ATTACK

OF

FORTIFIED PLACES.

INCLUDING

SIEGE-WORKS, MINING, AND DEMOLITIONS.

PREPARED FOR THE USE OF THE

CADETS OF THE UNITED STATES MILITARY ACADEMY.

BY

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PREFACE.

IN this work an attempt has been made to give in outline the best modern methods of attack upon a fortified position by assault, surprise, blockade, or siege; and also the detailed constructions of those types of trenches, batteries, magazines, etc., etc., which seem best suited to resist the fire of modern cannon, and to afford cover to a besieging force.

It is not supposed that these types will be exactly copied in all cases of actual practice, but that a wise discretion will be used in modifying or combining them when necessary or desirable.

The constructions given are standard types, which have grown up by combining the suggestions and the experience of the military engineers of all civilized nations.

In selecting them I have drawn freely upon the text-books of the schools of military engineering at Chatham, Fontainebleau, Vienna, and Berlin, as well as upon that of the late Professor Mahan, and the manuals of Duane and Ernst.

The standard work of Gumpertz and Lebrun is frequently referred to in "Military Mining"; and I am also under obligations to General H. L. Abbot, Corps of Engineers, for the use of his unpublished notes on the experimental mines at Willett's Point, and the result of his experiments upon the mining effects of shells charged with different explosives.

J. M.

WEST POINT, N. Y.,
October, 1894.

INTRODUCTION.

MODERN wars have been marked by sharp aggressive campaigns and great battles in the open field, with few close and long-continued sieges.

The subject of siege-works has therefore attracted less popular attention than was formerly devoted to it.

Fort Wagner, Vicksburg, Petersburg, Strasburg, Belfort, Paris, Plevna, and Géok Tépé have shown, however, that at their respective dates regular siege and mining operations were necessary to reduce either permanent or field fortifications, if well equipped and defended.

The volume of fire delivered by the small arms and machine guns now in use has made an open assault upon a well-supplied and well-defended parapet, under ordinary circumstances, a hopeless undertaking, and has necessitated more deliberate methods of attack.

The increased accuracy and penetration of modern cannon have rendered obsolete many of the older methods of making regular approaches.

The newer constructions described herein, while giving greater protection to the attack, are in general slower in their advance than those previously used.

This seems, however, to be an unavoidable evil, which is mitigated only by taking advantage of every opportunity for rapid advance offered by the errors of the defence.

It is not to be inferred that light field works and lines will in the general case require for their attack a system of regular approaches; but trenches and saps may be necessary for placing a battery or parapet in a commanding position or one favorable for enfilade, or for giving a covered approach over an exposed ridge; and their frequent employment may be expected on future fields.

The destructive effect of grenades and Coehorn shells charged with high explosives will doubtless in many cases check or stop the advance of saps and trenches, and necessitate the use of blinded approaches or mining-galleries in stubbornly contested sieges. The successful application of mines at Géok Tépé will doubtless lead to their future employment under similar circumstances. In the close attack upon a shielded casemate or disappearing turret their use seems a necessity, and when these defences are founded on rock or massive concrete foundations, tunnelling operations by drilling and blasting will be required. When practicable they will be expedited by the use of power-drills driven by electricity.

It seems hardly necessary to add, that in sapping and mining operations, as in all other branches of military engineering, all new and improved inventions and methods which are applicable to the work on hand will be used, as a matter of course.

The thickness of cover given in the text is based upon the penetrations of the hostile projectiles.

For ready reference the maximum penetrations obtained in experimental firing up to this date (1894) are given herewith, viz.:

Service bullets, copper or German-silver jacket, of 6.5 to 8 mm. calibre, initial velocity from 2000 to 2550 f. s.:

	At Muzzle. Inches.	100 yds. Inches.	900 yds. Inches.	2000 yds. Inches.	2730 yds. Inches.
Pine wood.........	30 to 50	31 to 35	10 to 14		4.4
Seasoned oak wood.	4 to 8			1.18	
Untamped clay....	60 to 78				
Light sand.........	8	At 500 yds.....17 inches.			

		330 yds. Inches.	440 yds. Inches.	880 yds. Inches.	2000 yds. Inches.
Sand and earth.....	36	33	20	14	4
Steel and iron plate.	0.31 to 0.38	0.28	0.24		
Brick masonry.....	4½				
Ice................	63				

Special steel-coated bullets, cal. 0.26 and 0.30:

Pine wood..... ...	55
Oak wood, seasoned	16 to 24
Beech wood........	23 to 30
Sand..............	14

Special steel-coated bullets, cal. 0.236, vel. 2600 f. s.

Pine wood.........	62

French authorities give a muzzle penetration of 12 mm. $= 0''.473$ in iron plates for the Lebel bullet. No published experiments confirm this.

But few experiments seem to have been made to determine the penetration of the projectile of field and siege guns into earth, and the published data are very meagre and unsatisfactory.

The German Engineer's Handbook (Pionier Taschenbuch, 1892) prescribes the following thicknesses of parapets for cover against small-arm and cannon fire, viz.:

Material.	Small Arm.	Shrapnel and Splinters.	Field-guns.	Siege-guns.
Earth, sandy..............	30″	20″ to 40″	16½′	23′
Turf and marshy earth.....	60″			
Wood...................	34″ to 40″			
Brick masonry............	15″			
Brick masonry, single shot.			3′ 4″	
Two steel plates each 0.32″.	0.64″			
Packed snow..............	6′		26′	
Sheaves of grain..........	16½′			

English authorities report craters of 21 feet length and 8 feet depth blown out from an earth parapet by a single 200-lb. 8-in. howitzer shell. They also state that the projectile of the pneumatic dynamite gun has penetrated 40 feet of earth.

Owing to the rapid development of ordnance the current scientific and military periodicals are in general the only source from which the latest results in penetration, etc., can be obtained.

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ATTACK OF FORTIFIED PLACES.

CHAPTER I.

THE ATTACK WITHOUT THE USE OF REGULAR APPROACHES.

1. A fortified position may be taken by *blockade*, *surprise*, *assault*, *bombardment*, or *siege*.

A **blockade** consists in so surrounding a place and closing its communications as to keep the garrison from receiving reinforcements, provisions, and supplies sufficient to enable it to continue the defence and to avoid starvation.

The object of the attacking force is, in general, to completely close all communications between the garrison and the exterior; but this is not always possible, nor is it necessary in all cases, since such obstruction of communications as will reduce the incoming supplies below the necessary expenditures of the garrison will ultimately exhaust its stores.

An efficient blockade, continued long enough, will consequently reduce any place.

Whether it is advisable to attempt to reduce a place by blockade will depend upon the time which will probably be taken in its reduction, the force required for surrounding it, and repelling sorties from the interior or beating back a relieving army, and the expense in men and materials of taking the work by other methods. Blockades are more effective in reducing cities and towns than in taking places occupied only by a military garrison, since the presence of a large number of non-combatants in a place rapidly exhausts its store of provisions, renders epidemics more likely to break out, and by the suffering and misery resulting demoralizes the garrison, unnerves the commander, and eventually causes its fall. This justifies the apparent harshness of not allowing non-combatants to leave a beleagured place.

The steps necessary for establishing the blockade are identical with those taken for the investment in a regular siege and will be described hereafter.

The capture of Paris in 1870–71 is one of the most recent and striking examples of a blockade on a large scale.

SURPRISE.

2. A sudden and unexpected attack made upon a garrison unprepared to receive it is called a **surprise.**

Formerly these were of not infrequent occurrence, but with modern means of communication and methods of warfare they can hardly be looked for, except in small affairs, where, through the weakness or exhaustion of a garrison or the incapacity of its commander, the necessary and ordinary precautions for their prevention are impracticable or are neglected; or where they are brought about through treachery in the garrison, by which the gates are opened to the attack.

Probably in the majority of cases attempts at surprise will be detected and defeated; but as a success is usually valuable far in excess of the losses suffered in its execution, promising opportunities for their trial should not be neglected.

Surprises, when thought possible, are undertaken under the cover of night, fog, or severe storms. The tactical disposition of the troops is similar to that used in open assault, the columns being preceded by ladder-parties for scaling walls, engineers for blowing down barriers, etc., etc., according to the nature of the case, and followed by a large reserve which is designed to hold any points captured by the advancing columns. It is usually considered best to make simultaneous attacks at several points, in order to confuse and divide the defence, holding the main reserve nearest to the column which is expected to succeed; but making provision also for promptly and fully supporting any other party which may have forced an entrance into the work. An entrance secured, consecutive points should be occupied and held, preserving communication between them, and avoiding too great dispersion of the troops, until a foothold is gained which can in all probability be held against the defence. After this greater boldness may be used in attacking important points within the place.

The complete capture of the work and its garrison cannot ordinarily be expected, however, until daylight allows the systematic movement of the attack throughout the place. In case of failure, any captured gate must be held if possible until all the troops have retreated through it and are covered by the reserves.

DEFENCE AGAINST SURPRISE.

3. The measures necessary to guard a fortified place against surprise are of two classes. First, for its prevention, by use of all the usual outposts and interior guards,—the organization and duties of which need not be repeated here,—and of telegraphic and other signals and communications with the surrounding country by which the approach and movements of any attacking force may be made known before it comes near the work.

Second, for its repulse, by so training and disciplining the garrison that, upon the alarm being given, the parapets, batteries, etc., will be manned and all defensive measures will be taken before the assaulting body can enter the work.

This will be accomplished by so thoroughly drilling the garrison in its duties that each man will go at once to his proper station fully equipped for his duties at any hour day or night, without confusion or unnecessary excitement. The subsequent measures are the same as for resisting any other assault.

ASSAULT.

4. By an **assault** is meant an open attack upon a position by troops in line or column.

Formerly it was recommended to make assaults at early dawn, in order to have the increasing daylight for securing the results of victory; more recently night attacks have been more strongly advocated in order to diminish the losses from the fire of the defence while making the attack, and the still greater ones which follow a repulse when, the fire of the supports and reserves of the attack being suspended for fear of injuring the retreating troops, the defence pours upon the latter the full close and deadly fire of all its arms. Whether the advantages of a night attack more than counterbalance the dangers resulting from the confusion due to darkness is, however, a question not yet settled.

Open assaults upon fortified positions, well manned and armed, have, since the introduction of firearms, been considered the most bloody, uncertain, and frequently the most unjustifiable operations in war. With the introduction of machine and rapid-fire guns and magazine rifles it may be considered as an established fact that a well-defended line cannot be carried by an assault in front until its fire is overpowered or its ammunition exhausted.

This conclusion, which has been drawn from attacks on field-works, is still more positive in regard to attack upon works of strong profile protected by deep ditches and other obstacles.

DISPOSITIONS FOR AN ASSAULT.

5. When an assault is ordered the tactical dispositions must be so made as to keep the fire of the defence down to its lowest possible limit, until the assailant can close in with the bayonet.

With this end in view, batteries are established sweeping the lines; the assaulting columns, well supplied with ammunition, are formed where protected from fire; working parties are arranged and provided with such tools and appliances as are necessary for removing or overcoming obstacles; and all preparations are made for simultaneous action by the entire force.

It is manifest that to silence the fire of the work the attack must have a marked preponderance of artillery arranged both for enfilade and front fire upon the front of attack and the collateral works; and that the batteries must be established, the fire opened, and the guns of the defence silenced before the assault is made; and that this fire must continue until the assaulting troops are so near the work as to necessitate its discontinuance to avoid injury to them.

The working parties—carrying axes, saws, crowbars, and similar tools which are needed for removing the existing obstacles; explosives for blowing down gates, barriers, etc.; fascines, gabions, hurdles, etc., for crossing ditches, covering trous de loup, and other purposes; and, when necessary, ladders for escalade—move forward with the columns of attack; the latter must be so handled that, when the artillery fire is suspended, they can keep down the fire of the defence with rifle and light machine-gun fire.

Under cover of this fire the obstacles must be removed by the working parties, and the first assault made by the troops detailed for this purpose. With these troops should be a certain number of artillerists provided with lanyards, friction primers, etc., to serve any guns that may be captured, turning them against the defence.

A party of engineers provided with high explosives for blowing down gates, etc., should follow closely behind the advance in case of an escalade; they should also be provided with appliances for blowing up magazines, etc., when possible, in case of a repulse. The gates being captured and opened, the mass of the assaulting troops enter by them and complete the capture of the place.

In case of repulse the retreat of the advanced parties is covered, when possible, by the infantry fire of the reserves, and that of the latter by the artillery, as in the advance.

DEFENCE AGAINST AN ASSAULT.

6. Permanent works being designed to be secure against assaults and surprise, their guns of position are protected as well as circumstances admit against the hostile artillery and infantry fire. During the cannonade preliminary to an assault a wise discretion must be used as to how much ammunition may be profitably expended in replying to it, and how great an exposure of the men to the artillery fire is justifiable. As a rule but little reply is made from the work.

The machine and rapid-fire guns should be withdrawn from the parapets and be protected under bombproofs until the relaxation of the hostile fire due to the near approach of the assault allows them to be run out and to open fire. The infantry of the garrison is similarly handled, being held under cover until the proper moment, then manning the parapet and pouring a close, rapid, and deadly fire upon the assault.

The fire of the fronts directly attacked, both machine-gun and infantry, will be directed principally at the assaulting columns and wcrking parties, the collateral works and fronts will, in addition to pouring a cross-fire upon the assaulting columns, direct a large part of their machine-gun fire upon the supports and reserves, while the more powerful guns will generally direct their fire upon the hostile artillery.

The troops not needed for manning the parapets are held under cover in a central position as a reserve, to strengthen the force at any part of the parapet or to meet and drive out any body of the enemy penetrating the work.

Should the attack be repulsed, the most rapid and destructive fire from all arms is directed upon the retreating troops with a view to inflicting the greatest possible losses; but a counter-attack is, as a rule, not attempted. When made, however, it should be limited to making an advance upon one or both flanks to a position giving a more effective fire upon the retreating troops, and retiring from this position to the cover of the work as soon as the main attack is completely repulsed and before the advanced troops become compromised by a close engagement with the enemy.

BOMBARDMENT.

7. By a **bombardment,** technically speaking, is meant a more or less continuous shell-fire upon a place with a view to destroying magazines, buildings, materials, and supplies of all kinds, in addition to inflicting the greatest possible losses upon the garrison and producing among the inhabitants a state of terror and unrest, frequently extending to mutiny, and finally causing the surrender of the place.

The term bombardment is also frequently applied to a cannonade opened upon a place to silence its artillery prior to an assault or during a siege.

A bombardment promises success when the place is small and not well provided with bomb-proofs, when the garrison is weak or of bad morale, when the inhabitants are numerous and not in sympathy with the garrison, or when the commandant is weak. A well-built and well-equipped modern fort can hardly be reduced by bombardment with any reasonable expenditure of time and ammunition; although the successful use of torpedo-shells charged with high explosives will probably render untenable works not designed to resist their effects.

When it is designed to reduce a place by bombardment a complete investment is, as a rule, necessary only to prevent the withdrawal of the non-combatants (a severe measure, but one frequently adopted), or to insure the capture of the garrison upon the fall of the place.

The disposition of the troops is made for the special object in view. The infantry, cavalry, and field artillery complete the investment, if made; or, when the place is not invested, are concentrated at such points as may be necessary to protect the artillery from any sorties from the place, and to meet and repel attacks from any relieving force.

The artillery of larger calibre used for the bombardment proper should consist principally of rifled howitzers and mortars, which are easier to transport and more suitable for high-angle fire. As it is not intended to dismount or silence the guns of the place by direct or enfilade fire, an artillery duel should be avoided.

The batteries should be located, so far as possible, in places screened from the artillery of the defence by undulations of the ground, etc.; or, if this is impossible, by artificial screens as a cover from sight, and by trenches as a protection from fire.

Considerable latitude is allowed in selecting sites for batteries. For convenience of supply and unity of command they should be collected in groups, the batteries of the groups separated by at least 100 to 200 yards; and the groups should be located, so far as other considerations allow, near the main lines of communication.

If these groups do not entirely surround the place, they should, when practicable, extend at least half way around, so as to bring a reverse fire on all covers.

The fire, once opened, should continue night and day. If a conflagration breaks out, a sharp fire of shells should be directed upon it and its vicinity to prevent its extinction. Special efforts should be made to blow up magazines and destroy shops, storehouses, docks, roads, bridges, or other communications useful to the defence; but, so far as is practicable consistently with these, an attempt should be made to avoid injury to public monuments, museums, antiquities, and works of art.

Bombardments are sometimes commenced and continued for a longer or shorter time without the expectation of reducing the place, but to destroy some of the constructions above mentioned or to prevent the completion or arming of a work which it is intended to attack by other methods. A slow bombardment may also precede the active cannonade which prepares for an assault, or the systematic artillery attack of a regular siege.

DEFENCE AGAINST BOMBARDMENT.

8. The defence against bombardment is frequently, from necessity, strictly passive, and consists in so disposing the troops and materials as to protect them under bomb- and splinter-proofs, repairing damages to the latter and to magazines and parapets as occasion offers; saving the ammunition of the place by firing only such shots as promise to pay for themselves by the effect produced; and reserving all the strength of the place to meet the subsequent attack, if made.

When circumstances admit, a more active defence may be made, by a strong garrison, by well-conducted sorties which may capture and destroy the hostile guns and batteries and defeat and drive off their supports.

Sorties of this kind may sometimes be profitably made against the flanks of the attacking force, or against isolated batteries, even when a general attack cannot be made. Opportunities for their use should not be neglected.

CHAPTER II.

SIEGE OR ATTACK BY REGULAR APPROACHES.

PRELIMINARY CONSIDERATIONS, DEFINITIONS, ETC.

9. By a regular siege is meant a systematic and more or less deliberate attack upon a fortified place, in which the besieger aims to invest the place and capture its fortifications in succession by regular approaches, beginning with the most advanced and ending only with the reduction of the innermost keep and the surrender of the garrison.

The successive steps of a siege are usually the following:

The investment.

The artillery attack.

The construction of parallels and approaches.

Breaching by artillery or mines.

The final assault.

The introduction of modern breech-loading rifled guns, howitzers and mortars, rapid-fire and machine guns, and magazine small arms has brought with it the need of a higher grade of mechanical skill and improved machinery for making the ordinary repairs. This imposes upon both attack and defence the necessity for providing machine shops and tools fitted for work of this kind, with the steam power required to drive them. In connection with these, steam saw-mills and other simple wood-working machines should be provided, as well as all other available labor-saving appliances which can be used to lighten the labor of the troops.

Portable tools, such as picks, shovels, crowbars, rammers, axes, hatchets, bill-hooks, gabion-knives, hammers, saws, carpenters', joiners' and blacksmiths' tools, etc., etc., must be provided.

10. The principal **special tools and appliances** used are the following, viz.: sap-forks, sand-bag forks, scrapers, sap-shields, measuring-rods of various lengths, pocket compasses with attachments for fastening them to measuring-rods, tracing-lanterns, dark and ordinary lanterns, tracing tape or cord, tracing pickets or stakes, fascines, gabions, hurdles, sand-bags, blindage and gallery frames and sheeting, etc., etc.

The *sap-fork* and *sand-bag fork* (Pl. I, Figs. 1 and 2), about $4\frac{1}{2}$ and 4 feet long, respectively, have steel heads with three and four prongs, as shown in the figures, those of the sap-fork being sharp and those of the sand-bag fork blunt.

They are used for handling and placing gabions, fascines, and sand-bags in position when, without their use, the sappers' arms would be exposed to fire.

The *scraper* (Pl. I, Fig. 3) is a large hoe, of about the dimensions given in the figure, used for levelling off the surface of parapets, etc.

The *sap-shield*, introduced by the English (Pl. I, Figs. 4 and 6), is a flat plate of mild steel 3 feet 6 inches by 1 foot 9 inches $\times$ $\frac{1}{4}$ inch, with two handles on its back as shown. Total weight, about 80 lbs.

It may be used as shown in the figure, and sometimes by small parties as a body-shield in such operations as blowing in gates, etc., etc.

Measuring-rods of rectangular cross-section, straight and divided into feet and inches, are needed for special purposes; but the ordinary rods are cut from round brush wood and to the length required.

Tracing-tape is usually a white tape, about $1\frac{1}{2}$ inches wide, in lengths of 150 feet, marked at equal intervals, usually 5 feet, by short pieces of tape sewed to it. A loop of strong cord is fastened to each end. For convenience in use it is ordinarily rolled into a ball.

Tracing-pickets are about 18 inches long and one inch in diameter. To make them visible in a dim light the bark is removed from them. *Ordinary pickets* are usually $3\frac{1}{2}$ or 4 feet long, $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in diameter, sharpened to a triangular point.

The *tracing-lantern* (Pl. I, Fig. 5) is a dark lantern with a reflector arranged to throw a light vertically downward.

The other tools, materials, and appliances above mentioned, not of the ordinary commercial patterns, are described in Field Fortifications and Military Mining, *q.v.*

CHAPTER III.

TRENCHES, APPROACHES, PARALLELS, SAPS, SPLINTER PROOFS, AND PASSAGE OF THE DITCH.

11. **Trenches.**—A *military trench* consists of a ditch and embankment affording cover from direct fire. Trenches are used for *approaches* (or *boyaux*), *parallels*, and *communications* with magazines, etc.

12. **Parallels** are trenches which take their name from the fact that they usually are located on lines approximately parallel to the general front of attack. In a regular siege at least three and frequently a greater number of parallels are used. The exterior one, which is first made, is known as the *first parallel*, the next one as the *second parallel*, and so on. They are used to cover the part of the besieging force known as "*the guard of the trenches*," which protects the men making the approaches, etc., and also as "places of arms" for assembling troops for assault or for other purposes.

The trench of a parallel is usually 10 feet wide at the bottom and 4 feet deep, finished on the reverse with a slope and on the front with two steps and a berm, with treads of 18 inches and rises of 15–18 inches (Pl. I, Figs. 7 to 13).

The parapet of the parallel should not be higher than 4 feet 6 inches. Its upper surface, particularly in the second and third parallels, should be made approximately plain with a scraper, and its interior slope should be finished and if necessary revetted, so as to afford a good infantry-fire. To allow the troops to move out to the front in line, portions of the interior slope should be cut into steps of not more than about 18 inches rise, and be revetted with fascines or other materials (Pl. I, Figs. 12 and 13). These portions should be 25 or more yards long and near the approaches. If a general assault is to be made, the parallels must be similarly arranged for the necessary length of front.

13. **Approaches** are trenches leading up toward the fortification on the front of attack; they connect the parallels and give protection to the besiegers in moving back and forth. To avoid enfilading fire they usually run in zigzags (Pl. VIII, Figs. 80 and 81) across the capitals of the work, with branches seldom exceeding 100 yards in length at the first parallel, and growing continually shorter as they approach the work. Each branch is so directed that its prolongation will pass from 30 to 40 yards outside the most advanced position within effective range held by the defence. At each turning-point of the zigzag the more advanced branch is prolonged from 10 to 20 or more yards to the rear, to cover the angle of the approach. These returns are also useful for storing trench material, etc.

After the return is completed the sharp angle in the trench is rounded off to allow gun-carriages, etc., to make the turn.

Approaches are usually 4 feet deep, 9 to 12 feet wide at bottom, with slopes in front and rear as steep as the earth will stand, and have a rough parapet not less than 4½ feet high, separated from the trench by a berm of 18 inches, or more if necessary (Pl. VIII, Fig. 82). When drainage requires it, as it very frequently does, the bottom of the trench is sloped from front to rear about 6 inches; a ditch cut along the reverse slope, discharging into the drainage ditches of the vicinity, or into drainage pits excavated in rear of and outside the approaches. These may be lined with a gabion to prevent their sides falling in.

TRACING AND CONSTRUCTING PARALLELS AND APPROACHES.

14. **Tracing Parallels.**—Parallels are located by engineer officers after careful reconnoissance of the ground. Guiding points and lines are marked so as to be readily found in the dusk, but so that they cannot be seen by the defence. When completely screened from view important points are marked by posting sappers at them.

When no other practicable method can be used, the directions are determined by the use of a pocket compass fastened to a straight measuring-rod.

Tracing is begun as soon as the approaching darkness will conceal the parties from the defence, while close objects are still visible. The length of parallel traced by each officer should not exceed that occupied by one unit, usually a battalion, as a working party. (A battalion of 500 men will occupy 800 yards).

The tracing party consists of one officer, one N. C. officer, and one sapper to each 50 yards of parallel, with one or two extra men.

The officer is provided with a pocket compass and measuring-rod. The N. C. officer has a tracing-lantern and a mallet with muffled head. Each sapper carries a roll of tracing-tape, a tracing-picket, and a six-foot measuring-rod. The officer stations the first sapper at the initial point, and, taking one end of his tracing-tape, moves along the line of the parallel, accompanied by the rest of the sappers; the first sapper places his picket between his feet, and the N. C. officer drives it into the ground far enough to make it secure. The sapper drops the ball of tape on the ground and lets it run out through his hands until nearly out, when he checks it, and when it is all out places the loop over his picket and lies down to await the arrival of the working party. The N. C. officer, as soon as he has driven the first picket, follows on to the second, etc.

The officer, having run out the tape of the first sapper, halts the second, takes thc end of his tape, and proceeds as before until the parallel is traced, and a sapper is left at each 50 yards of its length. Each sapper is told the designation, by number and section, of the point he occupies.

15. Tracing Approaches.—The approaches are traced in the same manner as the parallels, but at each turning point of the zigzags a picket is driven, around which the tape is carried. After tracing the branch in front, the tape is cut at five yards in rear of the picket, and the end carried out to the rear in prolongation of the branch in front to indicate "the return," which is then prolonged to the proper length (from 10 to 20 yards) by a short piece of tracing-tape.

POSTING THE WORKING PARTIES.

16. The working parties are commanded by their own officers, under the guidance of the engineers. They carry their arms and ammunition. Each battalion (or other unit) is marched in column to the depots, where the tools are laid out in lines, so that each man can take up his pick and shovel when drawn up in front of them. But when time does not allow of this arrangement, they are piled, the picks in one pile, the shovels in another, and the men pass the piles in single file to the right of the picks and the left of the shovels, each man receiving a pick and shovel as he passes the pile. If gabions are to be carried, they are distributed in a similar way. When two are carried, the shovel is secured inside one and the pick inside the other, and the gabions are then carried by the picket inserted for that purpose. When one only is carried, the pick is usually secured inside it, the gabion carried on the shoulder, and the shovel in the hand.

The working party, in column, provided with its tools, etc., is then led by the engineer officer to the parallel, and forms on right (or left) into line along it in single rank at five-foot intervals, beginning at the initial point of each section.

The N. C. officer of engineers assists in this formation, and each sapper points out to the men of the working party the five-foot intervals marked upon the tracing-tape of his 50 yards, verifies their positions along it, and subsequently superintends their work. Each man when properly placed drives his pick into the ground at the left of his task, places his shovel beside it, and lies down until the command "Commence work" is given.

When gabions are used the working party is posted in a manner entirely similar, except that the column is of necessity formed in single rank when marching to the initial point. The men form on right (or left) into line and place their gabions in front of the tape and touching each other; each man then takes out his tools, places them behind the gabions, lies down, and awaits the command to commence work. The sapper sees that the gabions of his 50 yards are properly aligned and touch each other throughout.

Both the sappers and working parties are divided into reliefs, usually of eight hours. The sappers of the tracing parties superintend the work of the first relief of the working party, but are relieved long enough before them ($\frac{1}{2}$ hour to 1 hour) for the second relief to become acquainted with the details of its sections before the second relief of the working party arrives. A similar arrangement is made for the third relief.

EXECUTION OF PARALLELS AND APPROACHES.

17. Simple Trench.—A trench made by excavating the earth and forming a parapet without revetment of any kind is known as a "*simple trench*," or as "*simple trench-work*."

Flying sap or *flying trench-work*.—When, in order to obtain cover more quickly, gabions are used to hold the earth first excavated, and subsequently to serve as a revetment to the interior slope of the parapet, the trench is known as a "*flying sap*" or "*flying trench-work*."

18. Construction by Simple Trench.—The first parallel and the distant approaches are usually constructed by the use of the simple trench, as follows, viz. (Pl. I, Figs. 9 and 10): The men having been posted along the tracing-tape at five-foot intervals, as previously described, and their positions verified by the engineer officers, the command "Commence work" is given. Each man marks the left and front of his task by a line dug with his pick, and, commencing at the left of his task, at once excavates a trench 3 feet long, 1½ feet deep, and 6½ feet wide, throwing the earth to the front, and making a parapet 1½ feet high, leaving a berm of 1½ feet. Then, commencing at 1½ feet from the front of his trench, he deepens it to 4 feet, making the parapet 3 feet high. When the task of a party is finished each man cleans off his pick and shovel, places them at the rear of the trench, and leaves them there for the use of the second relief.

By excavating in this way, partial cover while at work and a defensible parapet are rapidly obtained, and, at the completion of the task, the parapet admits of a strong defence, and affords cover sufficient to allow the first relief to be withdrawn and the second to be posted without exposure. Special care must be taken during the work to make the men face toward the parapet while digging, in order to avoid striking their neighbors with the pick when raising it for a blow.

The second relief widens the trench 4 feet; forms a bottom step 18 inches wide with such materials as are available; heightens the parapet to 4½ feet, and throws the rest of the earth to the front to thicken it (Pl. I, Fig. 8).

The third relief widens the trench 2½ feet at the bottom and slopes off the reverse as steep as the earth will stand. The earth is used to thicken the parapet, additional shovels and shovellers being provided if found necessary.

The approaches (Pl. VIII, Fig. 82) are extended in a similar manner; the tasks of the reliefs are marked on the sections.

Variations from these sections are made when rendered necessary by the presence of rock or water in the soil (Pl. I, Fig. 11); when a wider trench is required for a tramway or for free communication; or, in special cases, when a narrower trench will answer the purpose and save work. Should a specially heavy fire make additional cover necessary, it may be obtained by deepening the ditch and thickening the parapet, leaving its crest at the same height. The sections above given have been found best for ordinary cases.

19. Construction by Flying Sap.—The construction of the first parallel having indicated to the defence the front of attack, further operations will usually be subject to a more destructive small-arm and machine-gun fire. This will, as the siege advances, render the losses experienced in constructing a simple trench too extravagant, and a quicker method of obtaining cover must be used. This method is found in the flying sap (Pl. I, Figs. 8 and 13), which is executed as follows, viz.:

The men are posted and the gabions placed as previously described. The engineer officer having marked the lines, the order "Commence work" is given. Each man marks with his pick the front and left of his task (which in this case is $4 \times 6\frac{1}{2}$ feet, leaving a berm of $1\frac{1}{2}$ feet), and proceeds at once to dig on its left, filling first the left gabion, next the right, and then throwing the earth over and in front of the gabions. Each gabion, when it is half filled, is tipped outward until it has a slope of about 4 on 1. The filling is then completed.

As each man of the first relief occupies only 4 feet of front (2 gabions), his task is four-fifths as great as it is in executing the simple trench.

The second and third reliefs have the same tasks as in the simple trench. When the first relief finishes its task, every fifth workman (indicated by the sapper of the section) retains his pick and shovel and returns them to the depot when he marches past it.

The others leave their tools for the use of the second and third reliefs. In good soil the gabions may be filled in from 7 to 15 minutes.

The English sap-shield is designed for use when the fire is so severe that the flying sap with gabions becomes impracticable. Owing to its weight (80 lbs.) a man can carry but one; hence a carrying party equal to the working party assists in placing the shields and then retires. This gives to each workman a task of $3\frac{1}{2} \times 6\frac{1}{2}$ feet.

The shields are placed as shown in Pl. I, Fig. 6; the trench is executed as previously described, the earth being thrown over and beyond the shield. The shields are removed after the task of the first relief is finished.

The sap-shield is designed to be used in special cases for covering the head of a full sap (described further on), in which case it is placed as shown on Pl. I, Fig. 4; and also as a body cover for a man moving for a short distance in the face of a heavy fire, as is necessary at times in sapping and mining operations. It has not yet stood the test of service in a siege.

SPLINTER-PROOF COVER.

20. Splinter-proofs for the guards of the trenches, for field-hospitals, latrines, etc., should be provided as soon as possible after the parallels are finished. They may be placed in the returns of the approaches, or in rear of the parallels, and be connected with them by trenches. Pl. II, Figs. 14–16, show their construction when in rear of the parallel and revetted with logs, fascines, or sawn lumber. The trench is 9 feet wide by 4½ feet deep. Its front edge should be 25 or 30 feet in rear of the reverse slope of the parallel. This width of trench will allow 2 to 4 men per yard of its length to work advantageously. They should finish it in 8 hours.

In digging the trench the earth is thrown out on both sides, leaving a berm of about 1½ feet on each side to allow the woodwork to be properly placed. When this is completed the earth in rear is thrown forward to complete the cover, as shown in the plate.

Steps for egress and openings for light and ventilation may be placed at intervals along the rear, and, when desirable, bunks may be built, as shown in the figures.

When the splinter-proofs are built in the returns of the approaches, the overhead cover may extend entirely across, steps and openings being provided as in the previous case; or posts and longitudinal beams may be set in the trench to hold up the rear end of the cross-beams, leaving the rear of the splinter-proof open. Portions of this may be closed, if desired, by leaning short posts or fascines against the longitudinal beam and banking earth against them.

The splinter-proofs may generally be drained into the parallels or approaches. When this cannot be done drainage-pits must be used. Limited portions of the splinter-proofs may be protected against leakage through the earth cover by first filling over the covering beams with earth, packing it to a smooth surface with a gentle slope, placing upon it raw hides, roofing felt or other waterproof material, and then completing the cover by adding the necessary thickness of earth, giving finally to its top surface a slope to carry off the rain.

BOMB-PROOFS.

21. When, in the close attack of the work, the besiegers are subject to vertical fire from small mortars, better overhead cover must be obtained by **bomb-proofs**, constructed by deepening the trench, using stronger beams, and a greater thickness of earth. Twelve-inch timbers laid touching each other, with spans of 5 feet and 5 feet of earth cover, have been considered sufficient; but with the improvement of high-angle fire and the use of high-explosive shells greater protection will be needed in the future. Experimental data for fixing the amount is not now available; an approximate thickness of earth cover may be computed as indicated below.

The mining effect of dynamite in common earth is something less than twice that of an equal weight of gunpowder. (See Military Mining, Arts. 13 and 14.)

