the immediate vicinity of the Army. Revised edition soon to appear.)

(36) Notes on Military Explosives.—Weaver: J. Wiley & Sons, New York; 1912. May be obtained from Book Dept.; $2.20. (Elementary notes on this subject will be found in the Engineer Field Manual and other references cited. This work is more elaborate.)

"E" MISCELLANEOUS

(37) Regulations for the Army of the United States; Supt. of Docs.; 50 cents.

(38) The "Volunteer Law," approved April 25, 1914; Bulletin No. 17, War Department, 1914. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free.

(39) General Orders No. 54, War Department, 1914. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free. (Covers examination of candidates for commissions as officers of *volunteers*.)

(40) General Orders No. 50, War Department, 1915. May be obtained from The Adjutant General, U. S. Army, Washington, D. C. Free.

(Amends General Orders 54, 1914, as to examination of candidates for commissions in volunteer *engineers*.)

(41) Treatise on Military Law.—Davis; J. Wiley & Sons, New York. May be obtained from Book Dept.; $5.30.

(42) Elements of Military Hygiene.—Ashburne; new edition; Houghton, Mifflin & Co., Boston, 1915. May be obtained from Book Dept.; $1.30.

"F" PERIODICALS

(43) Professional Memoirs, Corps of Engineers, U. S. A., and Engineer Department at Large; Bi-monthly (formerly quarterly); Washington Barracks, D. C., Engineer Press; per year, $3.00.

(44) The Royal Engineers' Journal.—Royal Engineers' Institute, Chatham, England; Monthly; per year $4.00. (American agents, E. Steiger & Co., 49 Murray St., New York.)

(45) Journal of the Military Service Institution, Governors Island, New York. Bi-monthly; published by the Institution; per yaer $3.00.

(46) Journal of the United States Artillery; Bi-monthly; Fort Monroe, Va., Coast Artillery School Press; per year $2.75, including Index to Current Literature; without Index, $2.50.

(47) Journal of the United States Cavalry Association; published by the Association at Fort Leavenworth, Kans.; per year $2.50.

(48) Infantry Journal; Bi-monthly; published by the U. S. Infantry Association, Union Trust Building, Washington, D. C.; per year $3.00.

(49) Field Artillery Journal; quarterly; published by the U. S. Field Artillery Association, 601 Star Building, Washington, D. C.; per year $3.00.

In addition to the foregoing list, issued by the War Dept., the following text-books will be found of interest:

(50) The Nation in Arms.—Von der Goltz. Book Dept., $2.50. (An exposition of the modern theory of war, very readable and interesting.)

(51) Letters on Applied Tactics (with maps).—Griepenkerl. Book Dept., $1.70. (A standard German work on minor tactics, the principles being well presented by a series of problems and solutions.)

(52) Duties of the General Staff.—Von Schellendorf. Book Dept., $1.85. (A German work probably the best on this subject.)

(53) The Rifle in War.—Eames. Book Dept., $1.70. (A theoretical and practical investigation of the effects of rifle fire in battle.)

(54) Manual of Military Field Engineering.—Beach. Book Dept., 90 cents. (For many years the best American manual. It is now largely

superseded by the Engineer Field Manual (32) but is still of interest and value.)

(55) Examination and Repair of Simple Highway Bridges.—Sherrill. (A pamphlet of the Book Dept.)

(56) Military Demolitions.—MacArthur. (A pamphlet of the Book Dept.)

(57) Individual and Combined Military Sketching.—Cole and Stuart. Book Dept., 95 cents. (Describes the methods for hasty mapping of relatively large areas under war conditions.)

GLOSSARY
OF
MILITARY TERMS EMPLOYED IN THE TEXT

Abattis.—An obstacle consisting of felled trees, often interlaced with wire. The trees are felled or placed with their tops toward the enemy.

Applicatory method.—A system of military peace training by means of the solution of practical problems in strategy and tactics. These problems are solved on a map or on the terrain, and are called "map problems" and "terrain exercises."