An explosive enclosed in a strong case, however, expends a part of the energy due to explosion in rupturing this case. The stronger the explosive the less will be the percentage of the total energy required for breaking the case, and the greater the percentage remaining for performing other work. For this reason equal weights of high explosives and of gunpowder enclosed in strong shells will not produce the same relative effects in forming craters, &c., that they would if contained in paper cases. The effect of the high explosive is relatively much greater when contained in a strong shell. Experiments made at Fort Hamilton, 1890–91, with 8-inch shells loaded with explosive gelatine, showed this explosive to have between 4 and 5 times the effect of gunpowder, while in paper cases the relative effects were as 1.7 to 1.0. (See Report of Board of Ordnance and Fortification, Ex. Doc. No. 12, 52d Congress, 1st Session, January 5th, 1892.)

Since the mining effects of the charges contained in shells are, however, less than when packed in thin cases, the thickness of cover determined by the use of the usual mining formulas should err on the side of safety.

Knowing the charge contained in shells to be fired against a bomb-proof, and their probable penetration, the formulas given in Arts. 7 to 12, Military Mining, may be used for finding equivalent common mines and radii of rupture for dynamite and explosive gelatine by substituting in them $\frac{1}{17}$ for $\frac{1}{10}$.

The values given in Art. 11 will probably be sufficiently accurate for the radii of rupture. The cover given in the direction of the fire must be greater than the sum of the penetration and the radius of rupture.

When the penetration is equal to or greater than twice the L. L. R. of an equivalent common mine a camouflet will probably be formed, whose radius of rupture, from the formulas, will be equal in all directions and may be assumed as $\frac{1}{6}$ of the L. L. R. of the equivalent common mine.

In this connection, see par. 61, p. 58.

SAPPING.

22. When the trenches have been carried so near the work that the simple or flying trench cannot be used without undue loss, recourse must be had to the *sap*.

A **sap** is a narrow trench (subsequently widened), which is continually prolonged in the desired direction by digging away the earth at its head and throwing it to the front and exposed flank as a cover for the working party.

When the sap is subject to an oblique front-fire, exposing one flank only, the parapet is constructed on that flank and at the head. This is known as a *single* or *full sap*. When both flanks and the head of the sap are exposed to fire two full saps are driven parallel and very near to each other, each with its parapet on the outer flank. The tongue of earth left between them is removed to widen the narrow trenches, thus making a single trench with a parapet on each side. This is called a "*double sap*."

The trench is sometimes deepened and given a splinter-proof roof or cover. This is known as a "*blinded sap*." A sap gaining ground to the right and front is called a "*right-handed sap;*" its parapet is on its left flank. A "*left-handed sap*" has its parapet on its right flank.

To expedite the work in sapping several reliefs should be employed, and task-work should be adopted to induce the men to work rapidly.

In all sapping operations the use of the simple trench and flying sap will be resumed when circumstances admit without involving too great losses.

23. **The full sap** (Pl. II, Figs. 17–21) requires a detachment, or "brigade," of 1 non-commissioned officer and 8 men, provided with the following tools, viz.:

For No. 1, a miner's pick, a miner's shovel, a measuring-rod, 4′ 6″, marked at 3′, and a sand-bag fork.

No. 2, a measuring-rod of 1′ 6″ and a shovel.

No. 3, a pick, a shovel, and a measuring-rod 5′ long, marked at 4′ 6″.

No. 4, a shovel and a scraper with a handle 9′ long.

For the rest of the detachment, a 6′ measuring-rod, knee-caps for 4 men, 2 shovels and 1 pick (in reserve), and, when necessary, a crowbar, axe, and bill-hook. From 100 to 150 sand-bags are supplied to each detachment.

24. **Organization and Duties of the Detachment.**—The sappers are numbered 1, 2, 3, and 4 in each rank; the front rank extends the sap 1 yard and is then relieved by the rear rank, and so alternately. The sappers change places at each relief; those who serve as Nos. 1 and 2 during their first task becoming Nos. 3 and 4 during the second, and so on throughout their tour.

If a detachment is reduced below 8 in number by casualties it nevertheless keeps 4 men at work driving the sap, and reduces its reserve until new men are supplied.

25. **Driving the Sap.**—The sap is driven as follows, viz.: Nos. 1 and 2 dig a ditch 4′ 6″ deep, 1′ 6″ wide at bottom, and 3′ or more at top; the berm side has a slope of 3/1, and the reverse is vertical, or as nearly so as the earth will stand. They leave no berm, as they need all

the cover they can get. Nos. 3 and 4 widen this trench 2 feet and form a berm of 1′ 6″ by digging away the foot of the parapet and throwing the earth upon its top and exterior slope. The head of their work is kept at 9′ in rear of the head of the sap.

The side parapet made by Nos. 1 and 2 is about 2′ 6″ high and bullet-proof (about 2′ 6″ to 3′ thick) at 18 inches above the ground. The head parapet is made up of about 60 sand-bags, from $\frac{1}{2}$ to $\frac{2}{3}$ filled. It joins the side parapet and extends across the head of the sap. It is about 2′ 6″ high.

As the sap is driven forward the head parapet is advanced by throwing the rear sand-bags over to the front by hand or by the use of the sand-bag fork. In excavating the trench No. 1 kneels down, undermines, and digs down enough earth to advance his trench about 9 inches. He is replaced by No. 2, who shovels this earth upon the side parapet toward the head of the sap. No. 1 then resumes his place and throws the sand-bags at the head of the trench over the parapet until he has uncovered about a foot in advance. He uses a sand-bag fork when necessary. The trench is advanced 9 inches more in the same manner. No. 2, besides throwing out the earth dug by No. 1, trims up the slopes and gives the trench its proper width and depth.

Nos. 1 and 2 change places when they have advanced the head of the sap 1′ 6″, and are relieved as before stated when 3 feet is gained.

Nos. 3 and 4 work together upon their task. In shovelling the earth upon the parapet they throw it somewhat toward the front and regulate its height with the scraper. The rate of advance is usually from 2 to 4 feet per hour.

Widening the Sap.—The sap is widened by working parties, usually of infantry, who work at about, but not less than, 25 feet in rear of the head of the sap. In an approach their task is equal in volume to that of the sappers, and can be finished in one relief. In a parallel when steps are to be provided, a second relief makes the steps, drainage ditches, drainage pits, etc.

A change of direction in a full sap (Pl. II, Fig. 20) is made by No. 1 turning in the new direction and working through the old side parapet; No 2 throwing the earth over the old head parapet. The sand-bags of the old are gradually removed and used for a new head parapet, 20 or 30 additional sand-bags being ready for use if needed before the others can be safely removed. Nos. 3 and 4 follow on as before.

A *return* can be driven back when desired by another detachment of sappers. No head parapet will be needed, but the side parapet will be kept a little in advance of the head of the sap.

26. Breaking Out a Sap from a Parallel.—The head parapet of a sap is about 2′ 6″ high. The parapet of a parallel is about 4′ 6″ high. A sap of the usual form driven through the parapet of a parallel will expose the latter to fire through the opening formed. To reduce the danger from this exposure, the sap is broken out at night, and to cover the opening in the shortest time two or three men may creep over the parapet of the parallel and cover themselves by rapidly digging a hole, from which they may work back and join the sappers, who are working outward. The sap being driven obliquely to the front, the trench widened, and the parapet made full size (Pl. II, Fig. 21), the opening will be covered; or a few men may in some cases construct in front of the parallel a short section of flying sap, under cover of which the full sap may be broken out (Pl. III, Fig. 28).

Preliminary preparations for breaking out should be made during the day, but should be so conducted as not to indicate the selected point to the enemy.

27. **Circular places of arms** (Pl. IX, Fig. 83) may be formed in front of a parallel by breaking out two single saps from points 80 to 100 yards apart and so directing them as to meet at 25 or 30 yards in front of the parallel. They may be used by the guards of the trenches or as depots for trench material, etc.

28. **Shallow Sap.**—When the presence of water in the soil or of rock near the surface prevents driving the full sap 4′ 6″ deep, a shallow or modified sap (Pl. II, Figs. 22 and 23) may be used, provided a trench 3′ deep can be driven forward. In this case Nos. 1 and 2 must both work kneeling, and Nos. 3 and 4 must throw the earth well to the front and keep the parapet as high as possible, leaving the construction of the berm to the widening party, who will give to the trench the necessary width, and will then obtain earth for strengthening the parapet by deepening the trench when practicable and widening it when necessary, making, however, no irregularities which will injure it as a communication and no depressions which will collect water. This sap advances about as rapidly as the full sap.

29. **Overground Approaches.**—When the water or rock comes to the surface of the ground, approaches can, under favorable circumstances, be driven for short distances by carrying forward earth in sand-bags, forming with them head and side parapets, and moving

forward by continually building up the latter and advancing the former as before described.

The expenditure of time, labor, and sand-bags is so great in driving approaches in this way that the minimum height of parapet (possibly 5′) should be made with sand-bags. This may be subsequently heightened and strengthened with earth brought forward in barrows or hand-carts and thrown upon the top and exterior slope.

30. **Double Sap.**—(Pl. III, Figs. 24, 25, and 26).—The double sap consists of two parallel single saps driven side by side, the cutting lines of the berms, usually 10 feet apart, making the bottom of the completed trench 7 feet wide. It is used when the zigzags, to avoid enfilade, make such a slow advance as to be no longer profitable, i.e., when the amount gained in advance does not exceed $\frac{1}{8}$ the length driven. The double sap is directed toward the work, and is exposed to an enfilading and also to a slant fire from both directions. It must therefore have a parapet in front and on both flanks.

31. **Execution of the Double Sap.**—The double sap is driven by two detachments, each organized and equipped exactly as for a single sap, except that a greater number of sand-bags should be supplied when practicable. The sappers work as in driving a single sap, with the following modifications only: The Nos. 1 prolong their head parapets until they meet, and in advancing their heads of sap leave undisturbed the 4 feet of head parapet intervening between their trenches, but, by continually throwing sand-bags or earth obliquely to the front, keep the head parapet continuous and nearly straight.

This leaves between the trenches made by the Nos. 1 and 2 of the two detachments a tongue of earth 4 feet thick, surmounted with a parapet about 2′ or 2′ 6″ high, which serves as a parados and protects these sappers from reverse fire.

Nos. 3 and 4 of both detachments, in completing their tasks, remove this tongue and pass forward the sand-bags forming its parapet for use by Nos. 1 and 2; otherwise the tasks are as in driving a single sap. When sufficient sand-bags are not available the middle part of the head parapet must be made of loose earth, giving much less protection to Nos. 1 and 2.

This sap, from its method of construction, is completed by the sappers without the assistance of the infantry working parties. Its rate of advance is about the same as that of the single sap.

32. Changing Direction of a Double Sap.—When a change of direction is to be made No. 1 of the first detachment marks on the berm the width of the top of the trench (10′), Nos. 1 and 2 of the wheeling flank come around the tongue and the leading sappers of the two detachments start their sap-heads in the new direction. Nos. 3 and 4 of both detachments remove the tongue of earth and complete the parapets of the original trench and then follow up their Nos. 1 and 2 as before.

33. Breaking Out a Double Sap from a Parallel.—A double sap is broken out by methods entirely similar to those already described for the single sap (Pl. III, Figs. 27 and 28). The figures explain themselves.

34. Traversed Sap.—A sap may be traversed to protect it against enfilade by frequent changes of direction, generally rectangular (Pl. III, Figs. 29, 30, and 31), or by making hollow traverses by blinding the sap at points separated by limited distances (Pl. III, Figs. 32–35).

In traversing a double sap by change of direction, a single sap is broken out to the right or left (or one in each direction) and pushed forward to the desired length. From the flank of this the double sap is again broken out and driven to the front until another traverse is required. When the saps are driven to both right and left a double sap is driven to the front from the extremity of each, and at the next change of direction the single saps are driven towards each other until they meet, and the double sap is driven in the prolongation of its original direction. This forms what is called a *cube traverse*, and gives additional room in the communications. The single sap is used in making traverses, since by throwing all the earth on one side better cover is given. When the sap is so far advanced that it becomes subject to a reverse fire the double sap will have to be used in making the traverses.

Length of Traverses.—Traverses should extend at least 12 feet beyond the trench in their rear, which will give them a length of from 25 to 30 feet on the berm. The salient angles of the sides of the trenches should be rounded as much as practicable to allow the easy passage of guns, and those of the parapets should, when necessary to screen the trench, be held as nearly vertical as practicable by sand-bags. Ramps leading to the surface of the ground may be made in rear of the traverses when needed. For guns they are 8′ wide, with slope not greater than $\frac{1}{4}$. The work in making traverses being considerable, they should be spaced as far apart as practicable.

Spacing Traverses.—In driving the sap to the front the low head parapet of the sap will defilade a less length in the rear than would the finished parapet of the traverse, which is from 2 to 3 feet higher. The sap is, nevertheless, pushed forward to as great a length as will be defiladed by the traverse when finished, the sappers meanwhile passing the partly protected portion by stooping or creeping when necessary.

35. Traverse by Blinded Sap.—In traversing a sap by blinding a part of its length (Pl. III, Figs. 32–35) the sap is first deepened 2 feet over this part; mine-cases, frames similar to mining-frames, or regular blindage-frames (see Military Mining, Arts. 53–55) are then put in position, the side slopes are held up by sheeting, when necessary, and the top is covered with sheeting, fascines, rails, or other material; earth is then thrown upon the top to bring it up to the desired height for a traverse, which will usually give at least 3 feet of earth covering. When a considerable thickness of earth is to be used the frames must be made correspondingly strong. For a clear opening, 6 feet at bottom, 8 feet at top, and 6′ 6″ high the English engineers recommend frames at 3-foot intervals, with 6-inch square posts, 2-inch thick sills, and 9 inch × 6 inch caps 12 feet long. The end frames should be braced against outward thrust by 6″×6″ struts.

These traverses are usually made at least 20 feet in length. They can be used only when good drainage can be secured.

36. Crowning the Covered Way (Pl. IV., Fig. 36).—The traversed sap is used for "*crowning the covered way*," which consists in constructing a battery or infantry parapet along the crest of the covered way, from which a fire can be brought upon the ditch and the scarp-wall of the work. To accomplish this the sap is run parallel to the crest, with its nearer cutting line 18 or 20 feet from it. For an infantry trench the traverses may be of the dimensions already given.

To cover a battery they should be about 33′ long. It will generally be necessary to use the double sap altogether in their construction, but usually the earth excavated by Nos. 3 and 4 of both brigades will be thrown on the parapet next the work, the parapet on the reverse side formed by Nos. 1 and 2 affording sufficient cover for constructing the sap and traverses. The parapet is prepared for infantry fire as described for the parallels. The emplacements for guns, the service magazines, etc., etc., are prepared and the embrasures are cut, or the parapet prepared for the overbank carriages at the last moment, under cover of the small-arm and machine-gun fire from the parallels and places of arms, and the artillery fire from batteries, which do not endanger the working parties.

37. **Trench Cavalier.**—In order to obtain a greater plunge upon the covered way and ditch, short lengths of double sap are sometimes run at right angles to the direction of the crests of the covered way at about 30 yards outside its salient. The parapet on the side of the sap towards the work is thrown forward and built up to the desired height with gabions and sand-bags, and provided with steps and sand-bag loopholes, giving a short length of parapet with considerable command, firing directly along the covered way at short range.

This construction is called a *Trench cavalier.* It will be seldom, if ever, used in the future.

38. **Former Methods of Sapping.**—Before the gen-

eral introduction of machine and rapid-fire guns and of small arms of extreme accuracy and penetration saps were constructed by No. 1 sapper driving a trench 18″×18″, which was enlarged successively by Nos. 2, 3, and 4. Cover for the sappers was obtained by the use of a sap-roller (a large gabion, 7′ 6″ long and 4′ in diameter, stuffed with fascines and rods) as a movable head parapet, and the construction of the side parapet was expedited by the use of gabions, sap-fagots, etc. This method cannot be used against an enemy well equipped with modern weapons. It is referred to only as a suggestion that a readily improvised modification of it might be used to capture, with the least possible loss, a party of rioters, criminals, or other badly-armed men occupying an isolated house or other cover.

PASSAGE OF THE DITCH.

39. When breaches which are practicable are made in both counter-scarp and scarp of a dry ditch an assault may sometimes be made successfully; but when the scarp-wall is not breached, or when, for other reasons, an assault from the crowning of the covered way is not considered advisable, the ditch must be crossed and the breach, when made, must be crowned by regular approaches. This is accomplished by the use of a *sap*, *single* or *double*, depending upon whether it is exposed to fire upon one or both flanks. Owing to the plunging fire of the defence it may be necessary to make the sap deeper than 4′ 6″, or in some cases to *blind* it for a part or the whole of its length. It is generally impracticable to drive the sap down the slope of a breach in the counter-scarp; therefore a *blinded descent* (Military Mining, pars. 53 and 54) is used. It is so directed that when the counter-scarp is reached the floor of the gallery will be at the required depth below the bottom of the ditch; i.e., at the depth fixed for the bottom of the sap. When the small-arm fire of the defence is so severe as to necessitate blinding the sap from the counter-scarp across the ditch, it will usually be imperative to provide a *shield*, under cover of which the sappers may start the blinded sap. This may be made of boards covered with bullet-proof iron-plates, and of such width and length that it may be carried through the gallery, thrust out into the ditch, and then turned, placed in position, and blocked up at such angle and to such height as may be wished, by men who move on their hands and knees and support the shield on their backs. Under cover of this shield the head parapet of the blinded sap may be thrown up and the sap then driven in the usual way.

For method of breaching by mines, see Military Mining, pars. 91 and 92.

After breaching the scarp, if an assault is to be made, the counter-scarp, for a length equal to or greater than the length of the breach, should be blown down, to give the assaulting party access to the breach. If the breach is to be crowned, and approaches are to be driven against interior retrenchments, a gallery of descent should be driven to the counter-scarp at one side of the breach before the assault is made. From this a trench should be driven to the crowning of the breach (usually by flying sap), by means of which communication is maintained between the crowning of the breach and the exterior.

40. **A wet ditch without current** may be crossed by

building a causeway, upon one or each side of which a parapet is constructed (Pl. IV., Figs. 37, 38, and 41).

The floor of the gallery of descent should strike the ditch at about one foot above the level of the water. The counter-scarp wall having been broken through, a shield similar to that described in the preceding paragraph may be used to cover the sappers working at the outlet of the gallery in the first stages of the succeeding work. The causeway is built by throwing into the ditch short fascines or brushwood mats, having bound up with them stones enough to sink them, broken-stone gravel or other available material, until the causeway is 8 or 10 feet long, about one foot above the level of the water and wide enough for the roadway and parapets. The head and side parapets are then constructed with sand-bags, which are passed out under the shield and piled at its head and sides. The causeway is continued by throwing material over the head parapet, and the approach is driven forward somewhat like a sap. So soon as the head and side parapets are made the shield may be raised up and supported upon two or three cross-balks resting upon the side parapets. It may then be progressively moved forward and the approach in its rear be blinded by sappers working under its protection. Unless the plunge of the fire upon the approach is equal to or greater than 45° this shield will, however, when vertical, cover a greater length of trench than when in a horizontal position. It may, therefore, if desired, be turned into a vertical position and be supported by a frame built for that purpose, which can be moved forward as the approach advances (Pl. IV., Fig. 41).

When the head of the approach is subjected to the fire of rifle-bullets only, it may be practicable to dispense with the head parapet, replacing it with a bullet-proof screen covering the head of the approach and with wings extending back and overlapping the side parapets (Pl. IV., Fig. 40); the shield floating on a raft of light logs, or other material which cannot be sunk by rifle fire. This shield would, of course, be erected and launched under cover of the one already referred to. To save sand-bags, etc., the interior slope of the side parapets may be revetted with gabions about 4′ 6″ long, resting on two short fascines and crowned with three others, giving a height of about 6′ 3″. Upon these, when necessary, cross-beams are laid and the blinding of the approach is finished with sand-bags thrown on top.

41. **A wet ditch with current**, or one in which the water level may be varied by the defence, presents greater difficulties. The method of crossing which seems most promising is by a causeway made of materials which will allow the water to pass freely through it. For this purpose it is usually recommended to use casks with their heads knocked out, or strong gabions lashed to balks, so as to form continuous tubes, which are loaded with stones and sunk with their axes parallel to the counter-scarp by sappers working under cover of a shield. When the top of the causeway is about a foot above the high-water mark it is levelled off with fascines and the approach driven forward as previously described. When available, iron or terra-cotta pipes of large diameter may, perhaps, be advantageously substituted for casks or gabions. Cormontaigne, at Philipsburg, in 1734, successfully used floating bridges of fascines with parapets of gabions and fascines

covered with raw hides. Two bridges were made. They were 128 feet long, 48 feet wide, and 6 feet thick. The water was about 15 feet deep. To construct and hold in place, in a strong or varying current, a floating bridge of sufficient width and depth to support, without sinking or capsizing, the parapets necessary for protection against modern small arms and machine guns is a task presenting such great difficulties that it will hardly be undertaken, except as a last resort, and then with a very uncertain issue.

When, however, the fire of the work is nearly or entirely silenced, a floating bridge of pontoons, casks, spars, or other materials, with a slightly masked roadway, may furnish a sufficiently good crossing and may be constructed with little difficulty and loss.*

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* In the siege of Strasburg, 1870, a bridge of beer casks was built across the ditch of Lunette No. 52, between nightfall and 10 P. M., September 21st. The ditch was about 66 feet wide and 9 to 10 feet deep. This bridge gave access to the lunette. It was subsequently sunk by the fire of the work and was replaced by a causeway.—Franco-German War, Official Account, Part 2, vol. I., pp. 88, 89.

CHAPTER IV.

BATTERIES, OBSERVATORIES, AND MAGAZINES.

42. **Batteries** in siege operations are for field-guns, siege-guns, howitzers, and mortars.

When the gun-platform is on or above the level of the ground they are known as "*elevated batteries*," when it is below the surface as "*sunken batteries*."

When they are concealed from the view of the enemy by natural or artificial screens they are called "*screened*" or "*masked batteries*," and when on sites which can be seen by the enemy "*Exposed batteries*."

GENERAL REQUIREMENTS OF SIEGE BATTERIES.

43. 1st. A good *platform* for and sufficient space to work each gun. The platform must be suited to the gun used. The space required is about 15 feet front by 20 to 25 feet depth.

2d. A *parapet* which cannot be penetrated by the projectiles which will be fired against it, and which is high enough to afford cover to the gun and its detachment against curved fire. A thickness of 30 feet of earth will usually be enough for the most exposed batteries. A less thickness may be used when the conditions justify it. The height of the interior crest above the terre-plein should not be less than 7½ feet when this is attainable and may sometimes be greater.

3d. *Traverses.* Each gun is usually separated from the next by a traverse, whose thickness when subject to enfilade fire is the same as that of the parapet (30 feet); under other circumstances the thickness may be reduced if deemed advisable, but should, when practicable, be such that a shell bursting at any point within it will blow out at the top or on one side only.

4th. *Bomb* and *splinter proofs* sufficient to cover the gun detachment and reserves against vertical fire. The thickness of cover for these is to be regulated according to the principles laid down in par. 21.

5th. *Magazines* which will hold at least 24 hours' supply of ammunition, besides recesses near the guns for shells and a few cartridges.

6th. Easy and direct *communications* for bringing up the guns and placing them in position; including tramways, ramps, etc., etc.

7th. *Look-outs* or *observatories* from which the effect of the fire can be seen. These when possible will be placed in high sheltered places well on the flanks of the battery and preferably in advance of it. They may be connected with it by signals, telegraph, or telephone, when necessary.

8th. *Screens.*—Earthen screens should when possible be thrown up in front of all exposed batteries.

CONSTRUCTION OF BATTERIES.

44. **Batteries for Field Guns.**—When the place is invested, the field artillery is placed in positions considered most advantageous for repelling attacks from the garrison upon the investing force. *Gun-pits* (described in "Field Fortifications") are usually made at once for cover for the guns and their detachments.

When any of these sites are occupied during the siege the gun-pits may be connected and converted into a battery as indicated by Pl. IV, Figs. 42–45.

A similar construction may sometimes be used during the siege when the artillery fire of the place is weakened, and it is desirable to place a field battery in position for reaching some point in the work. As a rule, however, batteries for field guns will during the siege be constructed in the same way as are those for siege guns and howitzers.

45. **Batteries for Siege Guns and Howitzers.**—These may be *screened* or *exposed*, *sunken*, or *elevated*. As a rule each battery has a magazine on each flank. The amount of powder necessary to serve two guns for 24 hours (150 to 200 rounds per gun = 2500 to 6000 lbs.) is as much as it is advisable to have in one magazine, in order to limit so far as possible the disastrous effects of an explosion. For this reason the number of guns in a battery is usually restricted to four. This number may be increased when necessary, or when howitzers firing small charges render it unobjectionable.

Elevated batteries require much more labor for their construction and for obtaining cover for the men and material than the sunken batteries. They are therefore used only when the target has to be seen and the gun has to be raised for this purpose, or when owing to the presence of rock or water in the soil, or the liability of the site to be flooded it is impracticable to sink the platforms below the surface. As a rule they can be constructed only when covered by a screen either natural or artificial, and then with earth carried in wheelbarrows, sand-bags, etc., etc.

Sunken Batteries.—When constructed under cover of a screen the depth of the terre-plein of a sunken battery may be limited by the presence of rock or water in the soil, the character of the guns and carriages, and the time available for the work. In a hasty construction the depth of the terre-plein is usually limited to from 3 to 4 feet, which can be dug out in a short time. When more time is available the gun platforms may be put at 5 to 6 feet below the surface and the other parts of the terre-plein may be sunk still lower. This gives but little height of parapet, and the extra earth may be used for giving additional thickness of cover to the splinter-proofs under the traverses and flanks, and also to the magazines.

A great variety of plans and profiles may be adopted for batteries of this class, the details of which need not be given, since they will be modifications of those described in Field Fortifications and Permanent Fortifications, and of the exposed battery to be next described. As they are built under cover of screens and are not subject to fire during construction, work upon them may be continuous and by day as well as by night.

46. **Screens.**—The *natural screens* used for cover are elevations, woods, hedges, existing buildings, walls, etc., etc.

Artificial screens may be made by setting out bushes to imitate hedges or adopting similar devices, which, however, will usually fail to deceive an active enemy. A trench with the earth thrown to the front, forming a glacis-shaped parapet, will, however, generally be effective. It must be made of such length that the enemy cannot know the exact position of the battery, and of such height and thickness that he cannot ord to expend enough ammunition to breach it.

This affords not only concealment during construction, but also a remarkably efficient cover to the battery against hostile fire.

Screens, natural or artificial, should be from 50 to 100 yards in front of the batteries, so that the enemy's aim may not be corrected by seeing the points struck by his shells.

Unless the screen is of material which will break up into injurious splinters under hostile fire, only enough should be removed before opening fire to unmask the target of each gun, leaving the remainder for concealing the points struck by shells, even if it affords no cover against their penetration.

47. **Exposed Sunken Battery.**—Before describing the construction of this battery it is necessary to state that upon a site fully exposed to the accurate concentrated fire of a work, directed at night by light balls or electric lights, it will in general be practicable to construct batteries only by sapping, and even then with considerable losses. But these conditions seldom exist, since in the distant attack it is usually possible to construct and arm the battery before it is discovered by the defence, and in the close attack the fire of the defence is generally so much reduced that some exposure is justifiable. While the battery to be described is classed as an "exposed battery," it is understood that it may also be constructed under cover of a parallel or other trench, and that in all cases when practicable a natural or artificial mask is used to conceal the first night's work from the enemy. It is assumed from the results obtained in practice that, with the material con-

veniently stored, the battery can be traced, a central trench and splinter-proof covers be made during the first night, and the battery finished and armed during the second.

The general design and details of this battery are due to the Royal (British) Engineers.

48. Tracing the Battery.—The battery is traced under the direction of an engineer officer by one or two tracing parties, each composed as follows: 1 non-commissioned officer with a 6-foot measuring-rod and tracing-lantern, and 4 sappers, one carrying a measuring-tape and bundles of pickets, one a field-level, one several tracing-tapes, and one a mallet or hand-axe; about 75 pickets and 1200 feet of tracing-tape should be provided. The line of fire of the first gun of the battery (*xy*, Pl. V, Fig. 46) is accurately laid out and marked by daylight. At dusk one party drives a picket at *I*, where the directrix crosses the projection of the base of the interior slope, and from this as an origin lays out the cutting lines of the central trench, *I*, *II*, *III*, *IV*, *V*, *I*, making the trench 5 feet wide and of the length required for the number of guns (= No. of guns $\times$ 45′ — 10′); commencing then at a point *A*, 7′ 6″ to the left of *I* and in the rear cutting line, this party lays out the line *a*, *b*, *c*, *d*, *e*, etc., . . . *m*, *n*, *o*, as indicated, the direction *n*, *o*, leading to the parallel.

The second party, beginning at *A*, lays out *A*, *B*, *C*, communicating with the parallel, and then the inner cutting line of the ditch *D*, *E*, *F*, *G*, *H*, *I*, allowing for a thickness of parapet of 30 feet and an ultimate width of ditch of 12 feet (*D*, *E*, and *H*, *I*).

Two parties should trace the battery in 25 minutes, one party in 45 minutes.

49. **Constructing the Central Passage and Splinter Proofs.**—The first relief of working party for the central passage is posted and commences work at once (Pl. V, Figs. 47–48). Each man's task is 5 feet in length and 4 feet in depth (giving 100 cubic feet). It may be completed in 4 hours, and should be in 6 at most.

The second relief (Pl. V, Figs. 49–52) excavates the cartridge recesses, trims up the work done by the first relief, lowers any earth that stands too high, revets the slopes of the gun portions, puts in frames and sheeting when needed in the splinter-proofs, places the bearing planks and balks of the latter, which should be at least 9 inches thick and 9 feet long, except over the cartridge recesses, where they are 12 feet, and when possible deepens the central passage under the splinter-proofs to 5′ 6″ for a width of 2 feet to form a seat for the men. It also places one or two planks along the passage to serve as a bench for shells. The latter part of this work can be done by daylight. The parapet formed by this excavation is about 2 feet high. This is so masked or so inconspicuous as not to draw upon itself the artillery fire of the defence. The construction of the battery will be continued usually on the following night.

50. **Construction of the Battery** (Pls. V and VI, Figs. 53, 55, 60, 67).—Two reliefs are required for this. *The first relief* receives its tools and arrives upon the ground at dusk. It is divided into four parties, one for the front ditch, one for the gun portions, one for the rear trench, and a reserve of ten per cent for substitutes and casualties. They are posted and supervised by the engineer officer, n. c. o^{s}., and sappers as described in paragraph 16, *ante*.

The Front-ditch Party.—Each digger is assigned a task 5′ wide, 6′ long, and 3′ 6″ deep. He throws the earth as far into the parapet as he can. The shovellers, one to each two diggers, are posted 12 feet from the cutting line of the ditch. They pass the earth back toward the interior crest and the traverse, keeping the top surface nearly level.

The gun-portion party is divided up equally among the gun portions, each digger is allotted a task 4′ wide, 7′ 6″ long, and 3′ 6″ deep. The gabions around the gun portion are placed by the shovellers under the direction of the engineer soldiers, a short one being placed at the throat of the embrasure. The shovellers spread and level the earth thrown out by the gun-portion parties and the rear-trench party. They work in connection with the other shovellers to give to the traverses and parapet near the interior crest the proper shape.

The Rear-trench Party.—This party excavates to a width of 7′ 6″ the rear trench and the communications with the parallel or approach. Each digger has a task 4′ wide, 7′ 6″ long, and 3′ 6″ deep. The two directly in rear of each gun portion throw the earth to the rear, the others throw it to the front, leaving a berm of 4′ 6″ at the rear of the traverse. The men of the *reserve* who are not otherwise occupied fill sand-bags from the earth thrown to the rear, and cut a ramp 8 feet wide and not steeper than $\frac{1}{4}$, in rear of each gun-portion, when needed. It is essential that the excavation of the gun-portion be finished by the first relief, so that the platforms may be laid by the second relief in time to allow the guns to be placed before daylight.

The first relief leaves in the battery the tools required by the second and carries the rest back to the depot.

The second relief is divided into three parties and a strong reserve of one quarter or one fifth of its strength. The first, or *front-ditch party*, works in the front ditch, widening it 6 feet and throwing the earth back to form the front of the parapet. The shovellers, one to each two diggers, spread and level it. The task of a digger is 5′ wide, 6′ long, and 3′ 6″ deep.

The second, or *platform party*, places the platforms and gives way to the gun detachments.

The third, or *rear-trench party*, widens the trench 3′ towards the front by cutting off the rear of the traverses.

The *reserve* completes any work left unfinished by the first relief, fills sand-bags and places them around the gun portions, digs ditches and drainage-pits when needed, and does any other work necessary for the completion and arming of the battery.

When a tramway is laid in the trench for bringing up the guns and carriages, the ramps in rear need not be cut.

51. Alternative Construction in Position Very Much Exposed.—When the earth thrown up in making the splinter-proofs cannot be concealed, it may attract such a severe fire from the defence as to make the above-described construction impossible. In this case the battery is traced as above described, the balks for covering the splinter-proofs are placed in position resting on bearing-planks, and the construction of the front ditch, gun portions, and rear trench are commenced at once; and the battery is as nearly finished as time allows, and armed if possible. The splinter-proofs are subsequently mined out and the remaining necessary details finished before opening fire.

52. Splinter-proofs, in addition to those in the central trench, are usually constructed under the rear of the traverses (Pl. VI, Figs. 65–67). These may be made during the construction of the battery or after its completion. They are about 5 feet wide, 6 feet deep, and 10 feet shorter than the width of the traverse. Their floor is at 6 feet below the surface. The earth is held up by frames and sheeting, and the roof is supported by cross-balks resting on posts and running back into the traverse. The roof consists of railroad iron or heavy timbers covered with earth, and access is given by steps from the rear trench; the space not occupied by the steps may be shielded with inclined posts or other covering if thought necessary. These splinter-proofs differ in no essential from those described in Field Fortifications. The finished battery is shown in Pl. VI, Figs. 62–64.