Artillery.—The heavier pieces of ordnance, as distinguished from small-arms and machine guns. Artillery includes guns, howitzers and mortars of various calibers. All modern artillery is rifled. Mobile artillery is habitually mounted, both for transport and use, on wheeled carriages, and accompanies the mobile troops.

Balk.—A bridge stringer. Commonly applied to the stringers of the ponton equipage.

Battalion.—A unit of army organization consisting of several companies, usually four.

Bomb-proof.—A shelter, usually subterranean, against high-explosive shell.

Chess.—The deck plank of the portable bridge equipage.

Chevaux-de-frise.—An obstacle in the form of a saw-horse with several legs.

Clinometer.—A small hand instrument used to measure the inclination or slope of the ground.

Communications.—The prepared routes by which troops move from one part of a position to another; also their lines of supply and reinforcement. The term is also applied to telegraph, telephone and other signalling apparatus.

Concentration camp.—A camp at which troops are assembled for purposes of training.

Corduroy.—Logs or slabs laid crosswise to form a road on swampy ground.

Counter-attack.—Offensive operations by troops whose general attitude is or has been defensive.

Counter-mining.—The subterranean operations of troops on the defensive for the purpose of frustrating the efforts of the attack.

Cover.—Protection from fire and view.

Declinator.—A magnetic needle attached to the edge of a sketching board for the purpose of orientation.

Defensive position.—A line or belt of the terrain occupied by troops and prepared for defense by means of field fortifications.

Delaying action.—A combat entered into for the purpose of temporarily delaying the enemy.

Demolition.—The destruction of material objects by any means.

Detonator.—A small charge of explosive used to ignite a larger charge.

Division.—A unit of army organization, the smallest which includes all branches of the service. In the United States Army a division has a strength of about 20,000. It includes infantry, cavalry and field artillery and the necessary special troops such as engineers, signal, medical and sanitary, etc., with all the requisite wagon or motor transport.

Enfilade.—Fire from the flank, parallel or nearly parallel to the line against which it is directed. It is peculiarly effective and demoralizing and is always carefully guarded against.

Estimate of the situation.—A mental review of existing conditions and circumstances on which a commander bases his plans.

Fascine.—A long cylindrical bundle of brush used as a revetment.

Fire superiority.—Superior moral or physical fire effect as compared to that of the adversary. Fire superiority is implied if the assailant can advance or force back the defender. Fire superiority for the defender is implied if he can hold his ground and check the advance of the assailant.

Fixed ammunition.—Ammunition in which the projectile and propelling charge are a single piece, the charge being contained in a metal case with the projectile fixed in the end like a rifle cartridge. It is used in all small arms and machine guns and in many of the smaller field guns and howitzers.

Flanks.—The extremities of a defensive line and the ground in their vicinity.

Flying ferry.—A ferry in which the float is swung from bank to bank by means of a line anchored upstream.

Fortification.—Any engineering work or accessory device which increases the fighting power of troops by affording shelter or concealment or increased fire effect, or which restricts the tactical maneuvers or fire effect of the enemy.

Fortification, field or hasty.—Those works executed by combatant troops in the field to meet immediate tactical needs.

Fougasse.—A small land mine with a charge of explosive and broken stone. It is fired by powder fuse or electricity as the enemy approaches.

Fuse.—A device used for detonating the explosive charge of a shell or shrapnel. Fuses are classified as time, percussion, combination (percussion and time) and delayed action. Time fuses detonate at the end of a given time, percussion fuses on impact. A delayed action fuse is one which delays the explosion of the charge until the projectile has penetrated the structure which it strikes. The term fuse is also applied to powder trains used to ignite placed charges of explosive in demolition. Electric fuses are devices which detonate a charge by means of the heating effect of an electric current. They are also called primers.

Gabion.—A hollow cylinder of brush or other material which is filled with earth and used as a revetment.

General Staff.—A corps of highly trained officers charged with the study of the conduct of war and the detailed methods of military operations. In time of war they direct and administer the operations of mobilization, concentration, supply, transportation, etc., and assist the field commanders in planning and executing their operations.

Grenade.—A charge of high explosive in a container hurled a relatively short distance by hand or by means of a catapult, rifle, or small mortar. The charge explodes by time-fuse or on impact. Large grenades are called air-mines or air-torpedoes. They are distinguished from high explosive shell by their relatively short range, which ordinarily does not exceed 500 yards.

Gun.—A piece of ordnance fired from a platform or wheeled mount. A gun, as compared with a howitzer, has a relatively long barrel, flat trajectory and high velocity. Its effect is produced largely by the vigor of the blow struck by the projectile, which may be combined with the action of a charge of explosive. Guns, according to their size and uses, are classed as mountain, light or heavy field, siege and seacoast. All modern guns are breech-loading rifles.

Head cover.—A vertical shield of any material which protects the heads of the troops from fire.

High explosive shell.—A projectile containing a charge of high explosive fired from a gun or howitzer. The charge explodes by time fuse or upon impact. It is used principally to demolish material objects, such as fortifications, and is seldom employed against troops in the open, being for this purpose less effective than shrapnel.

Howitzer.—A piece of ordnance having, as compared with a gun, a short barrel and curved trajectory. Its effect is produced chiefly by the explosion of the charge contained in the projectile. (See mortar.)

Hurdle.—A revetment of woven brush.

Initiative.—A commander is said to have the initiative when he carries out a preconceived plan, dictating and controlling the course of operations and forcing the adversary to meet his lead. The initiative is ordinarily, though not always, possessed by the attacker, inasmuch as he usually selects the time, place and manner of attack, and forces the defender to adapt his measures to meet it. A vigorous counter-attack, which forces a suspension of the attack, transfers the initiative to the original defender.

Latrine.—A dry sewage pit or trench; a cesspool.

Line.—A general term applied to all combatant troops; a position occupied by troops, as a defensive line.

Line of investment.—A cordon of troops drawn around a fortress for the purpose of cutting off its supply and communication; usually the first step in siege operations.

Listening galleries.—Subterranean galleries driven to the front for the purpose of detecting the mining operations of the enemy.

Listening posts.—Sheltered positions in advance of a defensive line for the purpose of early detection of the enemy's movements. They are connected with the main line by a communicating trench or subterranean gallery.

Loop-holes.—Openings in a parapet or head cover through which fire is delivered.

Machine gun.—An automatic or semi-automatic gun of small caliber capable of great rapidity of fire. It uses fixed ammunition, preferably identical with that employed in small arms. The ammunition is fed automatically from a hopper, clip or belt.

Maneuver.—A movement of a body of troops. Strategical maneuvers include movements of troops, on a relatively large scale, in preparation for prospective battle, but usually at a distance from the enemy. Tactical maneuvers include movements executed on the battlefield or in the near presence of the enemy. As compared with strategical maneuvers they are usually on a smaller scale, in closer proximity to the enemy, and more immediately related to battle tactics.

Map distance.—The horizontal interval between contours (on the map) corresponding to a given slope or gradient.

Mining.—The operations of subterranean attack.

Mobility.—The power of rapid movement. Mobile troops are those capable of quickly changing their location and dispositions to meet tactical needs. Non-mobile troops are capable only of passive defense. It is therefore essential that first-line troops shall be highly mobile. Otherwise they can not seize or retain the initiative. Even in defensive operations mobility is essential to meet the movements of the assailant.

Mobilization.—The change from peace to war footing. An army is said to be mobilized when it is assembled, armed and equipped, and organized to take the field.

Morale.—The collective psychological condition or spirit of troops, especially combatant troops engaged in battle. High morale is implied when troops respond readily to the will of their commander. Morale is therefore measured by the extent to which troops submit to the control of their officers.

Mortar.—A piece of ordnance having a very short barrel and curved trajectory. It throws a projectile containing a large charge of high explosive.

Normal system.—A system of scales and contour intervals so arranged that a certain map distance represents the same slope whatever the scale of the map.

Observation posts.—(See listening posts.) Observation posts may also occupy commanding positions in rear of the firing line.

Obstacle.—Any device which retards the enemy's movements without affording him shelter from fire.

Ordnance.—A collective term applied to all firearms which hurl projectiles. As generally used the term excludes "small arms," such as rifles and pistols, and applies especially to the heavier pieces. (See small-arms and artillery.)