53. **Sunken Battery in a Parallel** (Pl. VII, Figs. 68 and 69).—A battery similar to the one above described is sometimes constructed in a parallel. In this case the traverses have to be built up, and therefore do not usually exceed 20 feet in thickness. Pickets are driven at intervals of 35 feet along the banquette of the parallel to mark the centres of the gun spaces, and the rest of the battery is traced in the usual way. The steps of the parallel are cut away and the slope revetted for the gun spaces and the central trench. Gabions are placed along the back of the central trench and the sides of the traverses. A rear trench 7′ 6″ wide is cut from the parallel at an easy curve, so that its front cutting-line shall be 25 feet from the foot of the interior slope; this, as before, is widened 3 feet by the second relief cutting away the rear of the traverses. The reverse slope of the parallel in rear of the gun

portions is cut back to the rear trench. A trench 2 feet wide and 2 feet deep is cut between the front of the traverses and the foot of the interior slope, and the cartridge recesses are excavated. The gabions of the traverses are filled, balks placed over the central trench, and the tops of the traverses and splinter-proofs are raised to the height of the parapet of the parallel. A ditch in the front of the parallel 12′ wide and 3′ 6″ deep, traced at dusk, and excavated during the night, supplies earth to make the parapet 30′ thick and 4′ 6″ high. The work done in and behind the parallel is not seen from the front, hence a great part of it may be done by day, undetected by the enemy. The upper part of the traverses is made by night, and the front ditch and front of the parapet are made the same night or subsequently, depending upon the number of workmen available.

Since the gabions of the traverses seriously obstruct the parallel, they should not be placed in position until all arrangements are made to open the rear trench.

In the special case of a battery on the crowning of the covered way, the traverses have been already constructed in running the sap. The splinter-proofs may be constructed by blinding portions of the sap, or by mining them under the traverses. Owing to the height of the parapet, embrasures of some depth will have to be cut through it. This is done by a shallow sap started by one man, who is subsequently assisted by a second, if the splay requires it. The cheeks are revetted with sand-bags, covered with hides. The mouth of the embrasure is left closed with the head parapet of the sap until fire is to be opened, when the earth is dug away or blown away by the gun.

54. **Battery Behind the Crest of a Hill** (Pl. V., Figs. 57–59).—In a battery behind the crest of a hill the front ditch may be omitted, the gun-portions may be entirely in excavation, and the platforms given such a reference as to require a shallow groove to be cut through the crest to allow the gun to fire. When the ground falls away very rapidly to the rear it may be stepped under the traverses to prevent their sliding, and the rear of the gun emplacement may be raised when necessary to give the platform the proper slope. The central trench is cut deep enough to give 5 feet of cover over the splinter-proofs.

55. **Batteries on Sloping Ground** (Pl. VII., Figs. 70–72).—When the ground to be occupied by the battery slopes towards or from the place or falls off on either side, the battery is constructed essentially as upon level ground. The central passage is driven, following the surface of the ground, the gun emplacements, front and rear trench are excavated as before described, the additional excavation or filling required in each gun emplacement to make the platform horizontal is regulated for the particular site, any excess of earth being used to give greater cover on the more exposed side, and any deficiency being supplied from the front or rear trench, as may be most convenient. Where the extra work imposed by the slope is considerable, a third relief may be required to finish the battery, and its arming may be necessarily postponed until the next night.

56. **Embrasures.**—Modern siege guns are generally mounted either on "overbank" or "disappearing" carriages, firing over parapets of sufficient height to give cover to the men. (The axis of the trunnions of

the U. S. 5″ siege gun is 6″ above the platform.) Embrasures when used are generally shallow grooves cut in the top of the parapet. In this case the bottom of these grooves must cut the surface of the top of the parapet at or in rear of the highest line visible to the enemy, so that no indentations which can be seen by him will indicate the position of the guns. To effect this, the exterior crest will usually be as high as and sometimes higher than the interior crest, and the top of the parapet (" superior slope ") will be level or will slope to the rear. In rare instances, however, deeper embrasures with revetted cheeks must be made. The only serviceable revetment for use with high-power guns is one of sand-bags wrapped in raw hides. This may be made by laying down a hide, piling a number of sand-bags upon it, and folding the free end back over them; placing another hide on top of this with more sand-bags and so on. Or large packages may be made by wrapping up a number of sand-bags in each hide and these packages may be used for making the revetment.

The embrasure should be bottle-shaped in plan, shaped like a segment of an ellipsoid immediately in front of the muzzle of the gun, then drawn in like the neck of a bottle and narrowed to as small a mouth as possible, so as to diminish the effect of the blast and give the least possible exposure to the gun. When the battery is exposed to slant or enfilading fire, instead of embrasures, bonnets of sand-bags may be built upon the parapets to protect the guns.

57. **Observatories.**—Observatories or look-outs, as previously stated, should as a rule be placed on high points well on the flanks of the battery.* When this is

* One of a group of trees may frequently serve for this purpose.

impracticable, they may be made by building up at the rear of the traverses, on the flanks, or even in the gun portions, glacis-shaped covers pierced with a sight-hole in all respects similar to a loop-hole for musketry, and with just sufficient splay to include the desired field of view. A number of these should be provided for each battery, so that the enemy may not know which one is in use at any time. If subject to close and accurate fire, the crest-line in their vicinity must be of the same level as the tops of the look-outs, and provision must be made to prevent the light showing through them.

58. **Drainage.**—After the completion and arming of the battery, gutters should be cut on each side of the gun-portion leading into one running along the reverse of the rear trench which carries the water to low ground on the exterior, or which is provided with dry wells or drainage-pits for collecting the water so that it may soak into the ground or be pumped out with hand-pumps.

59. **Mortar Batteries.**—The introduction of rifled mortars of all calibres, with the corresponding increase in accuracy of fire, together with the destructive effects of shells charged with high explosives, will doubtless lead to the extensive use of mortars in future sieges.

In a distant attack the requirements of a mortar battery are very simple, consisting principally of a stable platform, magazines for ammunition, and bomb-proof covers for the gunners; since the battery as a rule will be concealed from the view of the work by intervening obstacles, and will in consequence not be subject to direct fire. When the soil is favorable, cover against plunging fire will be most easily obtained by sinking pits for the mortars to such depth as may be necessary to furnish earth for a splinter-proof parapet surrounding the pit, and for cover for the bomb-proof shelters for the men and the magazines.

When ample space exists which is well concealed, and in which the soil is good, a separate emplacement should be made for each mortar. When necessary, however, two or more mortars may be placed in each pit. The magazines, splinter and bomb proofs are similar to those elsewhere described. When no natural mask exists, the battery may be constructed behind an artificial screen, and be made of the general type of the "exposed siege battery," the gun portions being made with front enough to accommodate one or two mortars as may be preferred, and of such length only as is needed for working the mortar employed. The terre-plein may be placed at any convenient depth below the surface of the ground, and the revetment of the interior slope, if any be used, will not ordinarily be carried higher than the muzzle of the mortar. As the traverses are not subject to gun-fire, the splinter-proofs afforded by the central passage may be added to by building others along both sides of the traverse; and by deepening the mortar emplacement sufficiently, they may be given enough cover to make them true bomb-proofs.

A mortar battery fulfilling these conditions can hardly be silenced by hostile fire.

The conditions under which the batteries may be constructed are, however, so varied that detailed dimensions will not be given. No difficulty will exist in making the battery of a size suitable for the pieces to be employed.

The U. S. rifled siege mortar is of 7-inch calibre, about

5 feet long, weighs 1715 lbs., and is designed to throw a 125-lb. shell with a charge of $5\frac{1}{2}$ lbs. of powder, giving an initial velocity of 685 f.s. and a range of about 4000 yards. With reduced charges the range may be reduced to about 650 yards without undue sacrifice of accuracy.

In the closer attack upon the work, batteries for the smaller siege and field mortars may be readily constructed in front or rear of the parallels, or in the parallels or approaches themselves; splinter-proofs and temporary magazines being constructed by methods previously indicated. In many cases, however, the lighter mortars, field and Coehorn, which do not require fixed platforms, may be placed behind any part of the trenches affording cover, and fire be opened and continued until the fire of the enemy becomes too annoying, when the mortars may be removed to some other locality.

MAGAZINES.

60. **Magazines** should be provided, at least two to each battery, not only to localize the injury due to an explosion, but also to prevent the battery being disabled by the explosion of a single one.

As previously stated (par. 43), they should contain 24 hours' supply (from 150 to 200 rounds) for each gun which they are designed to serve,* which may require a capacity in a single magazine of as much as 6,000 lbs. of powder.

This amount should be reduced when possible by increasing the number of magazines. The cartridges

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* The charge for the 5″ siege gun is 15 lbs. of powder; 200 rounds = 3,000 lbs.; 2 guns, 6,000 lbs.

should be made up and packed in boxes at the depots or parks, and the powder chambers in the magazines should be of such size as to store these boxes with only such vacant space as is necessary for ease in handling them.*

61. Cover.—The chamber should be covered with strong balks or rails and enough earth to form a sloping roof; over this raw hides or tarpaulin should be spread, and the remainder of the earth filling be spread upon this and rammed solidly. The amount of earth cover required for security must be determined from the principles given in par. 21. The English engineers recommend as sufficient protection against ordinary fire for a magazine 5 feet wide, two layers of 9″ × 9″ fir laid crossing each other, or one layer of 12″ × 12″ oak, covered with 5 feet of earth.

In experiments at Lydd in 1883, however, an 8-inch howitzer shell falling at an angle of about 30° penetrated through a covering of 7 feet of soft clay and burst upon the timber roof of a magazine, cutting it through. This shows that complete protection is not always possible, and that the chances of hitting must be reduced by making the horizontal area of the magazine chamber as small as possible, and placing its smaller dimension in the line of the hostile fire. The clear height of the magazine should be 4′ 6″ to 5′ minimum, when practicable, and the top of the covering balks should be at or below the level of the ground.

62. Location.—A magazine should be located at such distance from the battery that its explosion will

* No special box has been adopted in our service. The English box is 1′ 9″ × 1′ 5½″ × 1′ 5″ outside, metal lined, and holds almost 100 lbs. of made-up cartridges.

not disable the guns, injure the parapets or traverses, or seriously endanger the cannoneers;* but, on the other hand, it should be near enough to allow the ammunition boxes to be conveniently carried to the cartridge recesses; and the communications for this purpose should be well covered from hostile fire. The entrance to the magazine should be so protected that splinters cannot enter the chamber. Any natural hollows, banks, etc., in the immediate vicinity of the battery should be taken advantage of to facilitate the construction of and give better cover to the magazines. When nothing of this kind exists the magazines may be placed on the flanks or in rear of the battery, and should be masked and screened by the parapet of the parallel, approach, communications, or battery, or by special glacis-shaped screens made for the purpose; which should be much longer than the width of the magazines that they cover, so that the discovery of the location of the latter by the enemy may be made more difficult. The magazines should not be located in rear of the centre of the screens nor symmetrically with reference to the battery, nor, when it can be avoided, directly in rear of a gun. The passages leading to them should enter the battery in rear of a flank or a traverse, and should be so directed as to escape enfilade. They should be so graded that the surface water will run away from the door of the magazine and be discharged upon lower ground or received in drainage-pits placed at the lowest points.

* The crater radius of a mine with L. L. R. of 6′ to 12′ and a charge of 6,000 lbs. of powder would be about 44 feet (Art. 7, Military Mining). The radius of the mound of earth thrown out would probably be three times this.

63. Construction of a Magazine Subject to Direct Fire Only (Pl. VII., Figs. 73–77.)—The method of tracing the magazine and its approaches is too evident to need description. In this example an earth cover of 5 feet against vertical and 20 feet against horizontal fire is given. Should more or less be desired, a corresponding change may be made in the plan, depth of excavation, and depth and width of approaches; and the earth for additional cover may be obtained from a ditch or pit in rear of the magazine. The excavation for the chamber is given a width of 6′, a depth of 5′ 6″, and a length of 12′, the entrance a width of 3′, a depth of 5′ 6″, and a length of 6′.

The sides of the chamber and entrance are held up by frames 4′ 9″ high and 2′ 11″ wide, outside measurement. The caps are 6″ × 5″, stanchions 4″ × 5″, and the ground sills 3″ × 5″; sheeting 1″ thick is inserted between the frames and the earth. The covering balks are 9″ × 6″ and 10 feet long; their tops are flush with the surface of the ground; cleats nailed on their under side keep the tops of the side frames from being pushed in by the pressure of the earth. The earth cover is 5 feet high at the centre and 4 feet at the crest of the outer slope. The passages are 5′ 6″ deep, 3′ wide at bottom, and 5′ at the top. The entrance is blinded by placing balks across the passage for such part of its length as may be thought necessary, and extending the earth covering over them, as shown in the section (Fig. 75). A door, swinging outside, is hung on the outside frame. Heavy railroad iron may be substituted for the timber balks with advantage. When thicker balks are used, or when a second layer is added, the chamber and passage should be correspondingly deepened.

64. Manner of Executing the Work.—The powder chamber and passage are excavated and the frames and balks placed during the first night, while the central passage of the battery is being constructed. The excavated earth is thrown out far enough to allow the balks to be put in position, and is so spread as not to be seen by the defence. This may be done by one relief of 8 hours, or two reliefs of 4 hours each. If the work is not completed during the night, the sheeting, frames, and balks may be placed by day under cover of the earth thrown out and the existing screens.

The passages are excavated and the earth cover completed on the second night by two 4-hour reliefs, the first excavating to a depth of 3′ 6″, and the second to 5′ 6″, trimming up the slopes and completing the work. When necessary, the sides of the passage will be revetted by the second and a third relief.

When the necessity for great haste exists, the excavation of the powder-chamber, entrance, and passages may be carried on at the same time, the excavated earth being thrown in front and on the sides of the powder-chamber until the balks are in position, and then thrown back upon them, levelled and rammed.

65. Mined Magazine.—When the soil, by absence of rock and water, admits of mining, greater cover against vertical fire can be obtained with less work by mining out the powder-chamber and passages (Pl. VIII, Figs. 78, 79). The figures illustrate one of minimum dimensions, which is constructed as follows: The entrance 10′ × 5′ by 5′ 6″ deep is first excavated, revetted with frames and sheeting and covered with balks and earth as indicated. At 1 foot from the end a shaft 2′ × 5′ is sunk to a depth of 12′. From the front of this a gallery 2′ × 5′ 6″ is driven for about 6′; at the end of this galleries 5′ 6″ × 2′ are broken out on each side and driven so far as may be necessary to store the requisite number of ammunition-boxes. (For method of sinking shafts, driving galleries, etc., see Military Mining, Arts. 25, 33, and 44–48.) The excavated earth is spread on top of the magazine to increase the thickness of the cover already given by that excavated from the passages. A ring-bolt is placed in the balk directly over the shaft, for attaching a hoisting tackle for removing the earth during construction and for hoisting and lowering ammunition-boxes afterward.

A door opening outward may be hung at the entrance, and the passage may be blinded as previously described, if it is thought necessary. The communications are arranged in essentially the same way as for the magazine previously described.

The dimensions given are the least which will allow moderately free access and good cover. The magazine should be constructed, by good miners, in two nights and the intervening day, and will store about 4000 pounds of cartridges in boxes. When time and the character of the ground admit, and larger capacity is desired, the shaft may be made wider and deeper, the gallery wider and longer, and the powder-chamber deeper, longer, and wider, if desired.

The excavation for the entrance and approaches, the placing of balks, and the levelling and ramming of the earth-cover, should be done by night; the mining work can be carried on both night and day.

66. Elevated Magazines.—When the presence of rock or water in the soil prevents sinking the magazines to the full depth above given, they must be sunk so far as practicable and given the least possible clear height of powder chamber, with the best attainable overhead cover. This should be strengthened by the use of railroad iron or rolled iron beams, when available. The cover against direct fire should be increased up to 30 feet, and the front slope be made gentle, like a glacis. A screen made of an earthen bank with a glacis slope should also be used if possible. These precautions having been taken, the depth of the powder-chamber in the direction of the hostile fire should be reduced to a minimum, and the storage of large quantities of powder be avoided, so far as possible, by constructing a number of small magazines at the most convenient places in the vicinity of the battery.

67. **Precautions against Dampness in Magazines for Siege Batteries.**—Underground magazines of the character above described are, of necessity, sometimes damp. The only ventilation usually possible is obtained by leaving the door open, the air being changed more or less by the men going in and out.

The passage leading to the powder-chamber should enter it at the middle, and in the service of the guns one half of the chamber should be emptied on one day and the other half on the next. This will usually limit the time which a cartridge is exposed to the dampness of the magazine to a maximum of one or two days.

CHAPTER V.

SIEGE OPERATIONS.

THE ATTACK.

68. Siege operations include all the steps taken from the first approach to the work up to its final capture. These taken in regular order are as stated in Chapter II: the *investment*, the *distant artillery attack*, the *construction of approaches* and *parallels, breaching by artillery or mines*, and the *final assault*.

For convenience in description the siege has been divided into three periods. The *first period* includes the preliminary operations up to the completion of the investment.

The *second period* includes all the operations between breaking ground for the batteries of the first artillery position and the first parallel, up to the completion of the most advanced parallel and the occupation of a position near the foot of the glacis from which the attack is to be made upon the breach, either by assault or sap.

The *third period* comprises the advance from the last parallel, and all subsequent operations up to the capture of the last entrenchment and the surrender of the garrison.

The first and second periods are sometimes known as the "*distant*" and the third period as the "*close attack*."

FIRST PERIOD.

69. As a preliminary to the siege of any fortified place, all possible information is obtained as to the strength and character of its fortifications, the garrison, armament, stores of provisions and ammunitions, water supply, water routes, telegraph and railroad lines, manufactures, especially those which may be converted into factories of arms and munitions, the character of the population of the place, their probable food supply and their loyalty to their state; also the topographical features and nature of the ground in the vicinity of the work, the sites of camps and parks, the prevalent diseases of the locality and the best means of preventing their attacks, etc., etc. (see Bureau of Intelligence, Art of War, par. 128).

From these data the necessary materials and supplies are collected at convenient points, the railroad or water routes selected, and the cars, boats, wagons, etc., for their transportation provided; so that they may arrive promptly and in the proper order when needed.

70. The Investment.—The investing force is brought together, organized, and moved rapidly upon the place. When it is available a large force of mounted troops may be used advantageously in the investment, and be subsequently relieved by infantry and artillery.

When the investment is made, it adds greatly to the advantage of the attack to completely surround and isolate the work, and to push the investing line as near it as possible. When the investing force is more or less dispersed, and is to be concentrated for the siege, the temptation frequently exists to march them by converging lines upon the place as a point of concentration.

While this may be advisable in some cases (as where the garrison is very weak or under an inefficient commander), it will usually expose the subdivisions of the investing force to be beaten in detail (Art of War, par. 392). So also in surrounding the place; a premature subdivision of the force into small fractions not protected by field-works, or not within supporting distance each other, will afford to an active defence an opportunity, by well-conducted sorties, to inflict most severe losses upon the attack and very greatly delay the investment. Keeping these dangers in view, the investing force will move rapidly upon the work, seize, strengthen, and occupy strong points as near the work as possible, and extend the lines to right and left as rapidly as good judgment allows, until the place is surrounded. Meanwhile detachments of greater or less size will scour the ground around the place, seizing and carrying off or destroying, so far as possible, all cattle, grain, lumber, etc., and everything else which would be of use to the attack or defence. Under cover of these detachments and escorts specially detailed for the purpose, reconnoissances will be made to cover so much of the ground as can be reached, especial efforts being made to examine the ground near the works. These reconnoissances will necessarily be hurried and incomplete but, must be as accurate as they can be made under the circumstances. They should be directed principally to determining the heights and directions of the principal points of the works, and their positions with reference to prominent points that may be used as landmarks, in verifying and correcting maps and information previously obtained, to discovering the existing armament of the place and the steps already taken for its defence, and to collecting all possible information bearing upon the selection of the front of attack.

Systematic reconnoissances and surveys carried on throughout the siege must be relied upon for checking and completing the work thus begun.

So soon as the supporting points for the investing force are secured, a line of outposts is pushed forward towards the work and sentinels, pickets, etc., are established (Art of War, pars. 167–194). The lines of sentinels, pickets, and supports are placed as near the work as practicable, and the line of resistance is advanced at every favorable opportunity.

The usual rules for posting and relieving the outposts, establishing day and night cordons, the use of patrols, etc., are applied, with such modifications as circumstances render advantageous.

Any advanced points affording marked advantage to the attack which have been seized are strengthened and held when possible, even at considerable cost in men or with some delay in completing the investment.

71. Bringing up and Posting the Besieging Force.—The main besieging force, consisting principally of infantry, artillery, and engineers, with the siege train, follows closely after the investing force, and, upon arrival is encamped upon sites previously selected, sending out at once, however, such reinforcements and supports as are needed by the line of investment. Engineer and artillery parks are established outside the zone of fire of the works and in proximity to the main routes of communication. Branch railways and tram-roads running through the parks, storehouses, repair shops, etc., etc., are located and constructed. Sites for storage magazines for ammunition are carefully selected at the most secure places, and isolated when possible from the camps and parks by intervening elevations of ground. The cover of these magazines, so far as possible, is made up of wood and sand or earth free from stones large enough to be dangerous projectiles in case of explosion. Rooms for loaded shells and cartridges, and laboratories for making up ammunition are constructed upon similar principles. Carefully studied arrangements for the health and comfort of the men are made. Some of these are outlined in Chapter VII.

72. **Fortifying the Camps, Parks, etc., etc.**—In former sieges it was customary to completely surround the ground occupied by the besieger with a continuous line of works of simple trace and light profile called the "*line of circumvallation;*" and to construct between the camps and the work another line, either continuous or with intervals, called the "*line of countervallation.*" These lines were placed respectively at about 200 yards in rear and in front of the camps.

The principal object of the first was to prevent by a small force the entry of small reinforcing detachments and supplies; that of the second was to resist vigorous sorties by the defence, or sudden attacks from the outside by strong reinforcing parties. For this purpose the detached works of the line of countervallation were so disposed as to cover the main depots, parks, roads, etc., and to be in defensive relations with each other.

The great development of the line which must be occupied by the besieger, owing to modern methods of fortification and the range of rifled cannon, prohibits the construction of complete lines of circum-and countervallation. The besieger constructs in their stead one or more lines of detached works upon advantageous points, and covers the intervening ground more or less thoroughly by patrols, outposts, etc. He then so disposes his main force as to be able to concentrate enough to meet any sorties of the defence; and, if necessary, detaches a force, called an "*army of observation*," sufficiently large to meet any relieving army and defeat it; or hold it in check until he can concentrate the besieging force with the army of observation, and meet the relieving army in a favorable position. As a rule, this position will be one well outside the besieger's cordon of works; since the latter by its extent will necessarily be weak to resist a determined attack (Art of War, par. 258), and by its proximity to the work will render possible the co-operation of the garrison and the relieving army. This, under the circumstances assumed, would seriously endanger the besieging army.

In opposing sorties from the work, however, the conditions which fix the point of conflict are reversed, and place it as near the work as practicable. The shortening and strengthening of the line of investment by closing it in upon the work make it imperative to hold all ground gained; and this is generally best accomplished by intrenching the line of outposts with continuous shelter trenches, strengthened at intervals by batteries of field guns, and supported by field works of considerable strength, placed within accurate cannon range of each other, but not exposed to the direct fire of the guns of the place. Behind the shelter trenches the outposts, supports, and reserves, strengthened when necessary by troops from other points of the line, should be able to hold their own against all ordinary sorties.

The main line of field works serves to resist a general attack made by the mass of the garrison.

Placing the first intrenchments further back exposes the outposts to the confusion resulting from falling back, frequently at night or in a fog, and also enables the besieged to seize upon ground from which it may be very difficult to dislodge them.

To allow the different parts of the line to be rapidly reinforced, good roads protected from the fire of the work, and well marked with sign-posts, etc., must be opened between the adjacent divisons of the besieging force, and all streams must be provided with bridges secure against floods, ice, etc.

73. **Distance of the Line of Investment from the Work.**—This will result from conflicting conditions. Reasons already given, which need not be repeated, lead to establishing it as near as practicable. On the other hand, the accurate fire of the heavy guns of the place, and vigorous sorties by the defence, cause much annoyance and great loss to a line drawn too near the work. The more recent sieges indicate about 3000 yards from the most advanced works, as the least distance for the line of investment in open country and with an active defence. It may be necessary in some cases to increase this to 4500 or 5000 yards; but with ground favorable to the attack, and a weak and demoralized defence, it may frequently be drawn nearer.

74. **Strength and Composition of the Besieging Force.**—In former sieges when the place held out until the inner keep was breached and carried by the regular progress of the siege, the ratio of the necessary strength of the attack to the defence was estimated at 7 or 8 to 1, this large ratio resulting from the excessive labor in

the trenches and the losses incurred on the close attack. Modern writers (arguing largely upon theoretical considerations) have reduced this estimate to 4 or 5 to 1. No attack on a thoroughly-equipped and well-defended strong place having been carried through all the steps of a regular siege since the introduction of modern arms, absolute data upon this subject are lacking.

The besieging force at Strasburg was about 60,000, garrison about 20,000, total length of siege 49 days. The defence was very weak. Belfort, besieging force about 32,000, garrison about 16,000. After a siege of 100 days the approaches were at about 1200 yards from the works, which capitulated by reason of the general surrender of the French. At Metz the besieging force was 150,000 men; the garrison, demoralized by the previous defeat at Gravelotte, surrendered 173,000 men. At Paris the investing force was about 180,000, and the garrison nominally between 300,000 and 400,000, of which perhaps 30,000 were disciplined and effective soldiers; the remainder being made up of remnants of defeated regiments and bodies of the Garde Mobile and Garde Nationale. The investment of Paris was complete on September 19, 1870; its surrender from exhaustion of provisions took place January 29, 1871. Several sorties were made, but the general defence was paralyzed by the character of the troops and inhabitants. At Plevna the Turks had at the outset about 56,000 men, at the surrender 40,000. The Russian force suffered great losses in its assaults, but by continual reinforcement had at the end of the siege about 120,000 men. The defence by the Turks was desperate, but generally passive. One determined sortie was made immediately before the surrender. The surrender resulted from exhaustion of ammunition and provisions. The works were field works only.

At Belfort the investing force was at first but 10,000 and the line of investment 25 miles long, giving but 400 men to the mile. This force was subsequently increased to 20,000 men, and when the besieging army had all arrived, to 32,000 men.

At Paris (1870) the line of investment was about 3 miles from the line of the forts, and about 53 miles in length, the investing force 180,000, giving a mean of about 2 men to the yard. The distribution was, however, about 4 to the yard on the left bank and $1\frac{1}{3}$ on the right bank of the Seine.

At Plevna the line of investment was $2\frac{3}{4}$ miles from the forts, its length $43\frac{1}{2}$ miles, the investing force 100,000 men, about $1\frac{1}{4}$ men to the yard.

In each of these sieges the place finally fell under the attack of a force, in no case equal to $2\frac{1}{2}$ times the garrison; but inferences drawn from this fact are apt to be erroneous, since none of these places was well fortified according to modern methods, well garrisoned, well supplied, and defended to extremity.

The results show, however, that under similar circumstances, which are apt to arise in any modern war, the attack of a strong place which can be completely invested by a force of two or three times the strength of the garrison, may promise success; which seems to be assured if the defence allows the besieging force to complete the investment and thoroughly intrench itself.

On the other hand, tactical considerations would indicate that a well-equipped army, of good morale, under an active and aggressive commander, covered by a modern intrenched camp, should be able to prevent the investment; and by taking advantage of its interior lines, its heavy guns and its strong *points d'appui*, should be able to beat in detail a force very much greater than itself whose fractions, by reason of the extent of the line of investment, are necessarily not within supporting distance of each other.

These advantages of the defence evidently disappear, as above indicated, when the attack is allowed to complete its fortifications, since under their cover a small force can check even a determined sortie until a sufficient force to beat it can be concentrated.

From these considerations it is evident that an investment, once completed, may be maintained by a force less than that necessary to establish it in the first place (see Investment of Plevna, Pierron, Méthodes de Guerre Vol. III, pp. 647 *et seq.*).

75. **The Point of Attack.**—From the information originally in possession of the besieger, supplemented by that obtained by reconnoissance, a decision is made as to the fronts of the work or the particular detached works of the intrenched camp upon which the approaches are to be made. The portion selected in either case is called the "*point of attack.*" To reduce an intrenched camp, it will in general be necessary to capture at least two of the detached works and to silence the artillery fire of one or more on each side of those taken. In an attack upon a strongly-fortified enceinte, the least that is usually undertaken is to breach and capture one front with its adjacent outworks, and to silence the fire of those which enfilade the approaches and parallels or take them in reverse.

In selecting the point of attack the first consideration is, that when taken, it shall afford material advantage to the besieger and give him a foothold from which further approaches may be driven, if necessary. This condition being fulfilled, the choice will result from a careful study of the nature of the works and site. Those forts or fronts resting upon precipices, bordering deep marshes or deep and rapid streams, or which are so placed that approaches upon them will be swept in flank and rear by the fire of the works, which cannot be silenced, are considered impregnable by the ordinary operations of the siege. Most serious difficulties are presented by those in which the adjacent works are so disposed and of such strength that they can be carried only in succession and by regular approaches; those provided with wet ditches in which strong currents can be produced, those with dry deep ditches, those which are mined, and those which present long lines nearly straight, or even concave to the attack, and covering a front nearly equal or even greater than can be occupied by the trenches of the besiegers.

When the parallels and approaches have to be constructed upon ground sloping downward towards the work, in soil containing large stones, or in which the rock is close to the surface, in marshy ground or that containing much water or liable to be flooded, the difficulty of their construction and defilade are evident. The point of attack considered most favorable to the besieger is one which, fulfilling the first essential condition, is more or less salient, so that it can be partially surrounded, and which admits of the approaches being driven toward it in favorable soil, over ground sloping gently from the work, or gently rolling with the crests and valleys of sufficient difference of level to afford cover, and running generally in the direction of the parallels.

A favorable location for parks, etc., with free, safe, and short communications between them, also has great weight in selecting the point of attack.

SECOND PERIOD.

76. **First Artillery Position.**—Every siege begins with a bombardment, which is designed, as previously stated, to drive in the outlying posts of the defence, to silence, so far as possible, the artillery annoy and wear out the garrisons of the works to be attacked, to interrupt the communications between them, break up bomb and splinter proofs, destroy magazines and depots, and, if the enceinte can be reached by the artillery, to bring a fire upon the population which will lead to or hasten the surrender of the place.

The considerations which determine the location of the batteries for the general bombardment have already been given (par. 7), as well as the construction of the batteries and screens used (Chap. IV.). For the systematic attack, however, the necessity of dismounting or silencing the guns bearing upon the proposed approaches introduces the additional condition that the batteries should be so located that besides their general effect each shall fulfil, so far as practicable, its special design by bringing an enfilading or reverse fire upon certain fronts; or, in connection with other batteries, shall keep down the fire of certain fronts by a preponderance of direct fire. Many batteries which fulfil these last conditions occupy their original positions during the entire siege. The requisite concentration of fire upon the point of attack and its careful regulation for the special object in view will frequently restrict the arc occupied by the batteries below that desirable for a general bombardment only; and will necessitate a closer grouping of the batteries for their easier control by the artillery commanders. This line of batteries first established is known as the "*first artillery position*" (Pl. VIII., Figs. 80, 81). As the batteries must be secure against the attacks of the defence, they must of necessity be outside the besiegers defensive line. Their distance in yards will result from the character of the defence and may vary from 2000 or 2500 yards for a weak defence, to 3500 or 4500 yards for an active one. On account of their long range and the object to be obtained by their fire, they are armed with the heaviest rifles and howitzers available, supplemented with rifled mortars of as large calibre as can be obtained, firing, if practicable, torpedo shells charged with high explosives.

Batteries of field guns which have already been favorably located for the defence of the heavier batteries against attack, or for firing upon the more advanced works, may, by modification of their gun pits into finished batteries (par. 44), be used in conjunction with the heavy batteries of the first artillery position.

The total number of guns employed should be such as to give to the attack a marked superiority over the defence at the opening of the bombardment.

77. **Opening Fire.**—The batteries having been completed and armed, the magazines finished and supplied, and the parks, depots and communications put in such order that the batteries can be kept fully supplied with ammunition; the fire of the batteries is commenced simultaneously, the signal being given by a gun from

some selected battery. The fire once opened is continued day and night during the siege, unless stopped by the commanding officer or from inability to keep it up. It usually begins at daylight, in order to enable the ranges to be corrected by the first shots, before the defence has accurately located the batteries unmasked during the preceding night. To open fire from a few batteries before the others are ready is inexcusable, as it enables the defence to concentrate its fire upon them and destroy them in succession. The targets of each battery and gun and the rate of fire are prescribed before the fire is opened, and these are changed only by subsequent orders or from sudden emergencies. The fire is as a rule deliberate, seldom exceeding an average of 4 shots per hour for each gun by day, and 2 per hour at night. This rate may be increased or diminished by the commanding officer for special reasons and for a limited time.

The fire of the batteries is directed upon all the works of the place within range, but with greater vigor upon the more important, and especially upon those near the point of attack. The fire against powder-magazines and storehouses should be uninterrupted, to prevent the removal of powder and munitions. If the artillery of a part of the work is silenced, the fire upon it may be slackened, but some fire, especially vertical, should be kept up.

At night the fire is directed against the larger targets, such as communications and covers, rather than upon the guns; but the fire against the interior of the place (especially a city) is kept at about the same rate day and night.

If preparations for a sortie are detected, the fire of the large pieces is directed at the points of assembly, when known, and at the openings through which the sortie is to be made. The field guns direct their fire upon the troops in accordance with the tactical use of this arm.

If the batteries of the first artillery position have the proper preponderance over those of the place, they should soon clear away the advanced posts, and keep down the fire of the works so that the besieger may advance his outposts, control the exterior ground and prepare to open the first parallel and establish the second artillery position.

78. Plan of Attack.—By this time the reconnoissances and surveys should be so far advanced and so thoroughly checked up that the chief engineer will have been able to make, upon a large scale, a map of the place and its surroundings with considerable accuracy, and to locate upon it the proposed position of the first and second parallels, the approaches, and the batteries of the second artillery position. This map, with the accompanying memoirs, makes up the "*plan of attack*," which, when approved by the commanding general, serves as a working plan for the prosecution of the siege, and is continually corrected and added to as the siege progresses.

This map should be made in duplicate at least, and for accuracy in the history of the siege should be corrected so far as possible by redrawing or tracing, instead of by erasures.

79. The First Parallel.—The first parallel (Pl. VIII, Figs. 80 and 81) serves as an intrenchment for the troops who protect the second artillery position and who cover the workmen driving the approaches.

It also affords a covered communication between the different lines of approaches.

Its length must be sufficient to cover all the batteries of the second artillery position and protect their flanks; it must therefore extend beyond the batteries which enfilade those faces of the fronts attacked whose prolongations fall furthest out. Its flanks are usually more or less refused, and terminated by strong earthworks. Emplacements for batteries of field guns are provided at intervals to assist the infantry in repelling sorties. When the length of the parallel is very great, it is sometimes not continuous when first opened, but the portions covering the groups of batteries are first made and are subsequently connected. The ground between them is protected, meanwhile, by a strong fire of small arms, field and other guns. When communications covered by natural screens do not exist between the first parallel, the batteries of the first artillery position, and the parks, approaches are constructed at the same time as the parallel, in sufficient number to give free passage to the troops, guns, and materials.

These approaches (Pl. VIII, Figs. 80 and 81), as all others (par. 13), are so directed as not to be enfiladed by the fire of the work, and should be provided with portable or other tramways and cars, passing switches being placed in the returns where needed.

Its Distance from the Work.—As a rule, it may be stated that the first parallel is placed as near the work as possible. Most of the batteries of the second artillery position are from 100 to 300 yards in its rear, and the shorter their range the more effective is their fire. The small-arm fire from the first parallel may also be an important feature in modern sieges; to make it so requires the parallel to be located within 1500 yards of the work, if possible. By placing the parallel as near the work as possible, its length and that of the saps are correspondingly reduced, the amount of work lessened, and generally the fall of the place hastened. If an attempt be made to place it too close to the work, however, the working parties will be discovered; they will be within reach of strong sorties, and of the deadly fire of small arms and machine guns; in consequence of which they may suffer very great losses, be driven off, and the construction of the parallel prevented. The minimum distance under the most favorable circumstances is then about 600 to 700 yards. (This was the distance prescribed in the day of smooth-bore guns, and was adopted as recently as 1870 at the siege of Strasburg.) In an open, level country it may not be possible to place the first parallel at a distance from the most advanced work of less than 1800 to 2000 yards. When, however, it is necessary to establish the first parallel at a very great distance, it will not, as a rule, be made continuous, but in fractions covering approaches which are driven forward. The first continuous parallel is then built at from 1000 to 1200 yards from the works, and behind this the second artillery position is established.

80. Opening the Parallel.—The profile of the parallel is one of those already given (Pl. I, Figs. 7–13), and it is traced and constructed as described (pars. 14, 18, and 19), by simple trench, flying sap, or full sap, as may be most advantageous. In some cases, however, it is constructed by enlarging the line of shelter trenches already made by the outposts. To cover the working parties while excavating the trench, when the parallel is near enough the work to be endangered by a sortie, the outposts are advanced to about 300 yards in front of the line, the pickets and supports are posted respectively at about 100 and 200 yards in their rear, and are covered by rifle pits and trenches made for this purpose during the preceding nights. To conceal from the defence, if possible, the proposed location of the parallel, these trenches and pits are constructed by all the outposts in front of their positions. The reserves are held 800 to 1000 yards in rear of the flanks, and the whole covering force should be equal to $\frac{1}{2}$ or $\frac{2}{3}$ the garrison of the place if an active defence is looked for.

At daylight the trenches will be far enough advanced to protect the covering force which will occupy them. This force is from this time known as the "*guard of the trenches*," and is relieved usually every 24 hours, the time of relief being so chosen as not to interfere with the working parties.

The working parties are, as previously indicated, divided into reliefs of 4 or 8 hours.

For continuous work the besieging force should be large enough to allow each man, after being one day in the guard of the trenches and one day in the working party, to have one day in camp.

81. The Second Artillery Position.—By the second artillery position previously referred to is meant the position occupied by the guns of the attack, placed in batteries, accurately located for breaching, enfilading, counter-battering or other specific duty. These batteries are usually of the class described under the head of "exposed sunken batteries" (Plates V, VI, VII), and are constructed behind or in the parallels, as explained in pars. 48 to 55. When behind a parallel they should be, if possible, at least 150 yards from it in order that the blast of the guns shall not interfere too much with the occupants of the parallel.

82. **Counter-batteries,** designed to dismount guns or destroy embrasures of earth or masonry at ranges from 700 to 1000 yards by direct fire may well be armed with $4\frac{1}{2}$ or 5 inch rifles, since their projectiles have sufficient energy for the desired result, and the guns admit of a more rapid and long-continued fire than do those of greater calibre. The batteries must be so placed as to look through the embrasure attacked, and the number of guns pitted against any battery must considerably exceed that in the battery.

Counter-batteries designed to silence by direct fire guns in turrets or behind shields must be armed with guns of large calibre, mounted with the best available cover, and must be aided by rapid fire guns of moderate calibre, designed to disable the turret guns either by embrasure shots or by oblique shots penetrating the parts which project from the turret.

83. **Enfilading batteries** act in conjunction with counter-batteries or independently; they are designed to take the faces in flank or slightly in reverse, but are of necessity at times limited to a slant fire. They are located as nearly as possible in the prolongation of the terre-pleins. When the salients are obtuse these prolongations lie near the adjacent faces for some distance, and consequently the only possible emplacements of enfilading batteries will give ranges which may vary from 1000 to 4000 yards. They are armed with cannon of sufficiently large calibre to make their projectiles efficient even at moderate velocities, and, when the faces enfiladed are well provided with traverses, the

charges are reduced so as to give to the projectiles a large angle of fall. When the batteries are on commanding heights higher velocities may be used.

84. **Breaching batteries,** except those established on the crest of the counterscarp, can only breach the walls of modern forts by "curved" or "indirect" fire. To obtain the necessary angle of fall with the requisite accuracy and energy of blow, the guns must be of considerable size and placed at comparatively long range; the projectile must graze the crest of the glacis and strike the scarp wall at an angle not too oblique. Experience seems to indicate that the best effects are obtained, all things considered, when the vertical plane of fire makes an angle of from 55° to 60° with the face of the scarp wall. The distance of the battery from the wall to be breached is usually from 1000 to 1500 yards.

The same considerations govern the construction and armament of batteries designed to destroy réduits, barracks, gorge walls, city gates, magazines, depots, bridges, locks, etc., etc.

85. **Batteries of rifled mortars or of howitzers for vertical fire** should be so located, when possible, that the longest dimension of the target will be in the direction of their fire. The effect of their projectiles is greatest when they can be fired at elevations, of 60° to 70° and with large charges. These considerations, combined with those of good cover and easy supply, will govern their location.

86. **Opening and conduct of fire from Second Artillery position.**—The batteries which are ready on the morning of the completion of the parallel open fire simultaneously upon the work, and are supported by those of the first artillery position still armed. The

same rules govern the fire of the first and of the second artillery position.

When the defence combines a number of batteries to silence one of the attack a heavy fire is concentrated upon these batteries by those from which the fire has been diverted. New batteries unmasked by the defence, or established in intermediate or other works, should receive prompt attention from the attack, with a view to silencing them if possible before they correct their ranges. It is of the first importance that the superiority of the artillery fire of the attack shall be established at the opening of fire from the first artillery position and be maintained throughout, and that the defence shall be prevented from repairing any batteries which have been silenced. To this end a few guns will keep up a slow fire upon these batteries so long as it may be necessary.

Every gun of the defence must, if possible, be kept under a heavy fire, and the fire upon the enceinte must be opened at the earliest possible date and continued day and night, as previously described.

87. **Musketry fire** will be opened as soon as a parallel is established at such distance as to make it effective; and this may be, for a well-regulated fire of sharpshooters, at ranges of 1200 to 1500 yards, or in some cases even greater.

88. **The Advance from the First Parallel.**—It is assumed that the fire from the first and second artillery positions will silence almost completely the artillery fire of the work upon the fronts attacked; but the defence will still be able to develop when necessary a strong musketry fire, aided at times by machine and rapid-fire or even some field guns. Consequently, the advance from the parallel must be under cover.

Approaches are, therefore, broken out from the parallel and pushed forward towards the work, the workmen being protected by the fire of the guards of the trenches. Usually at least three lines of approaches are constructed, concentrating upon the point of attack and following generally the lines of the capitals of the adjacent salients.

When attacking a line of detached works two or more lines of approaches may be constructed towards each work attacked. The approaches are run in zigzags, each branch so directed as to pass a short distance (30 or 40 yards) outside the most advanced work of the defence from which it could be enfiladed; at each change of direction of the zigzags a return of 10 or 20 yards is made to cover the approach in rear (Pl. VIII, Figs. 80 and 81). The length of the branches is so regulated as not to mask too much of the front of the parallel; they consequently grow shorter as they approach the work and vary ordinarily between 200 and 50 yards, seldom exceeding 100 yards when near the work. The heads of the different approaches are advanced at about equal speed so as to afford mutual support.

89. **The Second Parallel.**—The second parallel is located nearer to the first parallel than to the covered way, sometimes very much nearer. It is constructed and occupied by the guard of the trenches. The principle followed is that the guards of the trenches shall always be nearer to the head of the sap than is the enemy in his most advanced place of arms; so that, in case of a sortie, the advantage will lie with the besieger. The flanks of the second parallel are refused and strengthened like those of the first, or are even carried back to the first parallel, to guard them against flank attacks.

The second parallel having been completed and occupied, serves as a base for further advance, which is conducted according to the same methods, "*demi-parallels*" (Pl. VIII, Fig. 81) being run out to the right and left of the approaches when they are well advanced beyond the second parallel. These demi-parallels are sometimes joined, forming a third parallel, from which the approaches are advanced as before, with additional parallels when needed, until the foot of the glacis or exterior of the counter-mines is reached. The number of parallels is determined by the distance at which the first is established and the vigor of the defence; formerly three were considered all that were needed, and this number was used at Strasburg, 1870. At other modern sieges a larger number has frequently been required. At Belfort (1870–71) the third parallel was established at 1200 yards from the place. Five parallels were used at the siege of Fort Wagner (July–September, 1863).

The approaches are driven in zigzags by simple trench, flying or full sap, until the direct advance becomes equal to about one third of the length of trench; and from this point they are driven directly upon the work by double-traversed sap (Pl. III, Figs. 28–35), the latter being, as a rule, used only in advancing from the foot of the glacis, or during the third period of the siege.

THIRD PERIOD.

90. **The Third Period of the Siege** frequently called the "*close attack*," includes all the steps between establishing the last parallel and the surrender of the place. These are the capture and crowning of the covered way, breaching the scarps and

counter-scarps, passing the ditch, capturing and crowning the breaches of the outworks and main works in succession, and the final reduction of the interior retrenchments, or keep.

All these operations are carried on within close and deadly range of small arms and shells of Coehorn mortars, and many of them within range of hand grenades and upon ground honeycombed with mines and countermines, or liable to be flooded or inundated. They are slow in progress, uncertain in results, and require an extravagant expenditure of men and material. They can be pushed to a successful issue only when the artillery fire of the place is silenced and its small-arm fire is almost completely kept down by the fire of the attack.

The conditions of modern warfare are such, however, that by the time the attack has reached the foot of the glacis the losses and exhaustion of the garrison are frequently so great as to preclude an obstinate, close defence; and, in the majority of cases, the place is compelled to surrender before the close attack is commenced.

91. **The capture and crowning of the covered way** is accomplished by *assault* or by *sap*. The former is an extremely hazardous and bloody operation, which all authorities unite in condemning, and which should be undertaken only in extreme cases. It is carried out usually at night, by forming an assaulting party in the parallel, who rush forward to the crest of the covered way; capture, if possible, its guards, and under any attainable cover open a fire upon the crest of the work. All available small-arm and machine-gun fire combines with this to keep down the fire of the

defence; and under cover of this fire the working parties construct, by flying sap, a trench crowning the covered way, and the communications between it and the parallel.

The trench is occupied as soon as it affords cover, and is subsequently completed and prepared for the reception of its guns and infantry guard.

In crowning the covered way by sap (Pl. IV, Fig. 36), the saps are broken out from the parallel, a circular place of arms is constructed, which gives additional communication and serves as a depot for trench materials, the traversed sap is pushed forward, and the covered way crowned as previously described (par. 36). It will frequently be necessary to run out at right angles to this sap short branches of parallels (Pl. IX, Fig. 83), to serve as places of arms, or as trenches of departure for mines or galleries, for underground warfare or for breaching walls.

92. Breaching the Scarps and Counter-scarps.—The counter-scarp, as a rule, and the scarp at times is breached by mining. (See Military Mining, pars. 91–93). When practicable, however, the scarp is breached with artillery and preferably by guns of the second artillery position; since a breaching battery on the crowning of the covered way, which must be provided with most ample splinter-proofs to protect the gunners from flying splinters of masonry and shot, is in general constructed only with great losses and delays; and the guns in this position must be fired under great angles of depression, requiring very deep embrasures to avoid exposing the cannoneers. When the ditch is deep and narrow it may be necessary to blow down the counter scarp and part of the glacis, in order to expose the scarp-wall to the fire of the breaching battery, whether on the glacis or at a distance. This necessity should be foreseen and provided for in locating the batteries.

A full or semi-detached scarp-wall will be breached when the battery is on the glacis by making vertical cuts at the ends, and a horizontal cut at about one third or one fourth its height from the bottom, and then firing shells into the part to be brought down, continuing the fire until the large masses of masonry are broken up, and the slope is made gentle and smooth enough to admit of easy ascent. A detached scarp-wall will be breached by a glacis battery, or any scarp-wall by a distant battery, by continued battering, which will not only knock down the wall, but also break up the fragments and make a practicable ramp.

93. **The Capture and Crowning of the Breach.**—The decision as to whether the breach shall be captured and crowned by *assault* or by *sap* will be governed by considerations similar to those which determined the character of the attack upon the covered way. The difficulties and dangers of the assault are perhaps greater than in that case. The **assault,** if undertaken, will be carried out in a similar manner, previous preparations having been made by making a practicable breach at least 25 to 30 yards wide, a practicable descent into the ditch of equal width, and a covered place of assembly for the working party and a depot of trench materials in immediate proximity to the breach.

The artillery defence of the ditch, whether from caponières, flank embrasures or casemates, or from adjacent works, must of course be silenced before crossing the ditch either by assault or by regular approach.

This is accomplished by counter-batteries on the glacis, by heavy field guns located in temporary batteries in the trenches, by mines, or by overhead or indirect fire from the distant batteries, or from light mortars in the advanced trenches, as may be necessary.

If the interior arrangement of the work is known by the besieger the assault may be made by night; but if it is unknown, the confusion resulting from a night attack will be so great as to render its success almost hopeless, and the assault will have to be delivered by day.

The assaulting columns will be made up of an advanced line of skirmishers (selected men, good shots, and generally volunteers), followed by a working party of sappers to clear away obstacles, these closely followed by the columns of assault; while the supports and reserves move forward in the trenches to join in the assault as circumstances require. The troops who first gain the crest establish themselves there and hold the breach until those coming after them pass and engage the garrison, while some detachments strive to capture and open one gate or more to admit the reserves. The assaulting force should be equal at least to once and a half or twice the garrison, and simultaneous attacks should be made upon other breaches or accessible parts of the work to divide the attention of the defence.

These false attacks are sometimes successful, and preparations for taking advantage of this contingency should not be omitted. The subdivisions of the assaulting force should each receive explicit instructions as to its special object, and under no circumstances should their lines of march intersect. Unmistakable signals of recognition should be prescribed to prevent conflicts arising between the different parties meeting within the work. The bombardment preceding the attack should not cease, and thus notify the defence when the assault is to be made; but the guns should be directed upon adjacent parts of the work until the assault penetrates the work or is repulsed.

94. In the **attack by the sap** the method of crossing the ditch adapted to the circumstances is used (pars. 39–41, Pl. IV, Figs. 37–41) and the sap is started at the foot of the breach, driven up it, and the breach is crowned according to the methods previously described (par. 36).

The sappers are protected from small sorties by the fire from the crowning of the covered way and any other points bearing on the head of the sap. Fire-balls, electric lights and other means will be used during the night to light up the parapets of the work and expose the defenders, in this as in the previous operations of the siege. The crowning of the breach will be extended and converted into a place of arms, from which further sapping can be carried on in a similar manner, until the breach in the last retrenchment is crowned and the preparations for the final attack upon the garrison are made, or the place surrenders. If the garrison takes refuge in an interior keep and continues the defence the keep must be reduced by similar methods.

95. **Additional Operations in the Attack of an Intrenched Camp.**—The operations above described are those necessary to reduce a fortified place of the older type, or a detached work of an intrenched camp. The latter, though of less extent and with a smaller garrison, offers as a rule greater resisting power, since it is usually subject to front fire only, has more com-

plete bomb-proof cover, and is free from the presence of non-combatants.

While a great advantage is gained by the capture of two or more of the advanced forts, the resisting power of the intrenched camp is by no means destroyed. These forts are subject to the fire of the collateral works, of which frequently two or more must be silenced before a further advance can be made. The beleaguered army may still be in condition to recapture the forts by vigorous assaults; and in almost every case, before the fall of the works of the outer line, a line of provisional fortifications of high resisting power, connected by trenches, will have been constructed by the defence in rear of the captured works, with its flanks secured by the collateral works of the outer line. An assault against works of this class offers no prospect of success. The besieger is therefore obliged, as soon as he captures a detached fort, to put it in condition to withstand the assaults of the besieged army and to afford protection from the artillery fire of the collateral works, and then to push forward his approaches against the successive positions prepared by the defence, which will as a rule present a front equal to or greater than that which can be occupied by the attack. The gorges of the captured works are repaired and strengthened, covered communications are made through the faces, either through the breaches or in more convenient points, traverses are repaired or built to protect against the fire of the collateral works, and the captured works are connected by trenches which afford emplacements for batteries and form a new parallel from which the saps can be driven in attacking the intermediate works. Simultaneously with this attack, it is usually advisable to advance from the flanks of the first or second parallel upon the forts of the outer line which form the flanks of the intermediate line. The approaches can generally be driven with comparative ease owing to these works having already been partly disabled and now being subject to a flank and reverse fire from the newly-established batteries.

The flanks of the intermediate line being turned by the capture of these works, a portion or the whole of it will of necessity be abandoned. The subsequent operations up to the capture of the enceinte will be of the same nature as those already described.

96. Occupation of a Conquered Place.—Immediately upon the fall of the place it must be occupied by a force (chosen when possible from the reserve which has not participated in the final assault) sufficient to control not only the inhabitants, but also the disorderly soldiers of the attacking force. All pillaging, wanton destruction, and abuse of the conquered must be restrained with a strong hand, immediate and exemplary punishment being inflicted upon offenders. The orderly portion of the defenders must be protected, and such steps taken for supplying their needs as humanity requires; while the disorderly ones must be repressed with such severity as may be necessary. So soon as order is established a careful inventory of captured property is made, and it is stored subject to the orders of the government. When the possibility exists of the place being attacked or besieged by the enemy, all its resources which are available for defence are collected, repaired, and stored for use.

VAUBAN'S MAXIMS.

97. Marshal Vauban, the great French military engineer (born 1633, died 1707), whose experience and success in sieges made him the great authority on the subject, formulated certain maxims for governing the conduct of a siege, the observance of which led to almost certain success, and the departure from them almost invariably resulted disastrously. The most of these are as applicable to sieges of to-day as they were to those of his own time. The following* bear upon the second and third periods of the attack:

1st. To delay the opening of the trenches until the besieging forces are all well posted and made secure by fortifications from an attack either from the garrison or from a succoring force; and until everything requisite for carrying on the work vigorously has been collected and is ready at hand when wanted.

2d. To make a single attack rather than a double one, unless the two attacks can be well connected and the besieging force exceeds considerably in strength the garrison. This, as a matter of course, excludes false attacks, and double separate attacks, unless the superiority of the besieging force is very great. By a single attack is understood one by which it is proposed to gain possession of the main work by a single breach at some point; by a double attack it is proposed to effect two breaches of the main work. The advantage of the latter lies in forcing the garrison to divide their strength for the defence of the two breaches, whilst the assailing forces, being under one leadership, can at any

* Quoted from Mahan's Siege Operations.

moment concentrate if necessary upon the point most favorable to their assault.

3d. To embrace within the parallels and approaches all the defences which bear upon the site to be occupied by the besieger's works, in order to have secure positions for establishing the batteries that may be required to silence the fire of these defences.

4th. To multiply the approaches, with the view of giving mutual support, less encumbered communications, and dividing the fire of the defences, which, if concentrated upon a single one, might soon destroy it.

5th. To throw up at least three main lines of parallels, placing them in the best positions for mutual support and for guarding the approaches and batteries from sorties of the besieged.

6th. To avoid attacking a point upon which the approaches can be run only on a narrow front, or one which can only be approached over marshy ground, or on causeways.

7th. To be careful not to push forward any portion of the trenches until they are well flanked and protected by trenches in their rear, which are completed and occupied by troops.

8th. To avoid encumbering the approaches with trench materials, tools, workmen, or troops; placing all of these in the parallels, on the right and left of the approaches, so as to be ready at hand when wanted, and to be rapidly sent forward through the trenches of the approaches, which should be kept free for this purpose.

9th. To place the ricochet (enfilading) batteries in such positions that they can have an enfilading and slant reverse fire upon the guns of the defences to be attained by them.

10th. To refrain from opening fire from any series of batteries until it can be done at the same moment from all of them.

[In connection with this and other siege operations, Vauban remarks that precipitation in sieges does not hasten the close of them, but often prolongs them and renders them more bloody.]

11th. To employ the fire of the batteries and trenches, rather than open assaults, to drive the besieged from their defences, before attempting to occupy them by the besieging force.

12th. When it is decided to make an open assault, to do so by day, if there is no portion of the fire of the defences which bears upon the point to be carried that is not completely kept under by the fire of the batteries and trenches; but, in the contrary case, when the fire of the defences is not completely kept under, to make an night assault.

13th. Not to attempt an obstinate resistance to an open assault of the besieged upon any unfinished portion of the trenches; but rather to withdraw the workmen and the few troops near them to some point behind the parallel immediately in rear, and then to open a vigorous fire from it upon the assailing force.

14th. To keep within the cover of the parallel when the assailant is advancing to the assault, and leave him to expose himself to its fire as long as he pleases, and then, when he is well cut up, and has got thrown into confusion, as he necessarily will at night, in the trenches that he may have carried, to fall upon him with the bayonet and drive him out.

15th. Not to push such charges too far from the parallel, but to retire promptly, so soon as the assailant has fairly taken to flight, within the cover of the parallel, so as not to draw the fire of the besieged works.

JOURNAL OF THE ATTACK.

98. In connection with the plan of attack previously referred to (par. 78), a complete *Journal of the Attack* will be kept in which will be recorded day by day a detailed record of the daily progress of the siege, giving the day and hour of starting and completing each battery, parallel, approach, etc., with their daily progress, dates of opening fire from each battery, and, generally, every incident connected with the siege. This journal will be supplemented by journals kept by the chiefs of engineers and artillery, in which will be consolidated the daily reports of all subordinate commanders of these respective arms, giving the expenditure of ammunition, the performance of the guns, carriages, etc.; the modification made in details of parapets, batteries, magazines, etc., with their value; the results of trials of new devices, and special reports upon any points connected with the siege. These journals will be carefully preserved and copies transmitted to the War Department from time to time for future use.

CHAPTER VI.

THE DEFENCE.

99. **Preliminary Considerations.**—The defence of a fortified place is entrusted to a commanding officer, who, when the siege is established, is generally known as the "Governor of the Place." His duties become more exacting and his powers more absolute from the beginning of hostilities until the place is invested and cut off from communication with the exterior, when, since the whole responsibility of the defence rests upon him, his powers over both the garrison and the inhabitants of the place, of necessity become autocratic in all matters affecting the defence, directly or indirectly. He, of course, avails himself of the counsel and advice of his subordinate officers and may make up a "Council of Defence" from his second in command and the commander of the engineers and of the artillery; but the ultimate decision of all questions must rest with him alone.

During peace and after the beginning of hostilities up to the near approach of the investing force, the civil authorities retain their ordinary jurisdiction, unless martial law is declared by proper authority; but after the place is invested, martial law (or state of siege) exists from necessity, and the police power, the control of provisions and supplies of all kinds, public and private, buildings, animals, vehicles, etc., and everything necessary for the defence of the place fall into the hands of the governor, who also is empowered to direct who shall be sent out and who shall be retained within the place, and what necessary service or labor shall be performed by the inhabitants. Having been selected for these onerous and exacting duties, he, under no circumstances, allows himself to be cut off from his post, and is therefore debarred from leading his troops in person in the active operations outside the work or exposing himself unnecessarily or recklessly during any period of the siege.

100. **The Garrison.**—The garrison should consist of artillery and infantry, and, in an intrenched camp, of enough mounted troops for escort, messenger, and a limited vedette service.

The strength of the infantry is generally regulated so as to give a suitable garrison to each detached work, and about 1½ to 2 men for each yard of the front of attack. The artillery is allowed about 12 men for each gun. The number of engineers is determined for each place by the probable amount of engineer work that will be required. These troops make up about one-third of the entire force.

A general reserve of all arms (principally, however, foot troops) makes up the other two-thirds, and is held as "a fighting force" for preventing the investment of the place, or for breaking up the investing lines when established. This reserve is called upon for work on the front of attack or in the trenches only when it cannot be avoided.

In smaller places the portion of the garrison called upon for the outer line of defence may be increased to one-half or two-thirds, and the general reserve be reduced to one-half or one-third of the entire force.

When the investment is strongly established the general reserve will usually be combined with the other troops.

The troops engaged on the front of attack are usually assigned to the different sectors of attack and are divided into reliefs (ordinarily three), each relief having as a rule a tour of one day in the front lines, one in the immediate supports, and one in the reserve and in interior fatigue duty. The Governor, however, so regulates the details as to impose upon the troops the least work consistent with an energetic defence.

101. Armament.—The guns for arming the place should be placed in position or in store within the works before the beginning of hostilities. There should be mounted in commanding positions a sufficient number of high-power guns to hold the enemy's first works at a distance and to fire upon his camps, etc., if placed too near. In addition to these, a full supply of light guns, including machine and rapid-fire guns, should be at all times equipped and supplied for immediate use in meeting an assault or surprise. Their emplacements, platforms, etc., should be in readiness for use at any moment.

In large places and for an active defence there will be needed also enough field-guns to properly equip the general reserve (about 4 guns per 1000 men). These should be considered a part of the equipment of the reserve.

It being, from economical considerations, impossible to supply guns to fully arm all the fronts of a place, enough only are usually provided to thoroughly equip the sector of attack and to replace those disabled. These are stored within the place where they are secure against deterioration or injury, and are mounted in the sector of attack when it is definitely determined. The numbers of high-powered guns, howitzers, mortars, and machine and rapid-fire guns needed must be determined from the size of the place, its garrison, and the character of attack which may be expected.

102. **Ammunition, Provisions and Supplies.**—A plentiful supply of ammunition, especially of projectiles, for all the guns should be kept constantly on hand. The projectiles, which may be stored for an indefinite term without deterioration, may be distributed in magazines in proximity to their batteries; the powder should be so stored as to preserve its properties, and be distributed to the service magazines at such times and in such quantities as may be necessary. Other equipments will be stored and handled in accordance with the same principles.

The utmost care will be taken in storing and issuing the provisions and supplies belonging to the troops; and in cases of necessity during the siege the sales of provisions to the inhabitants by the dealers will be regulated, both in prices and quantities, by the military governor.

103. **Sanitation and Hygiene.**—The most rigid sanitary measures and rules of hygiene should be enforced from the beginning of the siege, under the direction of the military governor, whose medical officers should join with the health officers of the place (if any exist) in guarding not only the troops but all the inhabitants from all avoidable causes of epidemic diseases. Extreme rigor in carrying out these regulations in not only allowable, but is most urgently required.

104. **Preparations for Defence.**—An active defence

being presupposed, all possible measures for its execution should be taken before the near approach of the enemy interferes with them. The principal ones are as follows, viz.: Advanced posts are established as far from the work as is prudent, say 3500 to 4000 yards, placed at points which may be easily defended or which would be advantageous positions for the enemy's batteries, etc. These, when possible, should be so placed that the ground between them is swept by their infantry fire and by the artillery of the place. They should be provided with good cover for the troops, and parapets for infantry and field-guns. When not naturally strong, field-works should be built. Quarries, ditches, sunken roads, villages, woods, etc., should be taken advantage of, either as points of defence, passive obstacles, or covers for communications, as may be best. Lines of retreat to the work as secure as possible from hostile fire should be provided. All supplies in the vicinity of the work which will be useful during the siege should be collected and taken into the place. Means of communicating with the exterior by telegraph, telephone, signal flags, lanterns and heliotropes, carrier-pigeons and balloons, should be secured. Search-lights for illuminating the exterior should be obtained, and as soon as practicable bombproofs and shelters for the inhabitants should be prepared in the body of the place; and in connection with the civil authorities the fire department of the place should be organized and taught how to extinguish fires with dry earth and by pulling down buildings when water is not available.

The service of security and information should be extended to the furthest possible limit, not only by outposts, etc., but by telegraph operators and reliable correspondents at long distances from the place; and preparations should be made to retard the approach of the enemy by the destruction of the roads, bridges, etc.

105. Defence during the First Period of the Siege.—Upon the approach of the enemy each work should receive its permanent garrison, and the fighting reserve should go out to occupy the advanced posts and to take full advantage of its interior lines to hold him back and punish any careless or ill-advised advance, being aided in this when possible by the fire of the heavy guns of the place. Care must be taken to avoid too great dispersion of the troops, and exposing advanced parties to being cut off and captured by pushing them too far to the front or holding their positions too long; but no opportunity should be missed of attacking and destroying or beating back hostile detachments when tactical conditions warrant it.

The defence during the first part of this period differs but little from the ordinary defence of an intrenched battle-field. The principal differences arise from the fact that the flanks of the advanced lines and the lines of retreat to the work are so well covered that with ordinary precautions they may be considered secure, and all energies may be directed to meeting the front attack and executing offensive returns. So soon as the point of attack selected by the enemy becomes known the advanced positions may be more fully manned and equipped; trenches with inconspicuous parapets, or preferably without any, may be made to cover the infantry, field-guns, and sometimes siege-guns on travelling carriages. These positions may be, as previously stated, 2500 to 3000 yards from the permanent works, and the intervals between them may be swept by the heavy guns of the latter.

If these positions can be so strongly held as to compel the besieger to attack them with his heavy guns, he will be compelled to establish his first artillery position at a very great distance—possibly 5000 to 6000 yards from the work. [At Belfort, 1870, positions of this kind were taken only after seventy-seven days of siege.]

As the advanced positions may be subject to the fire of the heaviest class of siege-guns, if any parapet is made it should be of the nature of a glacis of gentle slope and little command. Infantry trenches should be made narrow and deep as a protection against shells and shrapnel (Pl. IX, Fig. 84), and gun-emplacements should be as small as practicable and almost entirely in excavation, for the same reason. Positions so prepared suffer very little from gun-fire, and will frequently require attack by systematic approaches.

An efficient outpost service must be maintained in front of these positions to prevent their being taken by surprise.

When but a limited number of troops are available for defence it is of course impossible to push out the advanced posts so far to the front. In all cases, however, they should be placed at the greatest practicable distance.

106. Opening of Artillery-fire by the Defence.—The artillery-fire of the defence should be opened upon the besieger's batteries, etc., before they are ready for action, so that the ranges may be obtained and the tables of fire corrected without interference by the hostile fire. If this can be accomplished, the increased effect due to the accurate fire of the defence may more than counterbalance the numerical superiority of the attack, and result in preventing the completion of some of his batteries and in silencing others.

If, on the other hand, the attack anticipates the defence in obtaining the range, his superiority in numbers and accuracy will frequently necessitate abandoning some emplacements and mounting the guns in others, where they may be used in the later stages of the siege.

107. Defence during the Bombardment and Assault.—The amount of ammunition which can be profitably expended by the defence during the bombardment must be determined by the quantity on hand and the advisability of exposing by their fire the positions of the guns.

The infantry troops and the light guns are held under cover, ready to be moved forward to meet the assault if made. Special care will be taken to avoid being deceived by false attacks; and the assault, if made, will be met as previously described (par. 6).

If the attack is repulsed, an offensive return may be made by the general reserve, assisted, when necessary, by the local reserves of the front of attack; but the garrisons of the permanent works should not be withdrawn from them for this purpose, as it is always possible that they may be needed to protect the works and cover a retreat. If the assault succeeds, the defenders will retire to their positions in rear, from which the strongest possible fire will be directed upon the pursuing troops and upon the captured position to render its possession difficult or impossible. If the assailants are driven off, the position is immediately reoccupied by the defence.

108. Defence during the Second Period of the Siege.—The point of attack having been definitely determined by the preliminary steps of the attack in opening the parallels and establishing the batteries, the besieged will at once proceed to mount extra guns and reinforce the troops upon the threatened fronts. He will keep his outposts or sentinels during this and the subsequent periods as far to the front as possible, to prevent surprises and to keep out reconnoitring parties spies, etc., etc.

From observations previously established, he will locate at the earliest possible moment the batteries, etc., of the attack, and will prevent their completion and arming by the use of shells and case-shot charged with high explosives, fired from howitzers and mortars. He will use his long guns for counter-battering those of the besieger, and generally for direct fire upon exposed targets.

By taking the initiative he may frequently obtain the upper hand in the artillery duel, and possibly be able to prepare the way for strong sorties, and the destruction of the besieger's works. In any case he must at this stage develop the full fire of his guns and work them to their maximum value.

If, however, the superiority of the artillery of the attack is pronounced, and it becomes impracticable to serve any battery advantageously, it will be better to dismount its guns and remount them in other positions, as indicated in the preceding paragraph (par. 106).

All efforts will be made to prevent the construction of the parallels and approaches, their positions being discovered by the use of the search and other lights, and the work upon them retarded by direct and curved fire. For the latter light rifled mortars promise to be very effective.*

The trenches connecting the detached and intermediate works will be strengthened, and counter-approaches will when practicable be driven out to afford positions for enfilading the approaches. The field and machine guns will be held in constant readiness for use, and will be brought into action at every favorable opportunity; but will be withdrawn and placed under cover previously prepared so soon as the fire upon them becomes too severe to be endured.