Outpost.—A line of observation and resistance established between a body of troops and the known or supposed position of the enemy to guard against surprise attacks.

Overhead cover.—A horizontal or inclined shield of any material which extends over the heads of the troops and protects them from high angle fire.

Pace tally.—An instrument for counting paces.

Pack train.—A train of animals, usually mules, carrying packs on saddles. This form of transportation is used in mountainous country or where roads are very poor.

Parados.—A bank of earth in rear of a trench to protect the occupants from the back draft of shells bursting behind the trench.

Parapet.—A bank of earth or other material in front of a trench or emplacement which protects the occupants from fire.

Pioneer.—A member of the mobile engineer forces of an army.

Plane table, military.—A small plane table or sketching board used in military mapping.

Ponton.—A portable boat used as a support or pier for a floating bridge.

Ponton equipage.—The portable floating bridge equipment of an army.

Principal sketcher.—One who coördinates and controls the work of a number of individuals in combined sketching.

Reconnaissance.—A rapid examination of a structure, locality, district, etc., for the purpose of noting features and gathering information of military value.

Reserves.—Troops temporarily withheld from action for the purpose of reinforcement at critical times and places. Also individuals who have undergone military training and are *available for service* but not at the time a part of the standing army.

Revetment.—Any device used to hold earth or other material at a slope steeper than the natural slope.

Shrapnel.—A projectile containing a number of small bullets or fragments with a propelling charge. It explodes in the air and scatters the bullets and fragments of the case over a considerable area, being in effect a flying shotgun. The shrapnel of the 3-in. U. S. field gun, when properly burst, will sweep an area 200 to 300 yards in depth and 20 to 25 yards in width, killing or seriously wounding any man or animal in the area. It has little effect on fortifications and is used only against troops. Shrapnel is hence known as the "man-killing projectile."

Siege.—The formal investment and attack of a fortress.

Sketch, area or position.—A hasty military map of an area of ground showing the contours and all natural and cultural features of military significance.

Sketch, landscape.—A pictorial representation of a landscape.

Sketch, military.—A term applied to a hastily constructed map prepared in the field for military uses.

Sketch, place.—An area sketch executed from a single station where the sketcher does not have access to the terrain portrayed.

Sketch, road.—A hasty map showing the route of a road and the nearby topography.

Sketching board.—See plane table.

Sketching, combined.—Military mapping in which an area is divided into sections to be mapped by individuals, the results being subsequently combined.

Sketching, individual.—Military mapping operations where each individual operates independently.

Small-arms.—Firearms, such as rifles and pistols, carried by individuals. The term is occasionally applied also to machine guns which use small-arms cartridges.

Spar bridge.—A type of military bridge in which the support consists of two trestles which are tilted toward each other and locked together.

Splinter-proof.—A shelter similar to a bomb-proof but designed to afford protection only against rifle bullets, shrapnel and shell fragments. It is not proof against penetration by large projectiles.

Strategy.—The application of the broad fundamental principles of the art of war. The object of strategy is to place troops in the most favorable or least unfavorable position for battle, which is the culmination of strategy. Strategy deals with questions of national policy, national resources, geography, mobilization and concentration of troops, supply, transportation, etc.

Supports.—Troops held in rear of the firing line for the purpose of replacing losses.

Tactics.—The methods employed in handling troops in battle or immediate preparation therefor.

Terrain.—An area of ground considered as to its extent and topograp in relation to its use for a specific purpose, as for a battle or the erection fortifications.

Theater of war.—The territory covered by the operations of belliger forces.

Trajectory.—The path of a projectile. Guns of high power are said have a flat trajectory, that is to say, one which approaches a straight line

Traverse.—A bank of earth or other material in rear of and perpendicu to the parapet for the purpose of protecting the occupants from oblique enfilade fire and to localize the effect of shells bursting in the trench.

Trenches.—The purpose of trenches is to protect the troops occupyi them from hostile fire. According to their use they are classified as fi support and communicating trenches.

Wire entanglement.—An obstacle of wire or barbed wire strung on po or other supports; the most commonly employed obstacle.

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