Meanwhile a new position in rear, with its flanks supported upon the adjacent detached works, will be selected and made ready for defence in case the front line is taken.

The general reserve will be used for offensive movements, which are made whenever favorable opportunities arise, particularly in making counter-attacks after unsuccessful assaults.

109. Defence during the Third Period.—The defence of the detached works of an intrenched camp during the Third Period will be conducted, so far as the general reserve is concerned, in very much the same manner as during the Second Period; but in the immediate defence of the detached work itself, owing to the close approach of the besieger, its character will change. The artillery except the field and machine guns will be silenced, and the latter will usually be only available for defending the ditches and for repelling

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* A shell from a 9″.45 rifled mortar has in experimental firing produced in moderately hard ground a crater 8 feet deep and 19½ feet in diameter.

assaults. Light guns will, however, be held in readiness for temporary use when practicable.

The outposts will of necessity be drawn in and replaced by a chain of sentinels along the parapets of the covered way or the main parapet, who will pick off the besiegers at every possible chance, and will be reinforced by the rest of the garrison when an assault is imminent. All flanking defences will be kept in as good condition as possible, and in readiness to prevent the crossing of the ditch, or to repulse an assault. Grenades and shells will be kept in readiness to roll into the ditch, the breaches will be obstructed and mined if practicable, counter-mines will be brought into play, and all other possible measures taken to retard the approach of the besieger to the breach and to repel his assaults. When, however, the work is reduced to such a state as to make its defence hopeless, it should not be held at the expense of great losses to the defence, unless the besieger's works can be considerably delayed by doing so. When the position consists of an enceinte with ordinary outworks, the investment during the Third Period of the siege will be closer, the opportunities for using the general reserve will usually disappear, and its troops will be merged with those of the general defence.

When, in this case, the place is to be defended to the last, all measures will be taken for the defence of the breach; and after this is carried, for the final defence of the inner retrenchments or keeps.

The tactical handling of the garrison for this purpose is in accordance with the principles already laid down (par. 6, and Art of War, pars. 282–84.)

The sorties recommended during a siege are, when made by the general reserve and in large bodies, usually carried out by moving the troops from the collateral works upon the flanks of the besieger's works. In the close attack, however, they may be made by small parties moving to the front from the nearest outpost or salient. The object in all cases is the same—to destroy the enemy's works, delay his advance, and inflict upon him all possible loss.

THE CAPITULATION.

110. Should the defensive policy of the state not require a place to be held to extremity, the governor must be fully informed of the fact, and the extent of the defence and the conditions of capitulation must be fully understood by him before the investment. As a rule, however, no excuse will be received for the surrender of a place until every means of defence is exhausted, and further resistance is not only hopeless, but impossible, the only rule which can guide the governor being that "one additional day of defence may be of incalculable benefit to his country." The old rule, copied from the French, but no longer observed by them, requires the defence to sustain at least one assault on a practicable breach in the body of the place.

Within recent years, in civilized warfare, no cases have occurred in which such assaults have been made, the places having been reduced by the more distant attack; but assuming such an assault to be repulsed, it will not justify the surrender of the place so long as a possibility of repulsing similar assaults exists. The garrison must withstand all attacks of whatever nature to the last extremity, and continue the defence up to the full requirements of duty and honor—surrendering only when nothing else is possible.

JOURNAL OF THE DEFENCE.

111. **A Journal of the Defence**, entirely similar to that of the attack, will be kept by the besieged for use by the War Department in case of a successful defence. Nothing should be entered in the journal which might be of special value to the besieger in case the place is taken, but a separate journal of such matter should be kept in cipher, or should be destroyed before the surrender of the place.

CHAPTER VII.

PARKS AND DEPOTS, SHELTERS AND HUTS, KITCHENS, OVENS, SINKS, LATRINES, WATER-SUPPLY, ETC.

PARKS AND DEPOTS.

112. **The Engineer and Artillery Parks and Depots** are located and arranged for security against the artillery-fire and the attack, by surprise or otherwise, of the defence, and also for facility in receiving, storing, and distributing materials and supplies.

The first condition is fulfilled by placing them at a safe distance, concealing them from the view of the defence if possible, and guarding them against attack, and the access of incendiaries, etc., by strict application of ordinary defensive tactics, and a most thorough system of interior guards. Powder depots, trains, etc., especially are guarded against the access of all unauthorized persons.

The second condition, when railroad communication is used, is satisfied by making the park conform to the best-planned railroad terminals and freight-yards. A type arrangement is given in Plate IX, Fig. 85, in which switches from the main line give access to as many side-tracks, *a*, *b*, *c*, *d*, etc., and spurs, 1, 2, 3, etc., as may be needed. When practicable, these sidings should connect at each end with the main line in order to afford free ingress and egress from both directions. They should be placed at such distances apart as to allow loading-platforms and the desired room for sheds, piles of materials, etc., between them ; large areas being left for light, and small for heavy, materials. The spurs, 1, 2, 3, etc., should preferably be short; but if long, should be connected by switches. A Y, as indicated, is frequently convenient for reversing complete trains without uncoupling the cars, and is indispensable when a turn-table is not available.

When the powder-depot is separated from the main park it is better to reach it by a special track branching from the main line at some distance from the park, so that the ammunition-trains will not pass through or near the latter. The sketch given is proposed as a type only, since the park may occupy one or both sides of the main line, be long and narrow, short and broad, regular or irregular in outline, as may best conform to the ground available.

Standard-gauge roads will, when practicable, be laid between the main park and the smaller depots. When this is not feasible, narrow-gauge tram-roads will be used instead, and will also connect the smaller depots with the trenches and batteries. The portable tramways used by contractors are well fitted for use in the trenches.

When the park is located upon navigable water a number of piers and wharves are occupied. They should be provided with derricks or cranes, and tracks and cars upon which materials may be loaded directly from the ships. The park may then be arranged on the general plan above indicated. The switches are so arranged as to allow empty cars to return to the wharves on a track different from that used by the loaded ones.

In storing materials and supplies in the park care must be taken to place each class by itself, and to so pile them that they can be readily inventoried and inspected, and be removed or replaced without disturbing other piles. This requires the piles to be arranged in regular order, with unobstructed passages between them, and prohibits piling articles of different kinds or sizes on top of each other.

SHELTERS AND HUTS.

113. In a regular siege, the besieging army will, as a regular rule, eventually be provided with tents or portable huts for shelter ; but before this is accomplished much suffering and consequent disease may result from exposure, which could be avoided by the construction of temporary shelters, huts, and screens from materials available for this purpose.

In severe winter weather tents and thin wooden huts do not afford sufficient protection, and it may be necessary to substitute for them others with walls of logs, sods, sand-bags, adobe, or other materials, or even huts partly or entirely sunk into the earth. The greatest care must be exercised in enforcing proper ventilation and cleanliness in huts of this class. If this is not done serious fevers and other camp diseases are almost sure to occur. (Art of War, Art. 352–3.) The figures given (Plate IX, Figs. 86–94) have been selected from a great many examples to serve as suggestions. They may be modified or combined, as circumstances require. Their construction is evident from the figures, and requires no description. Ditches surrounding the huts are made to carry off rain-water.

Heavy roofs are supported by poles set up inside the hut as needed. Fireplaces are dug in the sides of the excavation, or are built up of sods, clay, etc. It is better to make two, as shown, to obtain a good draught in any wind. Chimneys are made of sods or of sticks plastered with clay, unless drain-tiles, tin cans, or other suitable materials can be found. Great care must be taken to prevent their setting the roof on fire.

In many cases water-proof roofing felts and papers may be obtained and used for roofs, etc., in huts and shelters. The lumber from packing-boxes, tin from canned vegetables, and wire from baled forage may frequently be utilized for doors, chimneys, ties, etc. Straw mats for mattresses, etc., are economical in the use of straw and conduce to cleanliness, as they can be easily taken up and replaced. The method of making them is shown in Pl. IX, Fig. 95. When twine is not at hand, they may be woven of straw rope. They, as well as all other bedding, should be taken out and sunned every dry day. Ordinary hurdles laid upon the ground or raised a few inches above it protect the blankets, etc., from the moisture of the earth.

It cannot be too strongly impressed upon officers, that all devices of the kind above indicated, which add to the comfort of the men, add also to their health, morale, and efficiency.

KITCHENS AND OVENS.

114. In our service a company will usually have a camp-cooking outfit sufficient for its needs, and generally of good pattern; but these are not always on hand when needed, and small detachments are frequently deprived of them for days or weeks. In ordinary soil, kitchens, and in a clay soil ovens, can be constructed, which, with a few kettles and cans, will enable the men to prepare for themselves fairly good meals without unnecessary waste of fuel. A few of these are figured in Pls. IX, X, Figs. 96–103. The banks of the trench shown in Fig. 96 afford support for cross-bars, and protect the fire from the wind. The type shown in Figs. 97, 102, 103 take the place of a stove, require but little fuel, and secure a steady heat. To obtain a good draught they should be so built that the wind blows toward the chimney. For this purpose they may radiate from a central chimney. (The flues of those not in use may be temporarily stopped up with sods.) The arch of the oven shown in Pl. X, Fgs. 98–101, may be built over a piece of sheet iron if it can be obtained ; if not, over a hurdle well smeared with clay. A slow fire will, under favorable conditions, dry and bake the clay arch so that it will stand after the brushwood of the hurdle is burned out. They may then be heated and used for baking.

LATRINES, SINKS, ETC.

115. Latrines and sinks for the reception of garbage, etc., are objects of the greatest importance in all camps, temporary or permanent; and, unless properly made and cared for, they speedily make their presence known, and become a most prolific source of discomfort and disease.

For permanent camps liable to be occupied for a long time special arrangements for the disinfection, removal, and destruction of garbage and excreta must be made. For temporary camps it will suffice to provide pits with suitable conveniences and screens; covering with a thin layer of the excavated earth all deposited garbage and excreta before they become offensive. When, as is sometimes the case, these pits cannot be kept free from water, it may be necessary to use in addition lime, copperas, carbolic acid, or other chemical disinfectants and deodorizers.

The ordinary constructions used in temporary camps are shown in Pl. X, Figs. 104–107. Separate latrines for officers are constructed and screened. The seat shown in Fig. 107, when one can be obtained, adds much to their comfort.

In more permanent camps the latrines may be roofed and screened with canvas or boards, and board seats be provided for the men. Uninclosed sinks and latrines should have earthen banks all around them, to indicate their position and to prevent men walking into them at night. Upon abandoning a camp all sinks and latrines are to be disinfected and filled up.

WATER-SUPPLY.

116. The problem of obtaining a sufficient and wholesome water-supply for a besieging army is usually one difficult of solution. The precautions which are necessary in ordinary camps (Art. of War, 352 and 358) become of still greater importance in this case, owing to the choice of the source of supply being limited to those which are not controlled by the besieged, and to the constantly increasing danger of pollution of all ground waters by the bodies of the dead men and animals and the refuse and filth of the camps. The evils arising from these sources may be largely or entirely removed by boiling the drinking-water, and the disagreeable tastes and smells may be removed by filtering through good filters. It is very difficult, however, to compel the men to boil the water, or to drink it after it is boiled, unless it is properly aerated and filtered. All available measures should, therefore, be adopted to supply them with wholesome water.

The results of the most recent researches show that properly conducted *intermittent filtration* with sand-filters will render a polluted water almost if not entirely safe. (See reports of Massachusetts State Board of Health on Purification of Sewage and Water, 1890.) And the analysis of water sterilized by a steam-jet at the Columbian Exposition in Chicago, 1893, gives reason to believe that this process may be very effective in removing disease germs. (See report of Allen Hazen, Chemist, Department of Water-supply, published in *Engineering News*, March 29, 1894.) In camps of some permanence one or both of these processes may be well worth applying.

Small filters for limited amounts of water may be bought in the market, or may be improvised and set up for officers or company messes. Figs. 108–110, Pl. X, are given as suggestions; they serve as strainers in any case. If used intermittently they *may* have a high sanitary value, and if made up partly of either animal or wood charcoal they remove more or less completely any offensive taste or odor which water may have. Security, however, requires doubtful water to be boiled.

In all cases arrangements should be made to protect the water from surface pollution, for convenient access for the men, and for watering horses.

(See the following books, treating on Military Hygiene in Camp and Garrison: Parker's Practical Hygiene; Traité d'Hygiène Militaire, Morache; Manuel d'Hygiène militaire, Viry; Military Hygiene, Woodhull; the Soldier's Pocket-book, Wolseley; etc., etc.)

PART II.

MILITARY MINING, BLASTING, AND DEMOLITION.

CHAPTER I.

NOMENCLATURE AND THEORY.

1. **Military Mining** includes all the operations necessary for placing charges of explosive underground and exploding them at the time desired, for the purpose of destroying the men, materials, or works in their vicinity, or for breaking up the surface of the ground either to advance or retard the operations of a siege.

The excavation for receiving the *charge* is called the *chamber*. The approaches leading to the chamber when horizontal or somewhat inclined are called *galleries*, and when vertical are known as *shafts*. When very steep they are sometimes called *slopes*. The charge, chamber, and approaches taken together constitute a *mine*.

The pit formed by the explosion is called the *crater*. When the ground is homogeneous and its surface horizontal, the intersection of its surface by the crater is approximately a circle, the radius of which is called the *crater radius*, *AB*, Pl. XI, Fig. 1.

The right line joining the centre of the charge with the nearest point of the surface toward which the explosion will take place, generally the surface of the ground, is called the *line of least resistance* (written generally L. L. R.), *C B*, Pl. XI, Fig. 1.

A right line from the centre of the charge to the edge of the crater is called the *radius of explosion*, *C D*, Pl. XI, Fig. 1.

The distance from the centre of the charge at which an ordinary mining gallery will be broken in by the explosion is called the *radius of rupture*, *CL*, Pl. XI, Fig. 3. The radius of rupture varies in length with its inclination to the horizontal.

Craters whose *diameters* are once, twice, etc., their lines of least resistance are called *one-lined*, *two-lined*, etc., craters.

Mines in which the L. L. R. is equal to the *crater radius* are called *common mines*. (Their craters are *two-lined*.) Those in which the crater radius exceeds the L. L. R. are called *overcharged mines* or *globes of compression*; when it is less, they are *undercharged mines*; and when the charge is so small that no exterior crater is formed, they are known as *camouflets*.

2. In the explosion of military mines on land it may safely be assumed that the circumstances of combustion of the charge when fired are such that the energy developed is directly proportional to the charge. A portion of this energy is generally lost by the escape of the compressed gases into the air, by the heat given up to the surrounding media, and by the transmission of earth-waves or shock; the remainder and greater part, however, is expended in rupturing the case containing the charge, compressing the soil in its immediate vicinity, separating that lifted up from that forming the sides of the crater, breaking up the portion thrown out into large or small fragments, projecting them to a greater

or less distance, and disintegrating the soil around the crater to a distance which varies with the soil and with the quantity and character of the explosive used.

As the proportional part of the energy expended in each of the effects above named cannot be determined in any particular case, and as each case differs in some respect from every other, it is manifestly impossible to express in any mathematical formula a rule for determining the exact amount of explosive required for any particular mine.

From the results of long experience, however, engineers have concluded that computations sufficiently exact for practical purposes can be made upon the hypothesis that *for common mines and those approximating closely to them in form*, the volumes of the craters are directly proportional to the charges used.

3. In order to apply this rule in practice the volumes of craters formed by known charges must be measured; but since the soil in the immediate vicinity of the crater is more or less disintegrated, and the crater itself is partly filled up by the material which falls back into it, the outlines of the original crater cannot usually be recognized or its exact geometrical figure be determined. Besides, the craters formed under circumstances seemingly identical differ more or less among themselves.

For convenience in computation, however, several simple geometrical figures have been assumed as giving with sufficient accuracy the form of the crater of a common mine. See Pl. XI, Fig. 1. Among these Vauban assumed a cone, *ACD*, with its vertex at the centre of the charge; Valière a paraboloid of revolution, *AHD*, with its focus at the centre of the charge; Müller truncated this paraboloid by a horizontal plane through its focus; while Gumpertz and Lebrun adopted the form in common use at their time, and which has been generally accepted since, viz., a frustum of a cone, *AEFD*, the smaller base of which passes through the centre of the charge and has a radius, *EC*, equal to one-half the crater radius, *AB* (or one-half L. L. R., *CB*).

The volumes of these figures are as follows:

Vauban's cone................1.05 (L. L. R.)^3,
Valière's paraboloid...........1.90 (L. L. R.)^3,
Müller's truncated paraboloid..1.84 (L. L. R.)^3,
The frustum of a cone.........1.83 (L. L. R.)^3 = nearly $\frac{11}{6}$(L. L R.)^3.

The cone of Vauban (lately assumed also by Höfer) was abandoned as unsatisfactory, because it did not conform to the craters produced, and, as treated by Höfer, because the charges computed by its use were found to be too small (an error in the wrong direction). The paraboloid of Valière or Müller would seem to conform more nearly to the actual shape assumed by the crater; but it will be observed that the volume of the latter is sensibly the same as that of the truncated cone, and as the volume of earth thrown out is the quantity to be considered, the truncated cone will be assumed as the measure for it.

4. The principle that "the volumes of the craters are proportional to the charges used" is the general statement of the *miner's rule*. Assume C and C' to represent the charges of two mines whose volumes are V and V', lines of least resistance l and l', and crater radii r and r'. Assume also that the craters are frustums of cones, the radii of whose larger bases are twice those of the smaller. Then

$$C : C' :: V : V' :: \tfrac{11}{6} l r^2 : \tfrac{11}{6} l' r'^2,$$

or

$$C' = C\frac{V'}{V} = C\frac{\frac{11}{6}l'r'^2}{\frac{11}{6}lr^2} = C\frac{l'r'^2}{lr^2}. \quad . \quad . \quad (1)$$

Equation (1) is applicable to *mines in which r does not differ materially from l or r' from l'.*

From an experimental mine giving a crater of this general type the relations between C, l, and r may be determined, and assuming any two of the quantities C', l', and r' for a mine with a crater nearly similar in form, the other may be found from eq. (1).

When $l = r$ and $l' = r'$, we have

$$C : C' :: \tfrac{11}{6}l^3 : \tfrac{11}{6}l'^3,$$

and

$$C' = C\frac{\frac{11}{6}l'^3}{\frac{11}{6}l^3} = C\frac{l'^3}{l^3}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Equation (2) is applicable to *common mines*, and shows that *in common mines the charge varies as the cube of the line of least resistance.*

Assuming $C_{\prime}$ as the charge which will produce a crater with a volume of unity, equations (1) and (2) become, by omitting the primes from l and r,

$$C = C_{\prime}\tfrac{11}{6}lr^2, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and

$$C = C_{\prime}\tfrac{11}{6}l^3. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Equation (4) gives the rule for determining the charge for common mines whose L. L. R. is given, viz.: *Multiply* $\frac{11}{6}$, *the cube of the line of least resistance in yards, by the quantity of explosive required to throw out one cubic yard.*

The latter quantity is determined by experiment. A similar rule may be written out from eq. (3) for mines differing but little from common mines.

5. The quantity of gunpowder required to throw out a cubic yard of material has been calculated from a great number of mines fired in different kinds of soil. The following table gives the quantities required according to Lebrun and Macaulay, respectively the French and English authorities on the subject:*

TABLE A.

Number.	Description of Earth, Rock, or Masonry.	Weight per cubic foot.	Charge, Gumpertz and Lebrun.	Charge, Macaulay.	Proportional value of charge.
		lbs.	lb. oz.	lb. oz.	
1	Light sandy earth (*common earth, Lebrun*)	85	1.8	1.13	1.12
2	Hard sand	111	1.10¾	2.0	1.25
3	Fat earth mixed with sand and gravel (*common earth, Macaulay*)	116	1.5⅞	1.10	1.00
4	Wet sand	118	1.12	2.2	1.30
5	Earth mixed with stones	118	1.14	2.4	1.40
6	Clay mixed with tufa	124	2.1	2.8	1.55
7	Fat earth mixed with pebbles	143	2.4	2.12	1.69
8	Rock	143	3.0	3.10	2.25
9	New or old moist brickwork or masonry	......	......	2.2	1.30
10	Inferior brickwork or masonry	......	......	2.11	1.66
11	Good, new ditto	......	......	3.10	2.25
12	Good, old ditto	......	......	4.1	2.50
13	Roman ditto, or other equally good in warm climates	......	......	4.11	2.90

6. For *common mines* in *ordinary earth* a convenient rule, very generally used, and which gives results nearly the same as those deduced from the table, is:

* From the unpublished records of three experimental mines fired at Willet's Point in 1877–83 it would seem that the quantities given in this table are greater than those required if good American powder is used. These mines, in a soil of modified drift,
with a L. L. R. of 12 ft. required 1.02 lbs. per cu. yd. = 1 lb. ⅛ oz.; and with a L. L. R. of 17 ft. required 1.15 lbs. per cu. yd. = 1 lb. 2½ oz.

The charge of gunpowder in pounds is equal to one tenth the cube of the ''ne of least resistance in feet, or

$$C \text{ lbs.} = \tfrac{1}{10} l^3 \text{ ft.} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

OVERCHARGED AND UNDERCHARGED MINES.

7. **For overcharged and undercharged mines** in which the L. R. R. and crater radius differ materially in length the results deduced from the preceding equations are not applicable. For such mines the following equations, due to Gumpertz and Lebrun, are in common use, viz.:

For an overcharged mine,

$$C = C_{,}\tfrac{11}{6}[l + \tfrac{7}{8}(r - l)]^3. \quad . \quad . \quad . \quad (6)$$

For an undercharged mine,

$$C = C_{,}\tfrac{11}{6}[l + \tfrac{7}{8}(l - r)]^3. \quad . \quad . \quad . \quad (7)$$

In which C = charge of explosive in pounds, l = L. L. R. in yards, r = crater radius in yards, $C_{,}$ = amount of explosive in pounds necessary to throw out one cubic yard of earth in a common mine in the same soil.

These formulæ are deduced as follows, viz.:

It was found by experiments made independently by Belidor and Marescot that 3660 lbs. of powder in a mine with L. L. R. equal to 4 yards gave a crater with a radius of 12 yards in earth requiring for a common mine $1\frac{1}{2}$ lbs. of powder per cubic yard. The charge for a common mine in the same soil with L. L. R. equal 4 yards is

$$\tfrac{11}{6}(4 \text{ yds.})^3 \times 1\tfrac{1}{2} = 176 \text{ lbs.}$$

Representing by l the L. L. R. for a common mine requiring a charge of 3660 lbs., since the charges of common mines are proportional to the cubes of their lines of least resistance, we have

$$176 : 3660 :: 4^3 : l^3 = 1330.8,$$

whence

$$l = 11^y; \qquad (11)^3 = 1331.$$

To find from these data the relations between charges for overcharged mines, construct Figs. 2 and 2*a*, (Pl. XI.)

Fig. (2) gives mines with crater radii of 4^y and 12^y and a common L. L. R. of 4^y.

Divide the distance between A and B into four equal parts, and assume the points of division as the extremities of the crater radii of overcharged mines, each of which exceeds the one next smaller by $\frac{1}{4}AB$, and all corresponding to a L. L. R. of 4^y.

Fig. (2*a*) gives common mines with lines of least resistance of 4^y and 11^y. Divide the distance $A'B'$ also into four equal parts, and assume the points of division as the extremities of the crater radii of common mines each of which exceeds the one next smaller by $\frac{1}{4}A'B'$.

Since the charges for the common mines whose lines of least resistance are respectively 4^y and 11^y are identical with those of the overcharged mines whose crater radii are 4^y and 12^y respectively, it is assumed that the charges for the intermediate common mines are the same as would be required to produce the corresponding intermediate overcharged mines.

The increment of the crater radius and line of least resistance of any one of these common mines is equal to $\frac{7}{8}$ the increment of the crater radius of the corresponding overcharged mine; consequently the charge which gives an overcharged mine whose L. L. R. and crater radius are l' and r', respectively, will produce a common mine whose L. L. R. l will be given by the equation

$$l = l' + \tfrac{7}{8}(r' - l'). \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

Since the charge for a common mine is obtained from equation (4), $C = C_{,}\frac{11}{6}l^3$; the charge for the overcharged mine will be

$$C = C_{,}\tfrac{11}{6}[l' + \tfrac{7}{8}(r' - l')]^3,$$

as above.

For ordinary earth and gunpowder, when L. L. R. is measured in feet, eqs. (6) and (7) become, respectively:

For an overcharged mine,

$$C = \tfrac{1}{10}[l + \tfrac{7}{8}(r - l)]^3. \quad . \quad . \quad . \quad . \quad . \quad (6')$$

For an undercharged mine,

$$C = \tfrac{1}{10}[l - \tfrac{7}{8}(l - r)]^3. \quad . \quad . \quad . \quad . \quad . \quad (7')$$

8. Giving to l the same value in equations (4), (6), and (7), we have

$$C' = C\left(\tfrac{7}{8}\frac{r}{l} + \tfrac{1}{8}\right)^3, \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

In which C = charge for *common mine* with L. L. R. and crater radius $= l$. C' = charge for *over* or *undercharged mine* with L. L. R. $= l$ and crater radius r. Equations (6), (7), and (8) having been deduced from the relations existing between C, l, and r for mines varying from common mines up to those in which $r = 3l$ may safely be used for *overcharged* mines up to this limit.* In their applications to *undercharged* mines they become uncertain when $r = \frac{1}{2}l$; and when $r = \frac{3}{8}l$ the computed charge generally produces a camouflet.

These computed charges are:

$$\text{for } r = \tfrac{1}{2}l,\ C' = 0.1779C; \text{ for } r = \tfrac{3}{8}l,\ C' = 0.1636C.$$

A rule of the French engineers states that a charge which will produce a common mine with L. L. R. $= l$ will produce a camouflet if the L. L. R. is increased to $\frac{7}{4}l$. At this depth $C' = 0.187C$, and the formula gives a crater radius of $\frac{25}{49}$.

As a safe "rule of thumb," we may assume that *a charge which will give a common mine with $L. L. R. = l$* will give a camouflet with $L. L. R. = 2l$ (r' from formula $= \frac{3}{7}l$). Conversely, *a camouflet will be produced by $\frac{1}{8}$ of the charge which will produce a common mine.*

9. Radius of Rupture.—The determination of the *radius of rupture* is an important consideration in underground warfare, since, when it is known, miners may so place their chambers as to break in the galleries of the enemy without injuring their own.

As different mining galleries, however, differ from each other so much in strength to resist crushing, and as the cost of an exhaustive series of experiments to determine their relative strength would be so great both in time and money, but little well-established data exist upon which to found a rule for determining the radius of rupture.

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* Six-lined craters ($r = 3l$) are generally considered as the practical limit of overcharged mines, although at Chatham mines have been fired giving $r = 3\frac{3}{4}l$. The published data concerning them indicate that they required charges larger than the formulas above given call for.

10. The rule deduced by Gumpertz and Lebrun, however, from the material available at their time corresponds very nearly with the results of later experiments and observations, and is generally admitted as sufficiently near correct for practical use.

This rule is based upon the theory that the surface of rupture is an oblate spheroid, (Pl. XI, Fig. 3), with its axis of revolution vertical and its centre at the centre of the charge; the intersection with the surface of the ground *AD* coinciding with the edge of the crater. The ratio between the semi-transverse axis *CF* and the semi-conjugate axis *CH* of the generating ellipse of this assumed spheroid is the same as that between the radius of explosion *CD* and L. L. R., *CK*. The rule is, that *the radius of rupture in any direction is equal the corresponding radius of this spheroid.*

From the conditions assumed the following values of the semi-transverse and semi-conjugate axes h and v (which are the horizontal and vertical radii of rupture) are obtained, viz. :*

$$h = l\sqrt{1 + 2\left(\frac{r}{l}\right)^2};$$

$$v = l\sqrt{\frac{1 + 2\left(\frac{r}{l}\right)^2}{1 + \left(\frac{r}{l}\right)^2}}.$$

* Describe the semicircle *BMNF*. Then

$$OD : ON :: CH : CM;$$

$$l : ON :: v : h.$$

$$ON^2 = \frac{h^2 l^2}{v^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

For common mines these formulas give:

$$h = 1.732l = \tfrac{7}{4}l = \tfrac{7}{4}r;$$
$$v = 1.225l = \tfrac{5}{4}l = \tfrac{5}{4}r.$$

For six-line craters,

$$h = 4.358l = \tfrac{35}{8}l = \tfrac{3}{2}r;$$
$$v = 1.378l = \tfrac{11}{8}l = \tfrac{1}{2}r.$$

$$BO : ON :: ON : OF;$$
$$h + r : ON :: ON : h - r.$$
$$ON^2 = h^2 - r^2. \quad \ldots \ldots \quad (2)$$
$$CF : CH :: CD : CK;$$
$$h : v :: \sqrt{r^2 + l^2} : l.$$
$$\frac{h^2 l^2}{v^2} = r^2 + l^2. \quad \ldots \ldots \quad (3)$$

$\therefore$ Eqs. (1), (2), and (3), $r^2 + l^2 = h^2 - r^2$.

$$h^2 = l^2 + 2r^2. \quad \ldots \ldots \quad (4)$$
$$h = l\sqrt{1 + 2\left(\frac{r}{l}\right)^2}.$$

. . . .

Eqs. (3) and (4), $(l^2 + 2r^2)l^2 = v^2(r^2 + l^2)$.

$$v^2 = \frac{l^2 + 2r^2}{1 + \frac{r^2}{l^2}} = \frac{l^2\left(1 + 2\left(\frac{r^2}{l^2}\right)\right)}{1 + \frac{r^2}{l^2}};$$
$$v = l\sqrt{\frac{1 + 2\left(\frac{r}{l}\right)^2}{1 + \left(\frac{r}{l}\right)^2}}.$$

11. The English authorities adopt the value of $\frac{7}{4}l_{,}$ for the horizontal and $l_{,}\sqrt{2} = 1.41421\, l_{,} = \frac{7}{5}l_{,}$ for the vertical radius of rupture of all classes of mines. In which $l_{,} =$ L. L. R. of an equivalent common mine $= l + \frac{7}{8}(r - l)$, etc.

Some later experiments at Chatham have given

$$v = \tfrac{5}{3}l \text{ for a 4-lined crater;}$$

$$v = 2l \text{ for a 5-lined crater;}$$

and

$$v = \tfrac{5}{2}l \text{ for a } 7\tfrac{1}{2}\text{-lined crater.}$$

12. There are other good reasons for believing that Lebrun's value for the vertical radius is too small; but as its use leads to increasing the charges designed to produce crushing effects, the error, if it exists, is in the right direction, and justifies the use of the formula until more exact data are available.

EXPLOSIVES.

13. No military mining operations of note have been carried on since the introduction of dynamite and other high explosives; consequently our knowledge of their value for work of this kind rests entirely upon the results obtained from experimental mines. Unfortunately but few experiments seem to have been made, and the published results of these are very meagre.

14. Two mines fired at Krems in 1873 with L. L. R. of 12 ft. in earth weighing 100 lbs. per cubic foot and charged, one with 173 lbs. gunpowder, the other with 58 lbs. dynamite (kind not stated), gave crater radii, respectively, of 12.75 and 10.25 feet. Lebrun's formulas applied to these give to gunpowder and dynamite the ratio 1 : 1.688.

Two powder-mines and one dynamite-mine, each of 12 ft. L. L. R., were fired at Willet's Point in 1878. The powder-mines were each charged with 200 lbs. cannon-powder and the dynamite mine with 82 lbs. dynamite No. 1.

No. 1 powder-mine gave a crater radius of 15½ ft.

No. 2 powder-mine gave a crater radius of 15¼ ft., or a mean of 15⅜ ft.

The dynamite-mine gave a crater radius of 14¼ ft.

The relative values of cannon powder and dynamite resulting from the application of the same formulas to these mines is 1 : 1.997.*

15. Choice of Explosive. — From these experimental mines it may be concluded that for forming craters in ordinary earth dynamite is not quite so efficient as double its weight of good gunpowder. For breaking up hard rock, blowing up strong masonry, and especially in demolitions where tamping is usually defective, this ratio does not hold; but the relative effect of the high explosive increases continually with the lack of tamping and the intensity of the local blow desired, until a point is reached at which the effect of gunpowder is almost imperceptible, while the high explosive does efficient work. This property of the high explosives renders them extremely valuable for

* General Abbot's experiments in submarine mining fix the relative values of cannon powder and dynamite No. 1 in water, measured by the pressure exerted by them (not by the craters formed), as 1 : 2.45. The characters of the media and the explosives would naturally lead to the inference that the superiority of dynamite over powder would be greater in water than in earth.—J. M.

use in hasty demolitions, such as blowing up palisades or barriers, destroying guns, etc., etc.

Owing to their varying values in different conditions the choice of explosive to be used in any particular case must evidently depend upon the circumstances attending it.

In underground explosions both gunpowder and high explosives give out noxious gases which penetrate the soil, and which entering a gallery in sufficient quantity would suffocate the miners. Of these gases the carbonic oxide given off by some of the high explosives is probably the most dangerous to human life, and if mixed with the proper proportion of air forms an explosive mixture, resembling in this respect the fire-damp of the coal-mines. Whether in practical mining operations it would ever be retained in the soil in such quantities as to produce this effect remains to be seen.

Some of the high explosives, on the other hand, seem to produce relatively small quantities of noxious gases. The gases produced by gunpowder, while suffocating in their nature, have the advantage of always making their presence known by their odor.

16. For use in overcharged mines designed to break in the enemy's galleries, the high explosives, from the violent character of their explosion and from the phenomena exhibited in submarine mining, promise to give relatively greater radii of rupture than gunpowder; but sufficient data are not available to state this positively.*

* The 82 lb. dynamite-mine at Willet's Point produced almost exactly the same effect upon the gallery of access as the 200-lb. cannon-powder mine, while its external crater was considerably less

17. Beside the considerations above stated, which refer to the effects produced by the explosive when fired, there are others equally important relating to the safety and facility with which the explosive may be transported, handled, and placed in the mines. The latter will frequently have greater weight than the former in determining the explosive to be used in any particular case which may arise in the practical operations of mining. Of the latter considerations some of the most important in deciding whether to use gunpowder or high explosives are the following, viz.:

Gunpowder is easily obtained, and most enlisted men are more or less familiar with its properties.

It explodes when ignited by fire.

It does not ordinarily explode when struck by a bullet.

It is injured by moisture and destroyed by thorough wetting.

It is not affected by ordinary changes of temperature.

It requires thorough tamping to produce good effects.

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in diameter. Its crater was surrounded, however, by concentric cranks spaced at intervals of 3 or 4 feet to a distance of about 40 feet from the centre of the crater. No such effect was produced by the powder-mine.

On the other hand, the actual radii of rupture produced by five experimental mines fired at Olmutz in 1871–2 agree very closely with the values which result from applying Lebrun's formulas to craters of the same size and shape produced by gunpowder, and indicate that charges of dynamite and gunpowder which produce identical craters will also have identical radii of rupture. The somewhat contradictory results given by the Willet's Point and Olmutz mines show the necessity for further experiments.

Many high explosives are not injured by moisture, and some are unaffected by total immersion in water.

They generally burn without detonation if ignited by flame.

Some of them do not explode when struck by a bullet. The more sensitive ones do.

The properties of some of them are materially changed by freezing.

On account of their greater strength, the same effects may be produced by smaller charges, requiring smaller chambers and cases.

By reason of the violence of their action they produce good results even if imperfectly tamped.

The last two considerations, together with the possibility of using them in wet places without protection against moisture, lessen greatly the time required to excavate, charge, and tamp a mine, and may frequently enable the one using them to anticipate an enemy using gunpowder and thus secure success, when the use of gunpowder would reverse the situation. In mining operations and in expert hands the high explosives, upon the whole, seem to cause fewer accidents than gunpowder.

CHAPTER II.

PRACTICAL OPERATIONS AND DETAILS.

18. **Tools and Appliances.**—The different operations of mining are carried on by the use of picks, shovels, bars, saws, axes, hammers (large and small), chisels, wheel and hand barrows, windlasses, ropes, wooden or leather buckets, gauge-sticks, mason's levels (Pl. XI, Fig. 4), plumb-lines, candles, closed lanterns, tin pipes, rubber and canvas hose, canvas, nails, etc., etc., of the kinds in common use; and the following special tools and appliances, viz.:

The *Miner's Pick*. Smaller and lighter than the common pick. Neither its head nor its handle exceeds 2 feet in length.

The *Miner's Shovel*. Similar in shape to a common shovel, but not exceeding 2 feet in length.

The *Push Pick* (Pl. XI, Fig 5), which has a lance-shaped blade about $3\frac{1}{2}$ in. wide and 6 in. long attached to a handle about 2 feet long.

The Field Level (Pl. XI, Fig 6), which consists of three strips of wood about $2'' \times \frac{1}{2}''$, arranged as shown. The strip *A* is 4′ between centres of pins; *B* and *C* are $2', 9\frac{15}{16}''$; the angle at $a = 90°$. A spirit-level is inserted in piece *C*, and a plumb-line attached as shown. The markings on *A* are used for gentle slopes, those on *B* for steep ones.

The other sides of *B* and *C* are divided into degrees of arc, the centre being at the middle point of the outside edge of *A*.

The *Slope Block*, which is a wooden cube used in connection with a mason's level for fixing slopes.

Angle Templets (Pl. XI, Fig. 7), making a definite angle, used in laying out galleries.

The *Miner's Truck or Car.* A small, four-wheeled wagon with fixed axles and very short wheel-base; exterior dimensions about 20″ wide, 18″ to 20″ high, and 30″ long. Used for carrying earth through galleries, and usually hoisted up the shaft and dumped outside, replacing the buckets used in sinking the shaft.

The *Miner's Bellows* (Pl. XI, Fig. 8). A leather bag with wooden top and bottom, provided with inlet and outlet valves, from the latter of which the air is led off in pipes or hose. In using the bellows the miner stands upon the lower handles and works the bellows with his hands by the upper ones.

This is frequently replaced by a common blacksmith's bellows or the rotary blower from a portable forge; and sometimes by an improvised air-pump, consisting of a large open cask filled with water and another smaller one, with one head removed and the other provided with outlet and inlet valves and an air-tube, inverted over the large cask, supported by a spring-pole and worked up and down by hand in the water of the lower cask.

The Miner's Candlestick (Pl. XI, Fig. 9), which holds a candle, and may be driven into the side or bottom of a gallery.

Miner's Lamps (Pl. XI, Fig. 10), can be used only when the ventilation is good, as they give off more smoke than candles.

When an electric-light plant is available, incandescent lamps will be used for mining.

Earth Augers, similar to those used for boring post-holes, but of different diameters, are sometimes used for placing camouflets. Their shanks are made in short lengths, which can be joined together to allow of boring a deep hole from a narrow shaft or gallery.

GALLERIES AND SHAFTS.

19. **The Dimensions of Galleries and Shafts** are determined by the use to be made of them, the necessity of ventilation, and the minimum space in which a man can work.

They are usually about as follows, viz.:

	Height, feet.	Width, feet.
1. Great or grand galleries	6	7
2. Common galleries	6	3½
3. Half galleries	4½	3
4. Branches	3½	2½
5. Small branches (*rameaux de combat*)	2½	2

Shafts vary in size—from the smallest in which a man can work (about 2′ × 4′), to any size that may be required, seldom exceding 10′ × 10′.

Great galleries are used for descent into a ditch, and when it is wished to pass cannon through them.*

Common galleries are used for descent into a ditch, and for communications. Troops can pass through them "by twos."

Half galleries answer for general purposes of attack. They allow the miner to work freely in different positions without being cramped, but are small enough to

* To pass a 5″ siege-gun, mounted upon a high or "over-bank" carriage (model 1887), requires a gallery 7′ × 7′ in clear.

admit of rapid driving. Branches and small branches are driven out from the galleries to the mine-chambers, etc. They can be driven rapidly for short distances (10 to 20 feet); but when of greater length the earth is removed from them with difficulty, they are not easily ventilated, and are too small for use as communications.

20. Shaft and Gallery Linings.—In very firm soil it is sometimes practicable to drive small shafts and galleries short distances without lining them; but if these are to stand for any length of time, there is always danger of their falling in, particularly if shaken by the explosion of mines in their vicinity. When it is considered safe to use them, however, the shafts should be elliptical in plan, and the roofs of the galleries should be pointed arches. As a rule, however, both shafts and galleries should be lined. Those which are permanent in their character—as the main galleries of the countermines of a permanent work—are lined with masonry. Masonry linings may be of brick, stone, or concrete walls and arches. The smaller galleries constructed during a siege, and all the shafts and galleries of the attack, are lined with wood. Wooden linings are of two general types, known as *cases*, and *frames and sheeting*.

21. *Cases* (Pl. XI, Figs. 11 and 12) are made of plank, from 6″ to 12″ wide, each case consisting of a cap-sill, a ground-sill, and two stanchions. The cap and ground-sills are cut to a length equal to the clear width of the shaft or gallery plus twice the thickness of the stanchions; a rectangular notch is cut in each end to receive a corresponding tenon cut on the stanchion. The length of the stanchions between shoulders is equal to the clear length of the shaft or height of the gallery. The length of the tenons is generally equal to the thickness of the cap and ground sill (usually 2″), and their width about three inches. Notches are cut in the sides of all the pieces of the case, as shown in the figure, for convenience in handling them.

In grand galleries the tenons at the top of the stanchions are usually shorter than the thickness of the cap-sill, and those at the bottom, as well as the mortises in the ground-sill, are omitted. The stanchions are kept from collapsing by blocks nailed to the ground-sills. These blocks are 2″ thick, and wide enough (about 9″) to so guide the wheels of a gun-carriage as to prevent the axle striking the stanchions.

In cases for smaller galleries also the tenons are sometimes omitted at the bottom of the stanchions, the mortises in the ground-sills cut an inch or two deeper, and the stanchions kept from collapsing by keys driven in the mortises (Pl. XI, Fig. 13).

22. **Shaft and Gallery Frames** (Pl. XI, Figs. 14, 15, and 16) are made of scantlings, halved together at the ends, as shown in the figures. *Sheeting* is made of boards or planks of the necessary thickness, sawn to proper lengths, and bevelled at the ends. When sawn lumber is not available, the frames may be made of saplings, and in some cases poles may be used for sheeting.

The middle of each cap and ground sill, both in frames and cases, is distinctly marked by a shallow saw cut or otherwise.

23. The following table gives the dimensions, in inches, usually adopted for the pieces of cases, frames, and sheeting, for galleries of different sizes, viz.:

	Cases.			Frames and Sheeting.			
	Ground-sill.	Stanchion.	Cap-sill.	Ground-sill.	Stanchion.	Cap-sill.	Sheeting.
	In.	In.	In.	In.	In.	In.	In.
Great galleries	3	4	5	6×4	6×6	6×9	2
Common galleries	2	2	2	6×3	6×6	6×8	1½
Half galleries	2	2	2	5×3	5×5	5×7	1½
Branches	1½ or 2	1½ or 2	1½ or 2	4×3	4×4	4×5	1 or 1½
Small branches	1 to 2	1 to 2	1 to 2	3×3	3×3	3×4	1

The cases of branches and small branches are sometimes made very strong, with a view to resist rupture by the explosion of neighboring mines. For this purpose cases made of oak plank 4″ thick are used, and the branch near its end is packed full of scantlings provided with rope-handles at their ends for withdrawing them after the mine is fired. This packing is, however, of doubtful utility, since a compression of the case sufficient to call the resistance of the packing into play is very apt to produce a permanent deformation of the cases, which will jam the scantlings and prevent their removal. For convenience in use the pieces of cases should be of uniform width.

24. **Relative Advantages of Cases, and Frames and Sheeting.**—In favorable soil, cases, when they can be obtained, allow of more rapid progress and give a lining with a smooth interior. In very bad soil they cannot be used for the larger galleries.

Frames and sheeting can be used in all soils which admit of mining operations, and can usually be improvised from materials found in the vicinity.

25. **Sinking a Shaft by Frames and Sheeting.**—

The size and position of a shaft are usually determined by the character and direction of the gallery which is to start out from it. It is evident (Pl. XI, Fig. 17) that the clear width of the shaft must be enough greater than the outside width of the gallery to allow the side sheeting of the gallery to be freely inserted outside the frames of the gallery and inside those of the shaft; also, that the shaft frames must be so spaced as to leave a clear space at the bottom for the gallery. This space must be equal to the clear height of the gallery, increased by the thickness of the cap-sill, the sheeting, and one or two inches for easy working. This and the thickness of one frame being deducted from the depth of the shaft, the remainder may be divided up into a number of equal or unequal parts called *shaft intervals.* In order that the sheeting may not yield under the pressure of the earth, these intervals seldom exceed 4 feet.

The length of the shaft must be great enough to allow the miners to work freely, and to insert the sheeting for the first gallery interval.

The sheeting for both shafts and galleries is cut in lengths about 1 foot greater than the interval between frame centres.

26. The size and position of the shaft having been fixed, the top frame (Pl. XI, Fig. 15) is placed in position and secured by pegs, and the direction of its axis is accurately fixed by the score marks at the middle of the end pieces. The side and end pieces of this frame are respectively about 3 feet longer than those of the other frames, and are so halved together as to make of their ends four projecting *horns*, $1\frac{1}{2}'$ long, which keep the frame in place during the excavation of the first interval.

This frame is usually placed with its top flush with the surface of the ground. The miner proceeds to excavate the shaft with pick and shovel, making it large enough in plan to admit the sheeting outside the frame. Usually the first interval can be excavated without supporting the earth at the sides, which are vertical or slightly undercut, so that at the bottom of the interval the shaft will be large enough to admit the second frame, the sheeting of the first interval, and a system of wedges which hold this sheeting out from the second frame a distance somewhat greater than the thickness of the sheeting of the second interval. The verticality of the sides is determined by the plumb-line, and the size of the shaft by two gauge-sticks cut respectively to the outside length and width of the excavation, and distinctly marked at their centres.

To avoid the inconvenience of working under the top frame, the first interval is frequently marked out and excavated before the frame is fixed in its position.

When the shaft is deep enough the second frame is put in place and nailed together; the notches in the ends of the side pieces turned upward and those of the end pieces downward. The top and second frame are connected by nailing to them four battens of proper length (two on each side), which suspend the second frame from the top frame at the established interval. The second frame is placed vertically below the top frame by using the plumb-line and the scores in the frames.

The sheeting is inserted outside the top frame, bevelled end first, bevel outside, and pushed down until its top is flush with the top frame. The lower end of the sheeting is held out from the lower frame by suitable wedges, and the excavation of the second interval is commenced.

In ordinary soil the sides of the shaft will now require support. Sheeting is therefore introduced and pushed down as the excavation proceeds, and the wedges previously placed are removed to make room for the sheeting.

27. If the pressure of the earth becomes great enough to spring the sheeting-planks inward, an *auxiliary frame* is introduced. This is a frame similar to the shaft frames, but from 4 to 6 inches larger in outside dimensions.

The sheeting rests directly against the outside of this frame, and is thus held out far enough to allow the third frame to be placed and the wedges to be inserted as before.

The auxiliary frame is then removed and used in the next interval.

28. Successive frames are placed in the same manner until the one directly over the gallery is reached. Great care is taken to place this frame at exactly the right height, and the shaft is then continued to the required depth. A frame is placed at the bottom with its top at the level of the floor of the gallery, and the sheeting is allowed to rest directly against the outside of this frame. When the soil will allow it, the sheeting is omitted wholly or in part over the portion of the shaft which is to form the gallery entrance.

29. **Precautions.**—In sinking shafts especial care must be taken to make the excavation no larger than is required for placing the lining, since if a vacant space is left outside the lining the sides of the shaft may give way through its entire height, and fall against the lining with a blow which will crush it in.

This is often the cause of fatal accidents both in shafts and galleries.

30. **Partly-lined Shafts,** i.e., those in which the sheeting-planks are separated from each other by greater or less intervals, should only be used for small depths and when they are expected to stand for a very short time.

They are a constant menace to the miners, owing to the danger of their caving in, and in a much greater degree to the probability of stones, etc., falling from the unprotected parts and seriously injuring or killing the men at the bottom.

31. **Driving a Gallery with Frames and Sheeting.** —The direction of the gallery has already been marked by the scores on the shaft frames; but it must be verified by plumb-lines, and two small pickets be driven on the line of its axis, which is located exactly by small nails, one driven in the head of each picket.

Two gauge-rods are prepared, giving the extreme height and breadth of the excavation, i.e., the height of the frame plus two thicknesses of top sheeting, and the breadth of the frame plus four thicknesses of side sheeting. The middle of each gauge-rod is also plainly marked.

A gallery frame is set up against the side of the shaft (Pl. XI, Fig. 17), its ground-sill flush with the bottom frame of the shaft; or its stanchions may rest upon the shaft frame as a ground-sill.

The gallery frame is carefully located and fastened in position with battens and braces. The shaft sheeting is then forced down two or three inches with a bar, and the top sheeting of the gallery inserted and driven in until its end is supported by the earth. It is given the proper upward pitch by a scantling laid across it and secured to the shaft frames. The shaft sheeting is forced further down, the earth at the top excavated, and the top gallery sheeting advanced. As this work proceeds the side sheeting-planks are successively inserted and driven forward.

In this way the gallery is advanced one gallery interval, usually about 4 feet, when a second frame is placed. Its position is verified by the score marks; for direction, by a line; for grade, by a spirit, mason's, or field level; and for verticality, by a plumb-line. It is then secured in place by nailing battens to it and the preceding frame. Wedges are inserted between the frame and the sheeting, and the gallery is continued by the same methods (Pl. XII, Fig. 19). When the sheeting is advanced only by hard driving the frames are slightly inclined to the rear at first, and are afterwards driven forward until vertical.

32. If; while advancing the sheeting, the pressure upon it becomes so great as to spring it, a *false frame* (Pl. XII, Fig. 18) must be used. This consists of a cap-sill, ground-sill, and two stanchions, connected by mortises and tenons. The stanchions have tenons and the sills mortises at each end. The cap-sill is usually rounded on top and, for facility in setting up and removing, its mortises are longer than the width of the tenons. The latter are held in place by wedges when the frame is in position. The false frame is usually made of the same height as the common frames and, when side sheeting is used, wider by twice the thickness of this sheeting. When side sheeting is not used, its outside width may be equal to the clear width of the gallery.

In using the frame (Pl. XII, Fig. 19) the ground-sill is first placed accurately in position at a half interval in advance, the stanchions are set up, and the cap-sill placed upon them and wedged. The whole frame is then raised about 2 inches by folding wedges placed under each end of the ground-sill, and is secured by battens. The sheeting will now rest directly upon the cap-sill and stanchions, and have the proper inclination to clear the next frame by its own thickness, as is required.

The next frame is then set up, the wedges driven under the sheeting, and the false frame removed; which is easily done, owing to its construction.

33. When the soil is very bad a *shield* (Pl. XII, Fig. 20) is used to prevent the earth in front and above from caving into the gallery. In starting out from the shaft the following method is adopted: As soon as the top sheeting is sufficiently advanced and the shaft sheeting is forced down about 1 foot, the top plank of the side sheeting is inserted and driven forward about 2 feet, and the earth at the top of the gallery is excavated for from 6 inches to 1 foot in advance. A piece of plank a foot wide and in length equal to the width of the gallery is then placed directly under the top sheeting and against the face of the excavation, and is held in place by braces at its ends secured to the shaft lining. The shaft sheeting is then lowered another foot, the next plank of the side sheeting inserted, the earth excavated, and a second plank of the shield placed in the same way as before. This is continued until the entire face is covered. The top and side sheeting are then driven forward, and the top plank of the shield is removed and replaced in advance; after which each plank is removed and replaced in succession, as above described.

34. **Inclined Galleries.**—*Method of fixing the slope.*

—If the gallery instead of being horizontal is *ascending* (Pl. XII, Fig. 21) or *descending* (Fig. 22), the proper slope is obtained by using a *slope-block* whose edge is equal to the rise or fall of the gallery in one interval. This is placed upon the lower of two consecutive ground-sills, and the proper height of the other is determined by a mason's or spirit level (Fig. 21). If a field-level or a mason's level properly marked for the slope is used, the slope-block may be dispensed with (Fig. 22).

35. **Position of Frames.**—In driving *descending galleries* better progress will be made and less material used if the frames are set at right angles to the axis of the gallery (Pl. XII, Fig. 22); and this is the usual custom. In driving *ascending galleries* this is impracticable, and the frames are set vertically (Fig. 21). In all other respects inclined galleries are driven in the same manner as horizontal ones.

36. **Partly-lined Galleries.**—In very firm soil side sheeting may be omitted entirely, and in that less firm the side planks need not be in contact. When the side sheeting is omitted the width of excavation may be reduced to the clear width of the gallery, and the stanchions be let into the side wall flush with its surface. In this case the ground-sills are frequently omitted, the stanchions resting upon wooden blocks, stones, or directly upon the earth.

To save material, the planks of the top sheeting are sometimes more or less separated also. This can only be recommended when rapid and temporary work is required with limited materials; and in these cases the earth between the planks should be supported by a packing of sticks, brush, etc., etc.

37. **Change of Direction in Galleries.**—In changing

the direction of a gallery, the new direction is laid off by using a carefully made angle-templet (Pl. XI, Fig. 7) or slope-block, field-level, etc., and it is prolonged in the new direction by the methods already described. When the soil is firm enough to stand safely while excavating and lining one gallery interval, even if somewhat short, no difficulty exists in changing the direction of a gallery in either a vertical or horizontal plane, since the excavation in the new direction may be made so large that the miner working in it can place the new frames and introduce the sheeting and wedges. The gallery can then be carried on without diminution in size.

When the soil is bad, however, special arrangements must be made for introducing the sheeting.

38. Change of Slope.—To pass from a horizontal to an *ascending* gallery (Pl. XII, Fig. 21) it is only necessary to give the top sheeting the proper angle by holding down its back end with a piece of scantling placed across the gallery for that purpose; and, to give the side sheeting the proper inclination, cutting trenches in the bottom of the gallery for the lower pieces, if necessary.

In passing from a horizontal to a *descending* gallery (Pl. XII, Fig. 22) the roof may be carried forward horizontally, and the floor given the desired pitch by increasing the height of the consecutive frames, until enough head-room is obtained to allow the top sheeting for the descending gallery to be inserted at the proper height and angle. The frame at this point is made with a cap-sill (upon which the sheeting rests directly), and a second cross-piece below it, serving as a cap-sill for the descending gallery. From this point forward the frames may be set perpendicular to the axis of the gallery, as previously stated.

If the descending gallery is very steep and the horizontal pressure of the soil great, it may be necessary to strengthen the stanchions of the last two or three vertical frames by cross-pieces near their upper ends.

39. **Change of Direction Horizontally.**—Slight changes of direction of narrow galleries, either to right or left, may be made in a manner entirely similar to that above described for descending galleries, by widening the frames until the side sheeting can be inserted at the required angle, and strengthening the cap-sills, when necessary, with additional stanchions.

When the gallery is wide or the changes of direction abrupt, however, it is customary to drive the gallery entirely beyond the turning-point, and then break out a gallery in the new direction from the side of the original gallery.

40. **Returns.**—A gallery starting out from the side of another is called a *return*, and is *rectangular* or *oblique* according to the angle made by its axis with that of the original gallery, which is called the *gallery of departure.*

That the return may be broken out, the interval between the frames of the gallery of departure at this point must be such as to admit between the stanchions a frame and the side sheeting of the return (Pl. XII, Fig. 23). This part of the gallery of departure is called a *landing*, and its floor is made horizontal.

If the return is oblique (Fig. 24), its width measured along the gallery of departure will be determined by an oblique section, and may be so great that the strength of the lining of the gallery of departure will not allow the necessary length of landing. In this case a short rectangular return is first broken out from the side of the gallery of departure, and the new gallery is broken out from the side of this return (Fig. 25). The latter method diminishes the length of the landing when the change of direction is less than 45°.

41. The floor of a return is started at the level of the floor of its landing. In firm soils which will stand for a short time without support the first frame may be set up entirely outside the gallery of departure (Pl. XII, Figs. 24 and 25) and may be of the same height in clear as this gallery. When the soil is bad, however, and side sheeting is required in the gallery of departure, the first frame of the return must be set up against this sheeting in the interval between the stanchions of the landing (Fig. 23). This makes the clear height of the return at this frame less than that of the gallery of departure by a little more than the thickness of the sheeting.

The first frame of an oblique return should be so made that the sides of the stanchions will be parallel to the side walls of the return, thus giving a good bearing to the side sheeting.

In very bad soil, the first few frames of a return must be firmly braced to resist the backward thrust of the earth, by battens connecting them together and by struts across the gallery of departure. The latter are removed when the return is sufficiently advanced.

42. **A Complete Map** must be made of every system of mines, showing the centres of shafts, and the axes and slopes of all galleries; giving also the references and lengths of all landings, and the locations, references, and dimensions of all mine chambers.

43. **Working Drawings** must also be made from which sheeting can be cut to proper lengths and angle-templets, etc., cut and framed.

These can be easily and accurately drawn by remembering that, to allow the miners to insert the sheeting, every return must have such dimensions outside its sheeting that, if it were free to move, its lining could be slid back across its landing as a drawer slides in a table. The size of the landings and dimensions of frames having thus been determined, the parts of the galleries between them may be divided into intervals, which, for convenience, should be equal, since this will allow the sheeting to be cut to a uniform length.

44. **Sinking a Shaft with Cases.** — (Pl. XII, Figs. 26 and 27.)—A case of the required size is put together and accurately placed upon the site of the shaft, whose dimensions are marked upon the ground outside it. The case is then removed and the earth excavated to the depth of the case, which is placed in the excavation with its top flush with the surface of the ground. Its position is carefully verified, and it is secured in position by packing earth around it. The excavation is then continued for the depth of another case, which is put in place as follows, viz.:

One end piece is placed in position, the tenons of the two side pieces are inserted in the mortises at its ends, and the side pieces are pushed back into position; a pocket-shaped excavation is made with a push-pick beyond the end of one of the side pieces and running back three or four inches into the side wall; the remaining end piece is inserted in this far enough to allow the mortise at its other end to slip over its corresponding tenon; it is then drawn back, and the tenons at both ends fitted into their mortises. The notches cut in the sides of the pieces allow them to be easily handled.

The next case is placed in the same way, care being taken not to excavate two consecutive pockets at the same angle.

When practicable, it is well to fill up these pockets by stuffing in sods from below before placing the next case.

Some miners prefer to place one tenoned piece first, then the two mortised pieces, leaving a wedge-shaped opening behind one of them, and insert the other tenoned piece last, drawing the mortised piece forward upon its tenon.

When the sides of the cases are tenoned at one end only and secured by wedges at the other, they are easily placed in position without cutting out behind them.

45. Upon reaching the level of the top of the gallery, the pieces on the gallery side of the shaft are omitted if the ground is firm, but if it needs support these pieces are put in place and secured by cleats or braces, but the tenons are not inserted in the mortises.

46. **Driving a Gallery with Cases** (Pl. XII, Fig. 27).—This is practicable only when the soil is somewhat firm. In breaking out from the side of the shaft, a frame is first placed inside the shaft to support the ends of the shaft cases resting against the pieces which are to be removed. The latter pieces are then taken out and grooves are cut in the earth for the ground-sill, stanchions, and cap-sill of the gallery, and these are put in place in a manner entirely analogous to that described for sinking a shaft. This case is set flush with the inside of the shaft and supports the side pieces, whose tenons rest upon its stanchions. The projecting earth is then cut away and grooves are cut for the next case, which is placed in position and the excavation continued as before.

47. When the earth shows a tendency to cave, which it frequently will in great galleries, the cap-sill must be put in position and supported while the miner excavates the grooves for the ground-sill and stanchions.

To support the cap-sill, two crutches are used. A *crutch* (Pl. XII, Fig. 28) consists of an upright piece of timber carrying a cross-piece whose length is equal to the width of two cases. The upright piece rests upon the ground-sill of the case already placed, and is raised to the proper height by wedges. The part of the cross-piece which projects in advance is made 2 inches higher than the rear part, to support the cap-sill somewhat above its final level, so as to allow the tenons of the stanchions to be easily inserted. The rear part of the cross-piece is attached to the upright by an iron rod or short chain.

So soon as the case is set and adjusted to position the crutches are taken down by removing the wedges, and are replaced under the next cap-sill.

48. In very firm soil shafts and galleries are frequently driven with cases not in juxtaposition, but separated by greater or less intervals. Pieces of planks (which may be parts of cases) placed vertically and resting against the sides and ends of the cases in shafts, or horizontally and resting upon the cap-sills in galleries, and somewhat separated from each other, are used to support the earth between the cases.

The same remarks apply to this construction as to the similar one sometimes used when mining with frames and sheeting.

49. **Change of Direction in Galleries Lined with Cases.**—Slight changes in direction in a horizontal plane can be easily and gradually made by setting

each case a little obliquely to the one preceding it, and separating the stanchions on one side while they touch on the other, supporting the roof in the wedge-shaped openings, if necessary, with pieces of wood, etc. For an abrupt change, it is better to break out a rectangular return from the side of the gallery and pass from this into the required direction by gradual change.

If the return is to be of the same height as the gallery of departure, the cap-sills of the latter, for a distance equal to the width of the return, are lifted off the tenons of the stanchions by struts and wedges, and the first case of the return is set as in breaking out from a shaft; the ground-sill is, however, narrowed by the thickness of the stanchions of the gallery of departure so that the face of the case of the return is flush with the inside of the gallery of departure, and the ends of the cap-sills of the latter rest upon the cap-sill of the first case of the return.

50. Change of Slope.—In passing from a horizontal to a *descending gallery* the change may be made gradually, in a manner similar to that described for a change in horizontal direction, and the cases remain normal to the axis of the gallery. (Pl. XII, Fig. 31.)

To pass to an *ascending gallery* by the method above described would require the earth at the face of the gallery to be undercut in order to introduce the case, and this undercutting would be continued so long as the cases were normal to the axis of the gallery. This construction is, as a rule, impracticable. In ascending galleries, therefore, the cases are set with their stanchions vertical, while their cap and ground sills lie in the slope of the roof and floor of the gallery.

51. To conform with this requirement, and for convenience in setting up, the ends of the stanchions receive the proper bevel, while the sides of the tenons and mortises are made parallel to the sides of the stanchions. (Pl. XII, Fig. 12.)

52. **Shafts à la Boule.**—In order to place a charge of explosive directly under the ground occupied, or for other reasons, it is frequently necessary to sink a small shaft in the least possible time. For this purpose a modified form of cases is sometimes used, in which the ends are halved together instead of being tenoned and mortised. (Pl. XII, Fig. 29.) They are spaced at greater or less distances apart, according to the nature of the ground, and are connected together by battens. Stones, pieces of wood, etc., etc., are driven between them and the sides of the shaft to support the latter.

This construction is called a shaft à la Boule. It is expected to stand for a few days at most. Many other extemporized linings may be used for similar purposes.

53. **Blinded Galleries.**—Galleries cannot be successfully driven with less than 3 to 3½ feet of undisturbed earth over their sheeting. In making a descent into a ditch, or in pushing forward an approach in siege operations, it is often impracticable to lower the bottom of the trench of departure sufficiently to give the requisite cover for starting a gallery at once. In these cases *blinded descents* or *galleries* may be used, the tops and sides of which are supported by *blindage-frames*, or *blinds*, each of which consists of two side parts of 4″ × 6″ scantling 9′ long, united by two cross-pieces of the same section 3′ 8″ long, which are mortised or halved into them, leaving horns at each end 1′ long. (Pl. XII, Fig. 30.)

54. The galleries are constructed as follows (Pl. XII, Fig. 31): A double sap with a width of 8′ is broken out from the side of the trench in the direction required and is driven forward in the usual manner, but with a continual increase in depth, at a slope not exceeding $\frac{1}{4}$. The side slopes are as steep as the earth will allow. Two blindage-frames are set up vertically on the sides of the sap, 7′ apart in clear, with their tops at the level of the tops of the trench gabions, their bottom horns resting in holes dug for them. These frames are prevented from falling inward by another frame placed crosswise upon them, with its horns resting on their cross-pieces. The side of this top frame toward the front may be held up by a stake or crutch, and the second pair of frames be placed at such an interval that their horns will interlock with those of the top frame. Successive frames may be placed in the same manner. The covering or "roof" is formed by three or four layers of fascines placed across the trench on top of the frames, and covered with earth thrown back upon them as the work proceeds. The sides of the gallery are held up by fascines, etc., laid along outside the frames.

As soon as the bottom of the blinded gallery has reached the proper depth a mine-gallery may be started and carried forward.

55. The blindage-frames described above give to the gallery a clear width and height of 7′. For smaller galleries the blinds may all be made shorter and of lighter scantling; or, if desired, those for the sides may be of a different length from those for the top.

56. **Rate of Advance of Galleries.**—The following table gives an estimate of the men and tools required

for shafts and galleries, with the probable rate of advance in good soil:

Kind of Gallery, etc.	Men.		Tools.														
	N. C. Officer.	Miners.	Picks.	Miners' Picks.	Push-picks.	Shovels.	Miners' Shovels.	Miner's Truck.	Field-levels.	Measuring-rod 6'	Tracing-line.	Mauls or Sledges.	Canvas Buckets.	Rope-ladder.	Wheel-barrows.	Miners' Bellows.	Progress, ins. per. hour.
Great gallery or Blinded gallery	1	12*	4	2	2	8			1	1	1	1			4		12
Common gallery.	1	4		1	1	2	1	1	1	1	1	1				1	12
Half gallery......	1	4†		1	1	2	1	1	1	1	1	1				1	16
Branch gallery...	1	4†		1	1	2	1	1	1	1	1	1				1	24
Small branch.....	1	3		1	1		2	1§	‡	1	1	1				1	30 to 36
Shaft............	1	4‖		1	1	2	1		1	1	1	1	1	1			18 24

VENTILATION OF MINES.

57. The gases resulting from firing mines and from the lamps, bodies, and candles of the miners so vitiate the air in galleries that, unless means for ventilating

* Four of these may be unskilled laborers.

† No. required at commencement of gallery. Beyond 4 feet add one man, and one additional for every 20 feet of gallery.

‡ One mason's level.

§ Instead of a truck a canvas bag may be used. A large hoe or drag may be used to draw back the earth from the face of the gallery.

‖ These numbers are for small shafts of about 2' by 4'; large shafts require a larger force. They advance at about the same rate as galleries of equal cross-section.

them are adopted, the miners must eventually abandon them or become asphyxiated.

In ordinary circumstances, when no powder gases are present, a gallery cannot be driven safely more than 60 feet without ventilation.

The measures adopted for ventilating galleries consist, 1st, in forcing in fresh air; 2d, in drawing out foul air; and, 3d, in assisting the natural diffusion and circulation of the air through them.

58. The first is accomplished by forcing air through pipes, which may be of tin, wood, or common hose, leading to the point where ventilation is required. The air is forced in by the use of the miner's bellows or other apparatus already described. This method is simple in its application and places the fresh air where it is needed, but drives the foul air back into the galleries occupied by other miners. It is the only practicable method of ventilating single, long, narrow galleries and branches.

59. The second method may be applied to a system consisting of a number of galleries connected by trans versals, by so placing an exhausting fan as to draw the air out through one gallery, while by light wooden or canvas doors and screens the other galleries are so arranged that the fresh air, entering from the exterior, sweeps through the galleries occupied by the miners, and escapes through the unoccupied gallery leading to the fan, carrying the gases with it.

In this method a single large gallery may be ventilated by using a canvas partition placed near the top or on one side, so that the fresh air will go in on one side around the end of the partition and back by the other side to the fan.

This method has the advantage of carrying the gases away from the galleries occupied by the men, and supplying fresh air throughout those which are occupied.

The exhaust may be produced by a fire constantly burning at the foot of a shaft instead of by a fan.

The method is, however, complicated in its application, and can seldom be used for military mines.

60. The third method, or assisting natural ventilation, is carried out by cutting numerous cross-galleries connecting those which are near each other, by making air-shafts and bore-holes connecting the galleries with the surface of the ground, and, when practicable, by placing the openings of the shafts and galleries at different levels. This method will serve for a few men working leisurely in preparing countermines before an attack, but is entirely inadequate during active mining operations.

61. By the use of masks covering the face, and supplied with fresh air either through hose or from a reservoir of compressed air carried with him, a miner may work in galleries in which the air is irrespirable. The advantages which may frequently result from the time thus saved justify providing apparatus of this kind for use in mining operations.

MINE-CHAMBERS.

62. Mine-chambers to contain the charge of explosive are preferably nearly cubical in form, and if not charged at once, or if of large size, must have sufficient lining to support the roof and sides.

When they are above the level of the gallery they are arranged to drain into it. They are made large enough to contain the receptacle for the charge and to allow the charge to be placed in it. They are, as a rule, placed in short returns at one side of the branch or gallery, but may be at its end, above or below it. The mine-chamber frequently consists of so much of the end of the gallery as is necessary to contain the charge.

LOADING AND FIRING MINES.

63. **Preparing the Charge.**—The weight of the charge necessary to produce the desired effect is determined by the rules previously given. Its volume, if of powder or compressed gun-cotton, may be found by allowing 30 cubic inches to the pound; and if of dynamite, about 20 cubic inches.

If the mine-chamber is perfectly dry, and the mine is to be fired at once, a layer of straw may be placed upon the floor of the chamber and the charge contained in canvas bags laid upon it. When the ground is more or less wet, or when the mine is not to be fired immediately, the charge should have a water-proof covering, which may be a thoroughly calked and pitched box, an ale-barrel or beer-keg, the metal barrels in which powder is shipped, or India-rubber or pitched-canvas bags, —depending upon the amount of moisture present and the time that the charge is to remain in place. Many of the high explosives are not affected by dampness, and but little if any by water; but to secure the fuse and its connections from injury, and to remove all danger of misfires, the explosive should in all cases be protected from water if practicable.

64. **Distribution of Fuses in the Charges.**—Gunpowder will explode with full effect if ignited, but to

prevent the explosion of the central part of a large charge scattering the exterior portion before it is ignited a number of fuzes should be used. They may convey fire only, but must all be ignited by the firing apparatus, and simultaneously. One fuze to each 100 lbs. of powder is not too great an allowance; but when lack of time or appliances does not admit of placing a number of fuzes, the desired effect may be obtained by increasing the charge of powder and using one fuze. (See Abbot, Prof. Papers Corps of Engineers, No. 23, 1881, p. 62, for number of fuzes needed; and pp. 244–51 for simultaneous ignitions.)

The high explosives detonate with full force only when exploded with a detonating fuze. Under favorable conditions one fuze will detonate a very large charge, but cases arise in which a portion of the charge explodes and the remainder does not. To insure the best results, therefore, it is desirable to distribute fuzes throughout a large charge, at the rate of perhaps one fuze to each 50 lbs. These fuzes should contain from 20 to 30 grains of fulminate of mercury, which is itself very sensitive to shock, and has in a high degree the power of detonating the other explosives. One fuze only (or, for safety against defects, two or three) need be connected with the firing apparatus, the others serving to reinforce and carry on the wave of explosion after it is started—differing in this respect from their use with charges of gunpowder.*

* In the blasting at Hell Gate, 1870–76, several cases occurred, both with nitro-glycerine and compressed gun-cotton, in which a part of the charge exploded, breaking the blast-hole nearly to the bottom, and leaving the remainder of the charge unexploded in the bottom of the hole, from which it was subsequently recovered. Similar results were

65. Character and Construction of Fuzes.—Formerly, for firing mines, trains of powders put up in linen tubes, quick-match, and other similar devices were used. Electric-blasting apparatus is now in such common use that it will always be available for any extended mining operations. For single mines with small charges it may, however, be necessary sometimes to resort to the older method of firing, the apparatus for which can be readily improvised. But even in these cases "Bickford" or "Safety" fuze will usually be available, and may be used alone for firing gunpowder, or with a common fulminate-of-mercury "blasting-cap" for high explosives. It burns at the rate of about 4 feet per minute. Very quick-burning fuzes are also made which may be used at times (e. g., *Bickford Instantaneous*, which burns at the rate of 120 feet a second; *Gomez Lightning*, which burns so rapidly that it may almost be said to detonate; etc.) Great care must be taken not to mistake them for the common Bickford.

66. Electric Fuzes are made of three general classes: First, those which are fired by a spark from a high-tension machine; second, those which are ignited by a current from a battery or "dynamo;" third, those which can be fired by either. (Abels, etc.)

67. Those of the second class are manufactured in large quantities, and, in connection with a portable dynamo or "blasting-battery," are almost universally used for blasting operations throughout the United States.

These fuzes (Pl. XII, Fig. 32) are made up of two insulated copper wires, *A*, *A*, passing through a small

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obtained in experiments, conducted by Capt. (now Major) Heuer, 1875–6, with long tubes filled with nitro-glycerine. See also Encyc. Brit., vol. xvi, "Mining," for similar information.

cylindrical block of insulating material, *B*, and terminating about $\frac{1}{16}$ inch above its end. A very fine platinum wire, *C*, about $\frac{1}{1000}$ inch in diameter and $\frac{1}{8}$ inch long, connects the ends of the insulated wires. Surrounding the platinum wire is a small quantity of gun-cotton, mealed powder, or fulminate of mercury, *D*. A copper capsule containing 15 to 30 grains of fulminate of mercury, *E*, is pressed down over the cylindrical block far enough to bring the fulminate in contact with the material surrounding the platinum wire, and the whole fuze is then coated with a water-proof composition. The insulated copper wires are cut to various lengths for convenience in connecting with the conductors or lead wires from the battery.

68. Fuzes of the first and third classes are now but little used. Many of them are unsatisfactory and dangerous. They differ in construction from those of the second class principally in that the platinum-wire bridge is omitted, and the exploding spark or current passes from one insulated copper wire to the other through a material which is ignited by it.

69. **Placing the Fuses in the Charges.**—A certain number of cartridges or packages should be selected, each fuse inserted and well packed in the explosive, and the wires or free end of the safety fuse brought out through the opening, which should be made waterproof, if necessary, by securely closing and thoroughly pitching it. The wires or exterior part of the fuse should then be securely fastened to the outside of the cartridge, so that an accidental strain upon them will not break the waterproofing or move the fuse from its place. They are then coiled up and remain so until the cartridge is placed in the general charge of the mine.

70. Several of the high explosives congeal at a temperature above the freezing-point of water, and in this state are less sensitive to shock, and explode with difficulty if closely packed in cartridges as usually delivered from the factories. They explode more readily when in the form of a powder. When using them in cold weather, therefore, each fuse should be put in a cartridge loosely filled with the powdered explosive, or with some high explosive not affected by cold. Others need special primers to cause detonation. The fuses should, of course, be placed in these primers.

71. **Placing the Charges.**—The charge is placed in the mine-chambers, either in the dark, by light reflected through the galleries, by closed lanterns carefully placed and guarded, or, when practicable, by incandescent electric lights. It is carried through low and narrow galleries on men's backs or in miner's cars, and should for this reason be put up in packages not exceeding 50 lbs. in weight.

It is packed in the chamber with great care, and under the immediate supervision of the responsible officer. The packages containing the fuses are distributed uniformly throughout the mass, and the wires uncoiled and led back into the gallery, the free ends of the two wires of each fuse having been previously twisted together for safety against electric currents and for identification.

These wires, which must be long enough to reach through the tamping, are all collected together and led back through it in a wooden or other conduit, which protects them from injury while tamping the mine.

When electric lights are used, great care must be taken to remove the light and all its conducting wires before the wires of the fuses are uncoiled and laid along the gallery.

72. **Tamping.**—Mines are tamped with sods and earth, wood and earth, sand-bags, etc., etc.

When sods are used the branch is filled for about 3 feet with sods carefully laid and packed with the joints filled with earth. About 3 feet of earth is solidly packed against this, then alternate layers of sods and earth until the desired length of tamping is obtained. To tamp with wood and earth or sand-bags, a wooden shield is first placed across the branch and firmly braced; behind this, earth is solidly packed or sand-bags carefully laid until the required length of tamping is obtained. Sometimes a second shield is put up behind the earth tamping, and firmly braced in position. The strength of the tamping is also increased by pieces of timber crossing each other diagonally, with their ends resting against the sides of the branch. Sand-bags make the best tamping, as they offer high resistance and are easily placed and removed.

The tamping should have a length equal to at least $1\frac{1}{2}$ times the line of least resistance of a common mine corresponding to the charge, and if not of the best quality, to twice this line.

73. **Firing Mines.**—If electric fuses are used the main conductors or lead wires coiled upon a reel are taken in and the ends properly joined to the fuse wires; they are then led through the galleries, attached to the battery, and fired at the designated instant. Under no circumstances should the main lead wires be connected to the battery or dynamo until everything is ready for firing.

If a Bickford fuse is used its length is regulated to the desired time of firing from its known rate of burning. The miner lights the end and retires; the explosion takes place approximately at the calculated time. With the "Lightning Gomez" or similar fuses a length reaching to the firing-point may be used. It is lighted at the desired time, and burns with such rapidity that for lengths not exceeding 300 or 400 feet the time of burning is inappreciable.

Instead of using great lengths of these fuses, they may be cut shorter and their ends be brought together and inserted in a little mealed powder which is fired by a piece of safety-fuse, slow match or port-fire, etc., long enough to give the miner time to retire to a safe distance after igniting it.

Bickford fuse is best ignited by a piece of cotton wicking soaked in oil and loosely tied around it. This, when lighted, will burn through the covering and set fire to the composition. By this device many fuses may be ignited in a short time. A slow match or "touch-paper" for igniting quick-burning fuses or powder-trains may be made by soaking common paper in a strong solution of nitre and drying it.

CAMOUFLETS BY BORING.

74. In favorable soil a camouflet or small mine may sometimes be placed and fired very quickly by the following process:

A hole 2″ to 3″ in diameter and of the desired depth is bored in the proper direction with an auger or boring-bar. A cartridge containing from ½ lb. to 2 lbs. of dynamite is pushed down to the bottom and fired. The explosion increases the diameter of the hole somewhat throughout, and obstructs it more or less with loose earth. At the same time it enlarges the part near the seat of the charge into a bottle-shaped cavity, whose size varies with the charge used and the nature of the soil. The hole is rapidly cleared out with a long-handled scoop, the cavity filled with powder, primed, and fired.

The enlargement made by the charges of dynamite above given may contain from 50 to 100 lbs. of gunpowder under favorable circumstances.

75. In stony soil this method becomes very difficult if not impracticable; and when it can be used the preliminary explosion of dynamite vitiates to a greater or less degree the air of the shaft or gallery from which the boring is made, and also informs the enemy of the progress and intention of the miner.

To remove the latter objections, the English authorities recommend the use of holes 6″ or 8″ in diameter, bored with earth-augers, charged to a length of 2 or 3 calibres, and well tamped. When applicable, this method is manifestly a great improvement upon the other; but the auger is so liable to be stopped by stones which a boring-bar might break or push to one side, that it can only be applied in very favorable soil.

CHAPTER III.

ORGANIZATION AND TACTICS OF MINES.

76. Organization of Mines.—Underground warfare is conducted in the dark, in bad air, with constant danger of caving earth, suffocation by noxious gases, destruction of men and galleries by intentional explosions of hostile mines or accidental ones of our own, in addition to the usual dangers and difficulties of opening and supplying the mines under the close fire of the enemy.

These considerations necessitate the rejection of all complicated systems in the attack, and in the work carried on by the defence during the siege.

Ignorance of the point to be selected for attack, and the great expense of permanent countermines, also require those prepared beforehand by the defence to conform to simple and economical systems.

For this reason it is not necessary to give in detail the systems proposed by the older writers. They are described in most of the extended treatises on military engineering.

77. The Attack.—The object of the attack is to advance his galleries in the most rapid manner possible, with the best available system of ventilation, and to place his mines in such position as to break up the galleries and destroy the men, materiel, and works of the defence, both above and below ground; or to form connecting craters which may be occupied and converted into parallels, trenches, etc.

78. To accomplish this, when no natural ravine exists, a deep trench or "*lodgment*" is made, usually connecting the entrances of all the galleries and serving as a communication between them, and as a depot for such supplies as must always be at hand.

From this lodgment the galleries are started by a shaft, blinded descent, or mining-gallery; the method depending upon the depth to be reached and the thickness of cover required.

The entrance of each gallery is protected from horizontal and vertical fire, and from splinters, by a bomb-proof cover and traverses of sufficient thickness and strength.

The galleries are generally driven in lines nearly parallel, and at such distance apart that the hostile miners working at any point between them will be heard, either from the main galleries or from returns called "*listening-galleries*" or "*listeners.*" *

Depending upon the depth at which they are placed and other circumstances arising in different cases, the main galleries in various sieges have been placed at distances apart varying from about 8 to 30 yards.

These galleries are connected at intervals by "*transverse galleries*" or "*transversals*," which assist the ventilation very much and give additional communication between them.

Branches for placing mines are driven in prolongation

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* In compact soil the sound of a pick can be heard up to about 40 feet, and at about 20 feet when the miners are working as quietly as possible.

of the gallery or obliquely to the right or left, and, when the gallery is at a low level, inclining upward so as to shorten the line of least resistance, economize powder, and diminish the injury to the gallery and branches, resulting from the explosion of the mine.

79. When the hostile miners come within striking distance of each other, each strives to run his galleries directly toward the other in order to avoid exposing its flank to the hostile mine; thus diminishing as much as possible the injury resulting from its explosion.

80. The mines of the attack are generally overcharged in order to do the greatest possible injury to the mines of the defence, and to open large craters, but undercharged mines and camouflets are also used at times.

81. **The Defence.**—The object of the defence is to retard or stop the advance of the attack, by the destruction of his mines and miners, without forming craters which will assist him in making his parallels and approaches.

82. For this purpose his galleries must satisfy nearly the same conditions as those of the attack. They usually start out from the counter-scarp gallery or from a parallel gallery a little in advance of it, and extend to a greater or less distance from the work, according to the time and expense allowable for their construction. For permanent works they are frequently prepared in time of peace, and lined with masonry. It is particularly for this class of countermines that many elaborate systems have been designed for completely covering the ground, and for throwing up the same earth several times by mines placed at different depths and exploded in succession. For reasons previously given, these cannot be recommended.

83. A simple system of galleries placed as far below the surface as practicable, parallel or slightly diverging, connected when necessary by transversals whose lines prolonged pass inside the enceintes, and with branches fulfilling the same conditions driven out for listening-galleries, will, under the direction of an energetic officer, fulfil the conditions of defence as well, probably, as any that can be devised.

The branches leading to mine-chambers can be driven out from the main galleries, transversals, or listeners, as may be desired; and if the hostile miners obtain possession of any part of the system and blow it up, the lines of craters formed will be so swept by the fire of the work that they can hardly be occupied by the enemy.

84. As a rule, the mines of the defence will be undercharged or camouflets, to avoid the formation of exterior craters, but the rule is not without exceptions.

85. **Shaft Mines**, mines placed in vertical shafts, are used by both attack and defence for destroying galleries, etc., in their vicinity. By the attack they are usually placed in craters already formed, or in other places protected from hostile fire. A shaft is sunk rapidly, generally "à la Boule," heavily "overcharged," filled up with earth, and fired.

The defence may use the same method or may sometimes prepare them beforehand, tamping them and leaving a tubular opening through the tamping for loading and firing them.

MINE TACTICS.

86. The tactics of mine warfare result directly from the consideration above given. The special details of

attack and defence vary in each particular case. The reports of mining operations in different sieges* supply precedents and give suggestions for future operations of a like character.

87. **Todleben's Rules.**—The general principles of mine tactics have been laid down by General Todleben from his experiences at Sebastopol (in Royal Engineers Occasional Papers, vol. i., 1877). They may be summarized as follows:

88. **The Attack.**—The besieger should advance by several galleries, securing those on the flank by listeners. He must be active and persistent, as the enemy will use every available moment to develop his countermines. When he receives the first camouflet of the defence he must hasten to fire his overcharged mines in the uninjured branches, in order to destroy the hostile countermines. He will generally suffer losses more or less heavy from this epoch forward, but must submit to them; since too much circumspection and delay will almost always result in complete failure.

Before firing the overcharged mines he must have everything in readiness to occupy and intrench himself in the craters formed; to open communication from the trenches to the craters either by sap or by forming a line of connecting craters; and for constructing shelters for the party occupying the craters and holding them against the sorties of the defence.

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* E.g., the sieges of Candia (1667–9), Schweidnitz (1762), Silistria and Brailow (1828–9), Sebastopol (1854–5), Vicksburg (1863), Petersburg (1864), etc., etc., and the experimental mining operations at Graudenz in 1862. See Woolwich and Chatham Text-books, Mahan's Field Fortifications, Guerre de Siège Blanchecotte et Chauvot Fontainebleau, etc., etc.

After occupying the craters, he should drive forward his galleries from them at once, unless the besieged has anticipated him and surrounded the craters with branches—which may be assumed to be the case if any delay has occurred in occupying it. In this case he should sink shafts à la Boule, heavily overcharged, and fire them, and immediately occupy the new crater and push out from it; and thus progress as rapidly as possible, by constantly placing and firing overcharged mines, whose craters will, with little alteration, form both communications and parallels.

When the fire of the defence upon the crater is so severe that a deep shaft cannot well be sunk, a shallower one with correspondingly small charge is first sunk and fired, and a deeper one is sunk from the crater thus formed.

The overcharged mines should be well tamped when time permits. If not well tamped the charge should be increased (*or high explosives used.*—J. M.).

89. **The Defence.**—The defence should push out his galleries as far as possible and at the earliest practicable date, connecting them by transversals for ventilation, and holding them at a level below any likely to be reached by the attack.

When near the enemy, he should stop work several times a day and listen for sounds from the hostile miners which will locate their position.

Hearing the sound of the enemy's miner, he may work toward him noiselessly, or prepare and charge a chamber and await the approach of the miner toward it, listening at the point where the hose trough (*tube for fuse wires.*—J. M.) comes through the tamping until the enemy is near enough to justify firing. Judgment as to distances must be formed from practice obtained while driving the countermines.

To avoid forming craters on the surface, and to do the greatest possible damage to the besieger's works, the besieged should not fire his mine until the enemy's distance from it is less than the line of least resistance reckoned toward the surface.

When this condition is fulfilled, he may give to his camouflet a charge of from $\frac{3}{10}$ to $\frac{4}{10}$ the charge for a common mine placed at the same depth, since the charge will produce its principal effect upon the enemy's gallery, and but little upon the surface.

Special care must be exercised by the defence to avoid premature explosions, since a mine fired at too great range damages only his own branch, and may make a crater; thus working directly to the advantage of the attack, who may prepare an overcharged mine or sink a shaft à la Boule in the crater thus made.

As successive explosions of necessity damage the branch in use, to avoid falling back, another one should be prepared as a reserve before the first is disabled, and at a little distance from it.

After the attack has fired his overcharged mine, the defence, by a strong fire of canister, musketry, etc., should prevent him from occupying the craters, and if he takes possession, should drive him out by a continuous mortar fire, keeping him from completing his communications by fire from guns.

The defence should push forward branches and establish himself under the slope of the craters, in front and on both flanks, and by exploding camouflets prevent the attack from driving galleries or sinking shafts à la Boule.

When the nature of the soil admits, many of the camouflets will be placed by boring. Should the defensive measures above and below ground not debar the enemy from establishing himself in the crater, the defence may establish overcharged mines immediately in its front, with a view to destroying the advancing galleries of the attack, blowing up the men and their lodgment in the crater, and opening up the latter to the fire of the work.

Shafts à la Boule being very dangerous for the countermines, the defence should do his best to prevent their use, by artillery and musketry fire above ground, and by camouflets placed by boring under ground. In addition, he must take advantage of every favorable opportunity to delay the progress of the attack by sorties from the works.

90. **Remark.**—In underground warfare the besieger has a decided advantage, but the besieged, by a cool consideration in handling his mines, and by persistently holding back the attack, foot by foot, may very greatly retard it, or even cause such losses and delays as to lead to its being abandoned.

BREACHING BY MINES.

91. The attack having reached the scarp of the work, mines are prepared for breaching the counter-scarp and scarp.

Experience shows that the charges are best located in rear of the counterforts when they exist, or at equal intervals along plain walls. The charge should not be placed immediately in contact with the masonry, but in the earth behind it, and at a depth below the top of the wall equal at least to $1\frac{1}{2}$ the L. L. R., measured to the face of the wall.

The charge should be estimated by the rules already given, and increased by 20 to 30 per cent, so as not only to throw down the walls, but also to break up the earth and form a practicable breach.

92. The galleries for placing the chambers behind the counterscarp are branches from the gallery of descent into the ditch; those behind the scarp may branch out from a gallery driven under the ditch, when water or rock do not forbid, or from a gallery driven through the scarp wall after crossing the ditch by sap or by a bridge.

93. To start the gallery through the scarp wall, a miner is "*attached*" to the wall by protecting him from fire along the ditch, from sorties, and from loaded shells, etc., rolling down upon him from the parapet by suitable traverses and splinter-proof.

This operation is of course very dangerous, and is generally impossible unless the fire of the defence along the ditch is previously silenced. To expedite the work of the miner a gun is sometimes brought down through the gallery, and the face of the wall is shattered by its fire before the miner is "attached."

CHAPTER IV.

BLASTING AND DEMOLITIONS.

BLASTING.

94. **Blasts** are small mines used generally for breaking up rocks, or masonry in demolitions.

95. Holes for placing the charges are drilled usually with *drill-bars* or *churn-drills*, known also as *jumpers.*

These are steel bars sharpened to a chisel edge. The *drill-bar* is usually held by one man and struck with a hammer by another; it is turned slightly after each blow in order to make a round hole.

For small holes the driller holds the drill in one hand and strikes with the other.

The *churn-drill* is a longer bar, generally sharpened at both ends and enlarged in the middle. It is used for drilling vertical holes by raising and dropping it in the holes, turning it slightly after each blow.

96. The *charge* may be gunpowder or high explosive. If the former, it must be thoroughly tamped. If the latter, tamping will greatly increase its effect; but it is in some cases preferable to obtain the desired effect by increasing the charge and saving the time taken in tamping.

97. Blasts are fired by electric fuses, Bickford fuse, firing-tubes, needles, etc.

The fuses have been already described.

The *firing-tube* is a very small iron pipe, which is inserted in the powder charge and the tamping rammed around it.

After the tamping is finished the tube may be filled with fine powder poured in it if the hole is vertical or inclined downward, or straws filled with powder may be inserted if it inclines upward or is horizontal. A "squib" of wet powder is also sometimes placed in the tube and ignited, when it passes down the tube like a rocket and fires the charge.

The *needle* is a smooth copper wire, longer than the depth of the hole. It has a ring handle, by which it may be turned around and withdrawn. It is inserted in the charge, the tamping is well rammed around it, and it is withdrawn, leaving a pipe in the tamping, through which fire may be communicated, as described for the firing-tube.

98. **Tamping.**—The best and safest tamping is perfectly dry silicious sand, poured in the hole so as to fill it completely, but not rammed. It cannot be used in holes which incline upward nor when the needle is used.

In such cases moist clay, brick-dust, etc., are used The first layers are pressed in upon the charge, and the subsequent ones thoroughly rammed down with a copper tamping-bar. A hammer is used with the bar, when necessary, in deep holes and hard rock.

With high explosives no tamping should be used except dry sand or water. Holes which incline upwards should receive an extra charge and be untamped.

99. **Determining the Charge.**—The charge of gunpowder or high explosive required for any particular hole in ordinary blasting can be best estimated by an experienced blaster. If one is not to be obtained,

an approximate estimate for the first experiment may be made from the formulas (counting the high explosives about four or five times as strong as gunpowder for ordinary use), and the charges for subsequent blasts may be estimated from the effects of those first fired.

100. Precautions.—If a *tamped* hole misses fire *it should never be cleared out for recharging.* A new hole should be drilled near, but not breaking into it.

Electric fuses or Bickford fuses (with blasting-caps for high explosives) should always be used when they can be obtained.

DEMOLITIONS.

101. Deliberate Demolitions, such as the destruction of walls, casemates, etc., in time of peace, or at a distance from the enemy in time of war, should be so made as to economize powder and work. To accomplish this, the mines and blasts should be located where they will produce the best effects attainable, and the charges should be proportioned to the work required from them.

The table previously given (p. 124) will serve as a guide for computing the first charges used, and from the results of these the charges of subsequent ones may be determined.

Judgment must be used in placing the charges, so that, when possible, they will destroy the supports and allow the superstructure to break up by falling.

The charges will usually be placed in chambers under or hollowed out in the masonry. Sometimes they are more advantageously placed in a trench outside and close to the foot of the walls. They should always be well tamped: when in mine-chambers, by methods previously described; when in trenches, or laid along the exterior of walls, by loading them with earth, etc., until the line of least resistance passes through the wall to be destroyed.

102. Hasty Demolitions are made when the time available for the work is limited.

The structures usually destroyed are houses, walls, stockades, bridges, tunnels, canal-locks, railroads, rolling-stock, etc., etc.

The time does not usually allow the charge to be placed in the most advantageous position or to be properly tamped. For this reason the high explosives are best suited for this kind of work, and large charges are a necessity.

103. Houses and Magazines are best destroyed by placing several charges with connecting trains inside and along the walls, laying strong timbers upon them, with struts from the timbers to the floors and roof above; barricading the doors and windows from within, and firing the powder from a safe distance without.

104. Walls.—A wall not exceeding 3 or 4 feet in thickness may be breached by charges of gunpowder placed at intervals along it. Calling the thickness of the wall in feet t, the charge in pounds may be $3t^3$, placed at intervals of $2t$.

For gun-cotton the Woolwich rule calls for charges in pounds of from $\frac{1}{3}t^2$ to $\frac{1}{2}t^2$ per running foot. Experiments made in New York with dynamite indicate that the charges should be at least $\frac{1}{2}t^2$ per running foot, and for very good masonry should exceed this.

A charge of dynamite of $\frac{1}{2}t^2$ per running foot will be given by a cylindrical cartridge whose diameter in inches equals the thickness of the wall in feet.* The effect of the charge will be very much increased by throwing over it even a very light tamping of earth or sand.

105. Stockades.—A strong stockade or palisade may be broken down by charges of from 40 to 60 lbs. of gunpowder placed in contact with it, and preferably covered with sand-bags. 10 or 15 lbs. of high explosive should produce about the same effect.

106. Bridges.—Arched bridges are best attacked in the piers if high and thin, or at the haunches and crown of the arch. Two or more charges in the length of the pier, or width of the roadway, will be more effective than the same amount in a single charge at the middle.

The charges should be placed in chambers cut in the piers or down through the roadway to the back of the arch.

The abutments of single-span arches are generally very strong, and the haunches well covered with earth and masonry. In hurried work, therefore, the crown will generally be selected, a trench dug down to it across the roadway, the charge placed in the trench, tamped if possible, and fired.†

High explosives, from their shattering effect, are perhaps most advantageously used by suspending them beneath and in contact with the arch at the crown and haunches. The plank or timber upon which they are

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* A dynamite cartridge 1″ in diameter weighs ½ lb. per running foot; 2″ in diameter, 2 lbs. per ft.; etc.

† Capt. Schaw's (R. E.) rule for an untamped charge of gunpowder placed as above described is C lbs. $= \frac{3}{8}$ L. L. R.$^2 \times B$, in which $C =$ charge in pounds, $B =$ breadth of bridge in feet, and L. L. R. = line of least resistance in feet, measured through the arch.

placed should be as heavy as possible, in order to act as a partial tamping, and should be drawn up so that the explosive will be in actual contact with the soffit of the arch.

Under these circumstances they should produce as great an effect as four or five times their weight of gunpowder.

Iron and wooden truss-bridges should be thrown down by breaking the main braces near the piers, or the chords near the centre, by charges placed in a joint if possible. High explosives are particularly valuable for this purpose.

In wooden bridges they may be placed in auger-holes bored for them, and in iron bridges inside the hollow members, between eye-bars, or in other similar places.

107. **Tunnels, Canal-locks,** and similar constructions must be attacked with large charges, so placed as to temporarily or permanently disable the work, as may be considered necessary. The location of each charge should be determined and its amount computed from these considerations before the destruction is attempted.

A temporary obstruction is frequently all that is necessary or desirable for these works, and the damage done to them should be carefully regulated with a view to their subsequent repair and use.

108. **Railroads.**—Railroads are temporarily disabled by tearing up the track, making hot fires of piles of ties, placing the rails upon them so that they will heat and bend by their own weight; or, better still, twisting the rails while hot by suitably-shaped steel hooks and wooden levers of the kind devised by General Haupt (Pl. XII, Fig. 33). Rails so twisted cannot be again used until re-rolled.

109. **Rolling-stock.**—Railroad cars may be disabled by breaking one or more wheels with sledges, or may be destroyed by burning. Locomotives may be disabled temporarily by carrying away the smaller parts of the mechanism, or permanently by breaking the engine-cylinders with sledges; bursting the boilers or burning out their fire-boxes by drawing out nearly all their water, fastening down the safety-valves, and building a hot fire in the furnaces; or by making a hot fire under them so as to heat and thus bend or warp the reciprocating parts of the machinery.

110. In all hasty demolitions with explosives the charges should be well in excess of those computed by the ordinary rules: first, because the explosives will not be so placed as to act to the greatest advantage; and, second, because the demolition should be *immediate* and *complete.*

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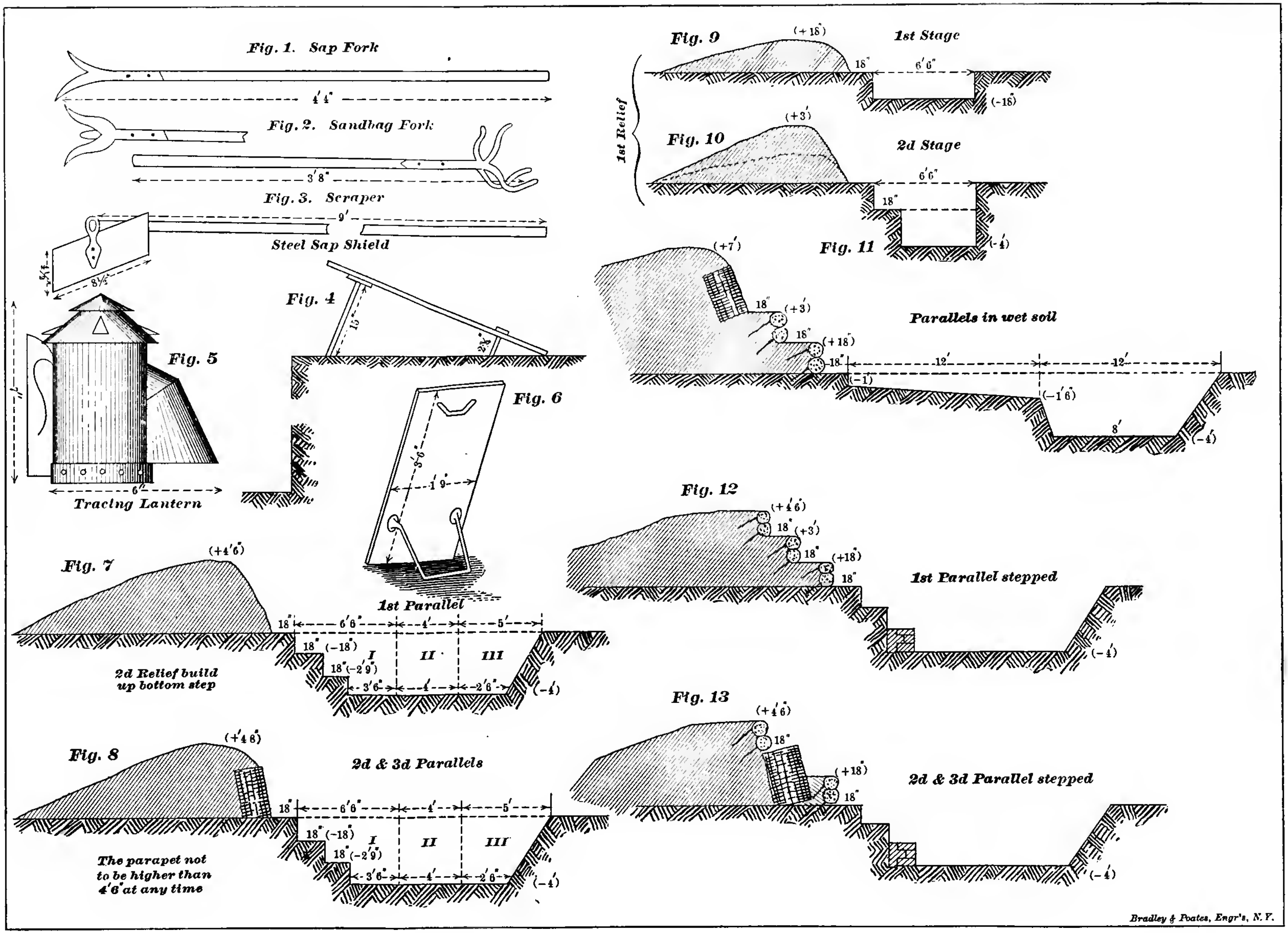

Fig. 1. Sap Fork
4' 4"
Fig. 2. Sandbag Fork
3' 8"
Fig. 3. Scraper
9'
Steel Sap Shield
8½"
Fig. 4
15"
Fig. 5
6"
Tracing Lantern
Fig. 6
3' 6"
1' 9"
Fig. 7
1st Parallel
(+4' 6")
18"
6' 6"
4'
5'
18" (-18")
18" (-2' 9")
I
II
III
3' 6"
4'
2' 6"
(-4')
2d Relief build up bottom step
Fig. 8
2d & 3d Parallels
(+4' 6")
The parapet not to be higher than 4' 6" at any time
1st Relief
Fig. 9
1st Stage
(+18")
6' 6"
(-18")
Fig. 10
2d Stage
(+3')
(-4')
Fig. 11
Parallels in wet soil
(+7')
(+3')
(+18")
12'
(-1')
(-1' 6")
8'
Fig. 12
1st Parallel stepped
(+4' 6")
Fig. 13
2d & 3d Parallel stepped
Bradley & Poates, Engr's, N.Y.

Plate II

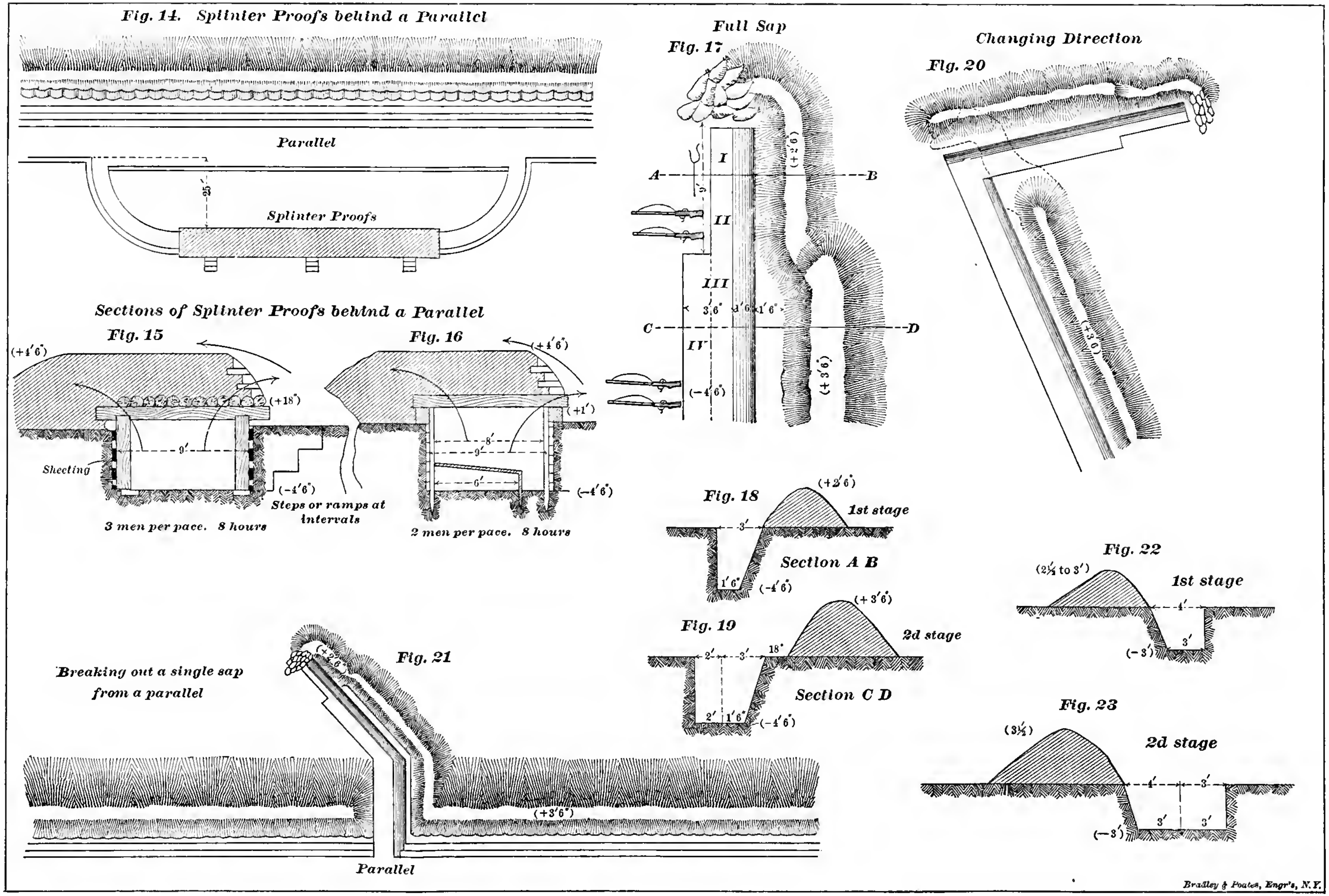

Fig. 14. Splinter Proofs behind a Parallel
Parallel
25'
Splinter Proofs
Sections of Splinter Proofs behind a Parallel
Fig. 15
(+4'6")
(+18")
9'
Sheeting
(-4'6")
Steps or ramps at intervals
3 men per pace. 8 hours
Fig. 16
(+4'6")
(+1')
8'
9'
6'
(-4'6")
2 men per pace. 8 hours
Full Sap
Fig. 17
I
II
III
IV
A
B
C
D
(+2'6")
(+3'6")
(-4'6")
Fig. 18
(+2'6")
1st stage
3'
Section A B
1'6"
(-4'6")
Fig. 19
(+3'6")
2d stage
2'
3'
18"
Section C D
(-4'6")
Changing Direction
Fig. 20
(+3'0")
Fig. 21
Breaking out a single sap from a parallel
(+2'6")
(+3'6")
Parallel
Fig. 22
(2½ to 3')
1st stage
4'
3'
(-3')
Fig. 23
(3½)
2d stage
4'
3'
(-3')
Bradley & Poates, Engr's, N.Y.

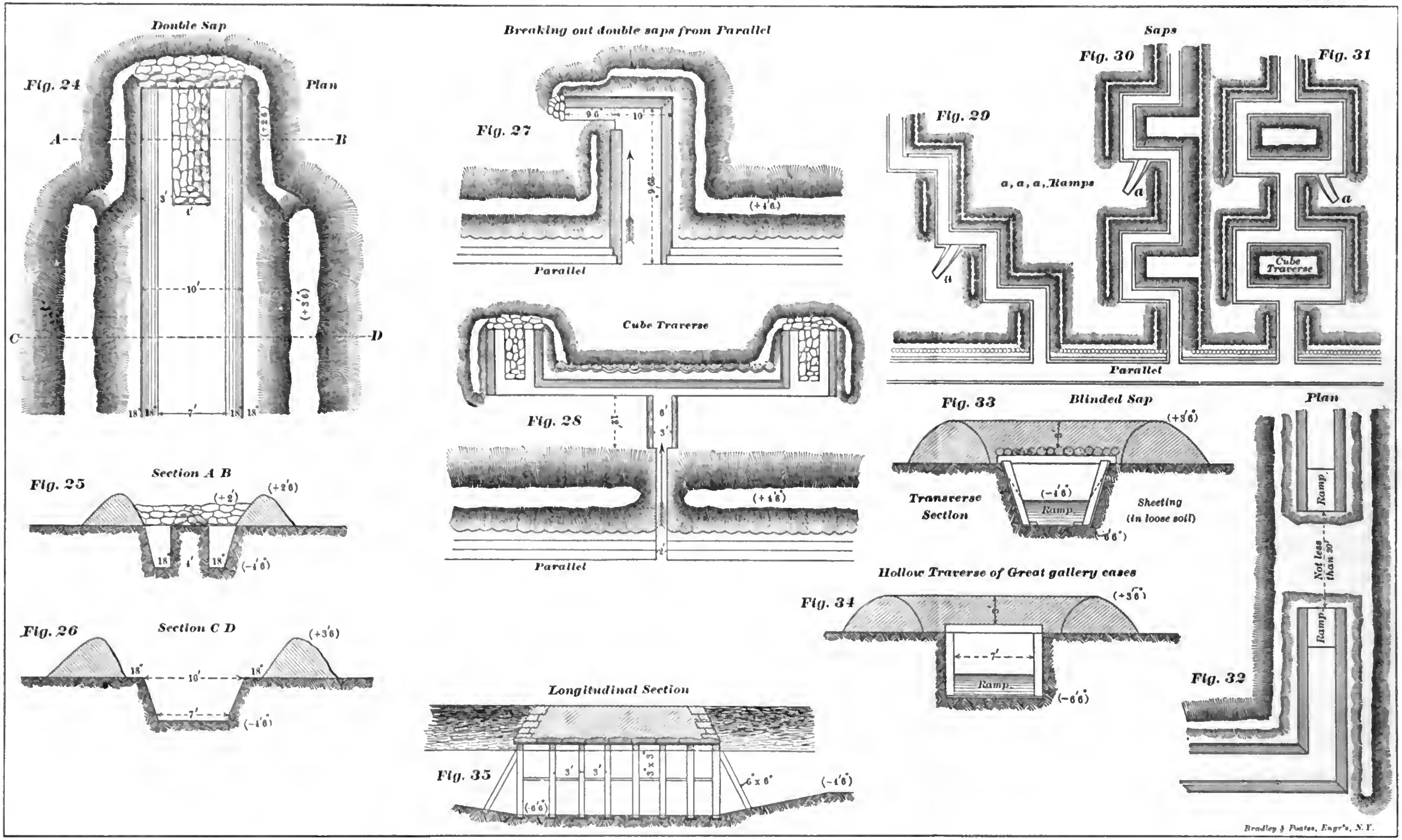
Double Sap
Fig. 24
Plan
Fig. 25
Section A B
Fig. 26
Section C D
Breaking out double saps from Parallel
Fig. 27
Parallel
Fig. 28
Cube Traverse
Parallel
Longitudinal Section
Fig. 35
Saps
Fig. 29
Fig. 30
Fig. 31
a, a, a, Ramps
Cube Traverse
Parallel
Fig. 33
Blinded Sap
Transverse Section
Ramp
Sheeting (in loose soil)
Hollow Traverse of Great gallery cases
Fig. 34
Ramp
Plan
Ramp
Not less than 30'
Fig. 32
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Plate IV.

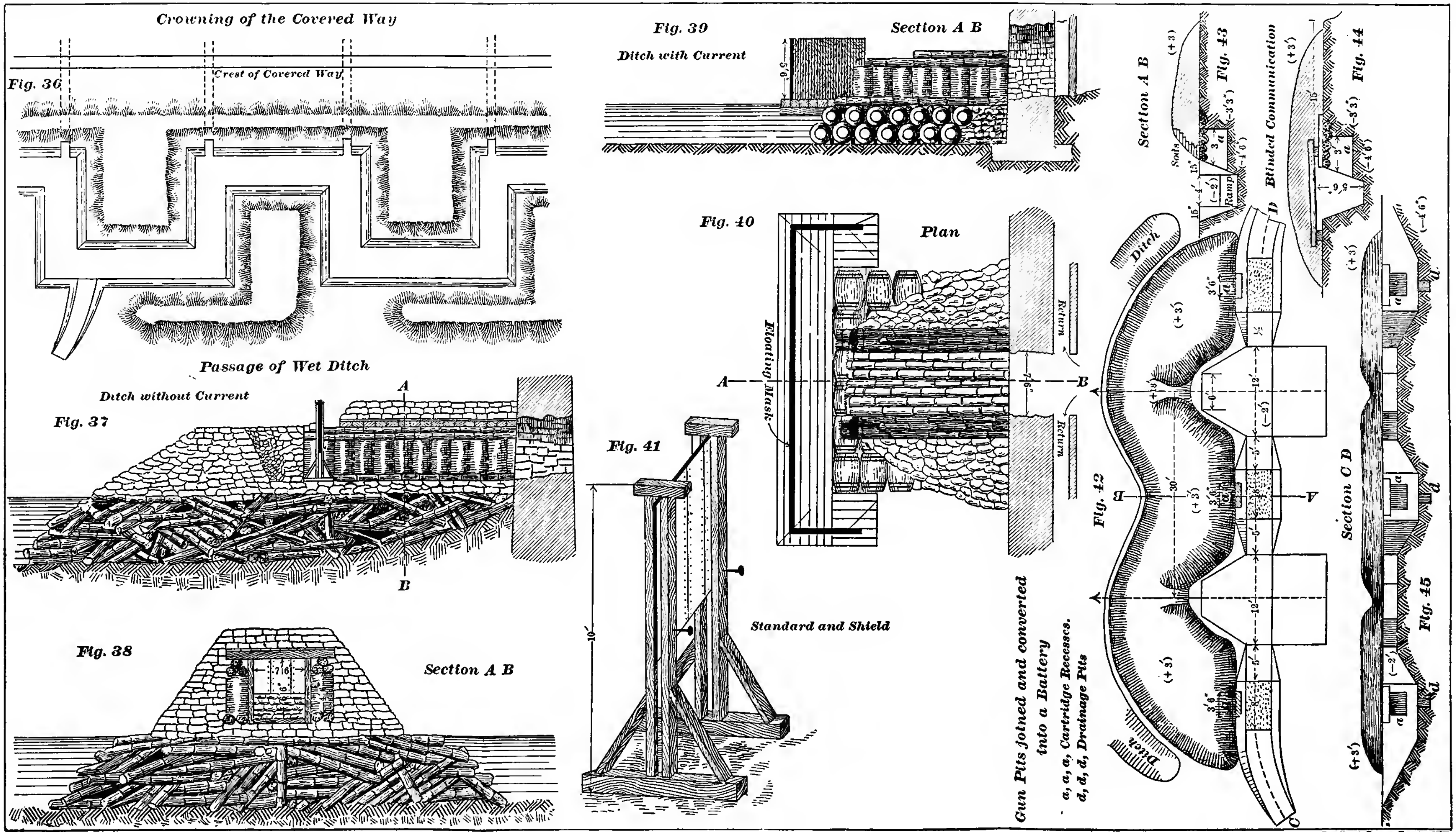

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Plate V.

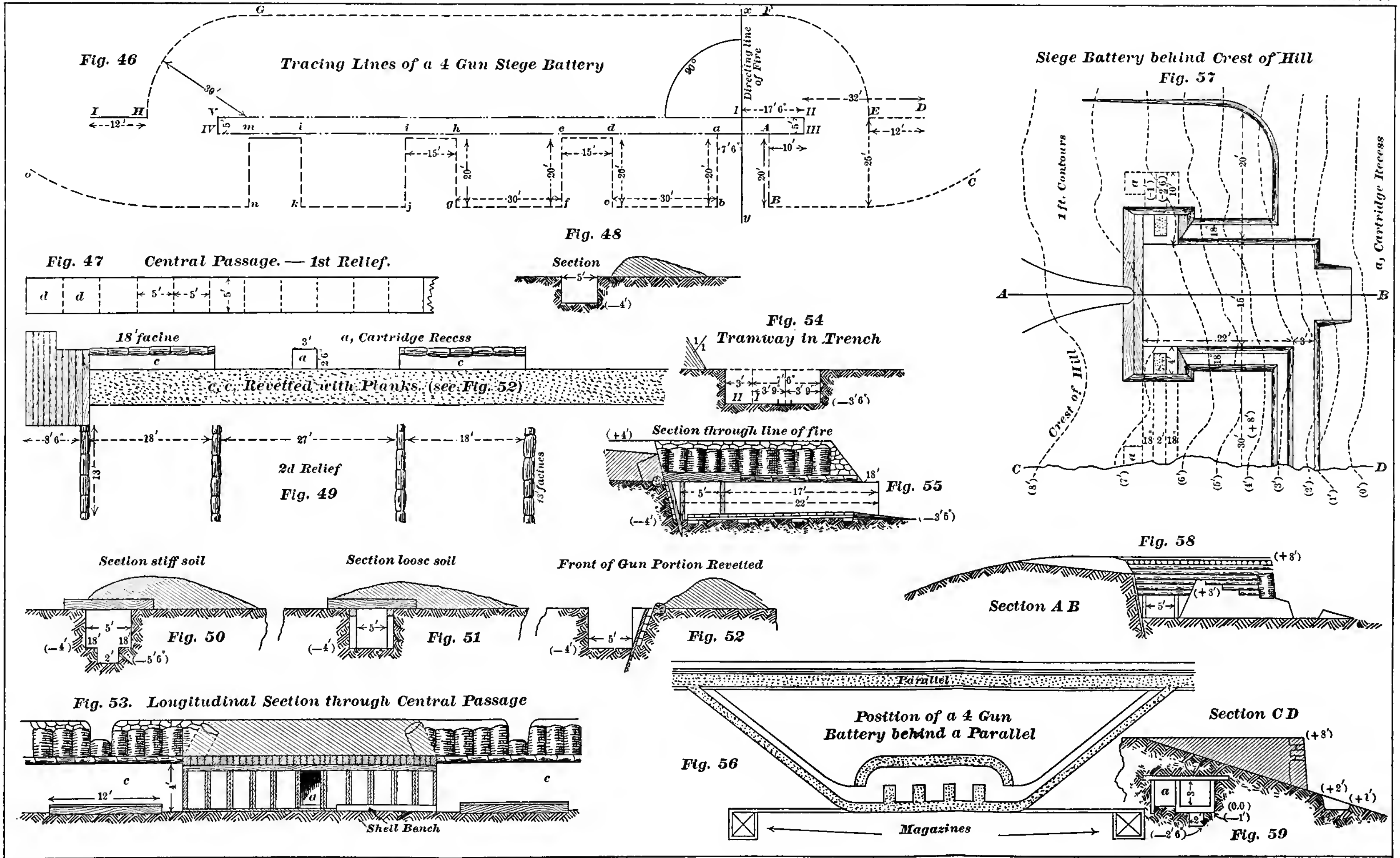

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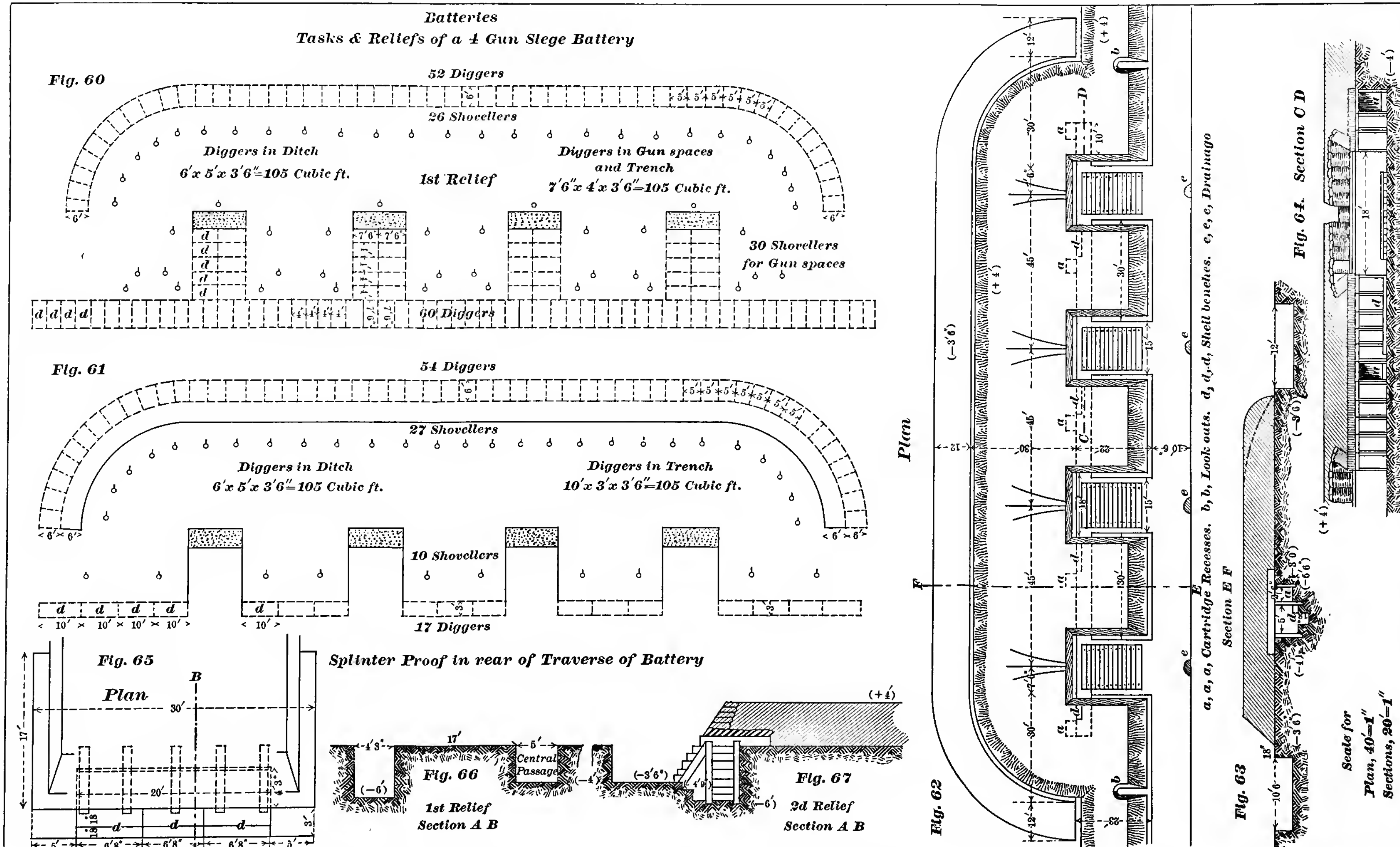
Plate VI.



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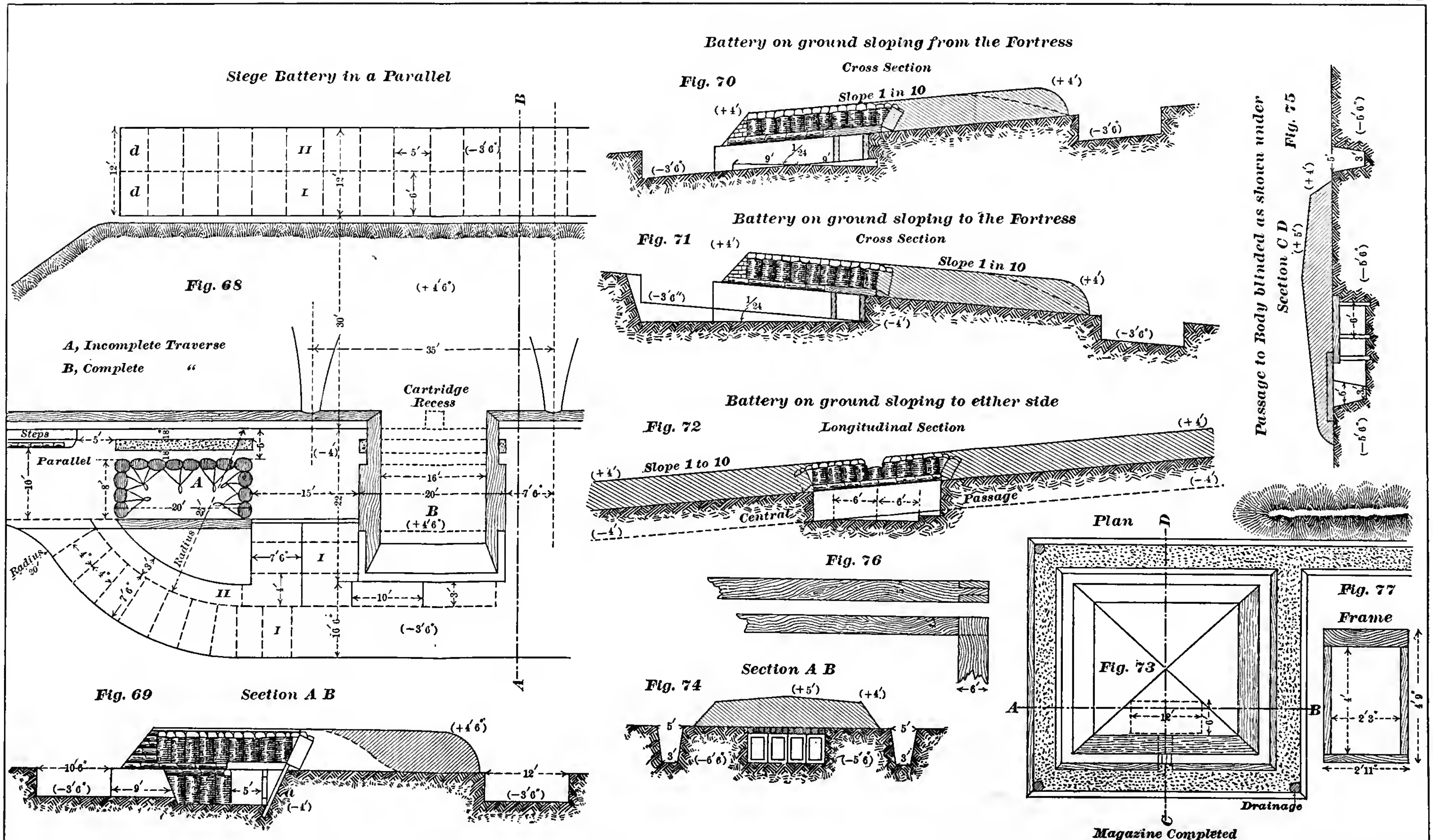

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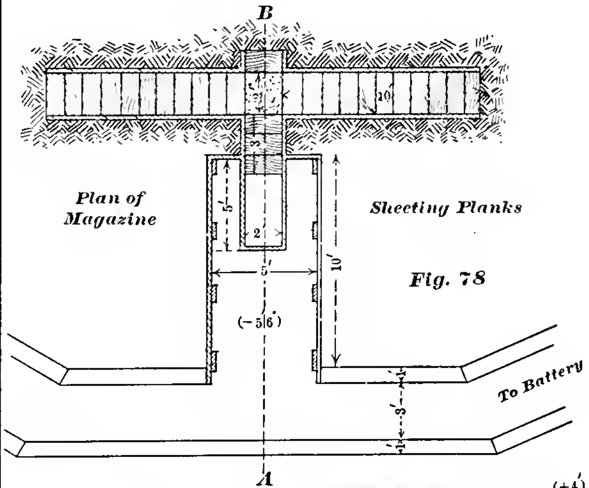
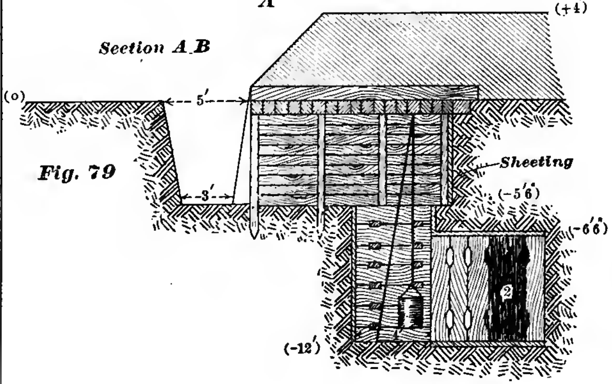
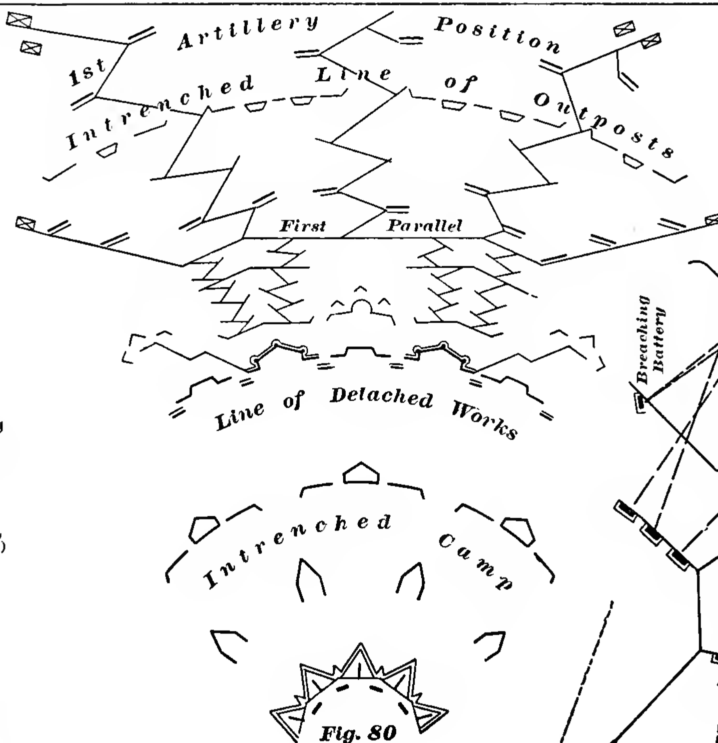
Mined Magazine







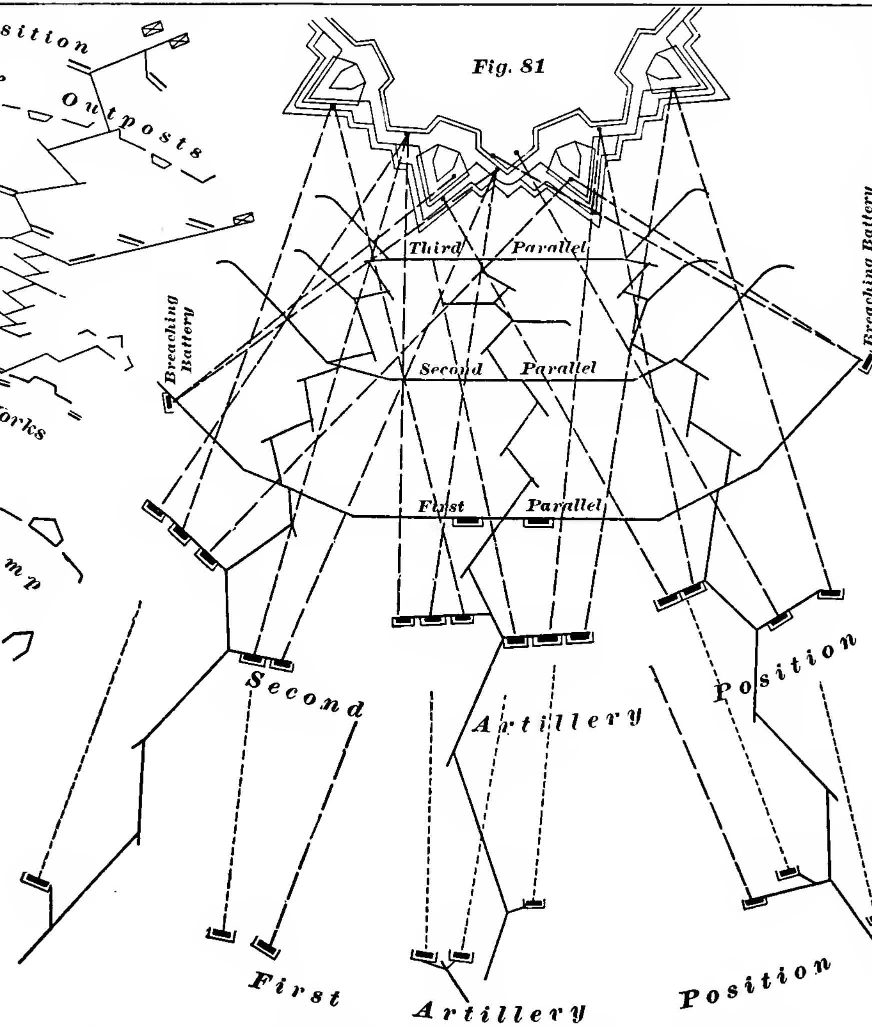
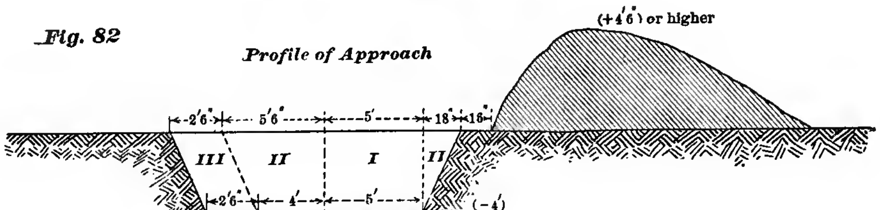


Fig. 82



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.

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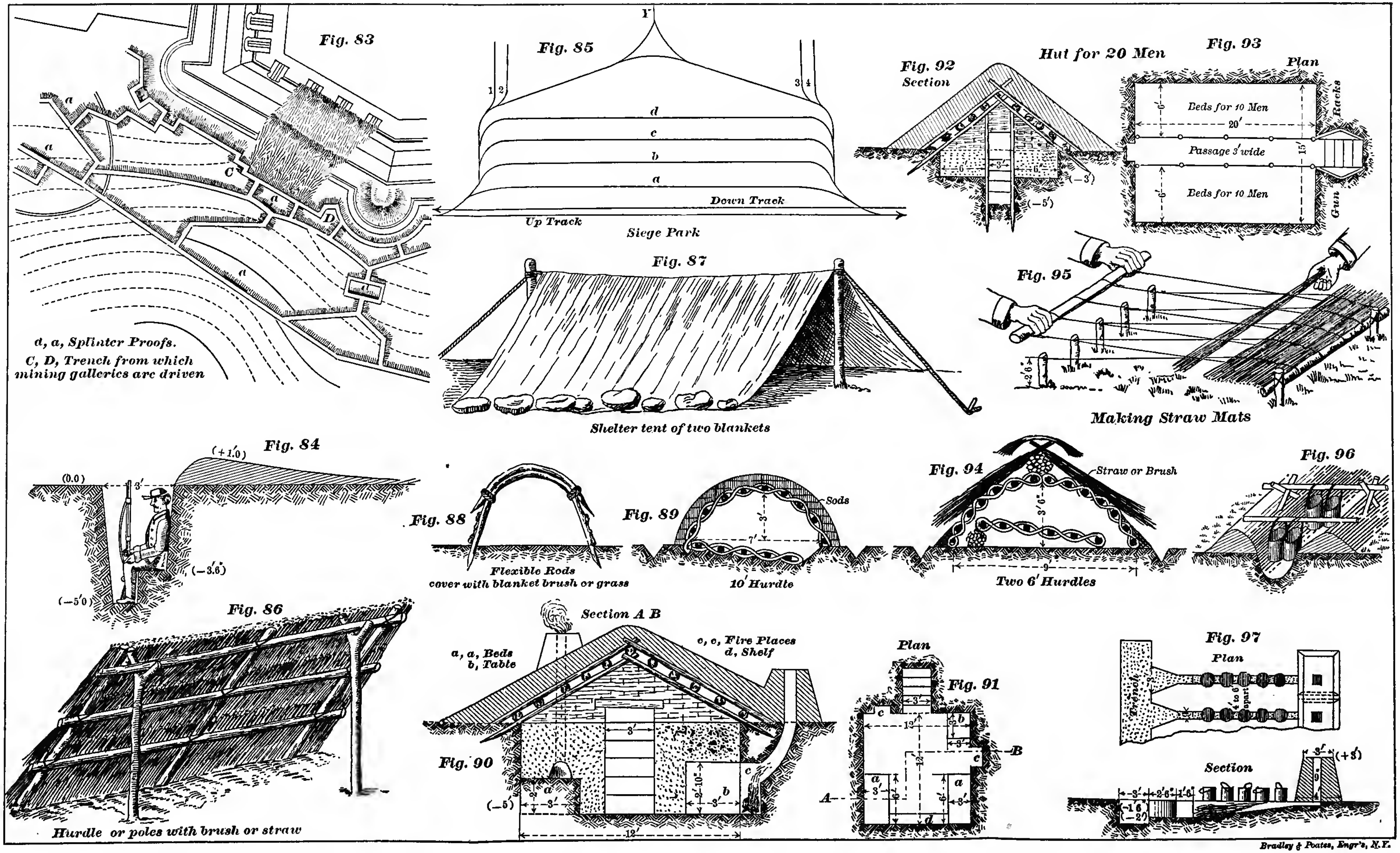

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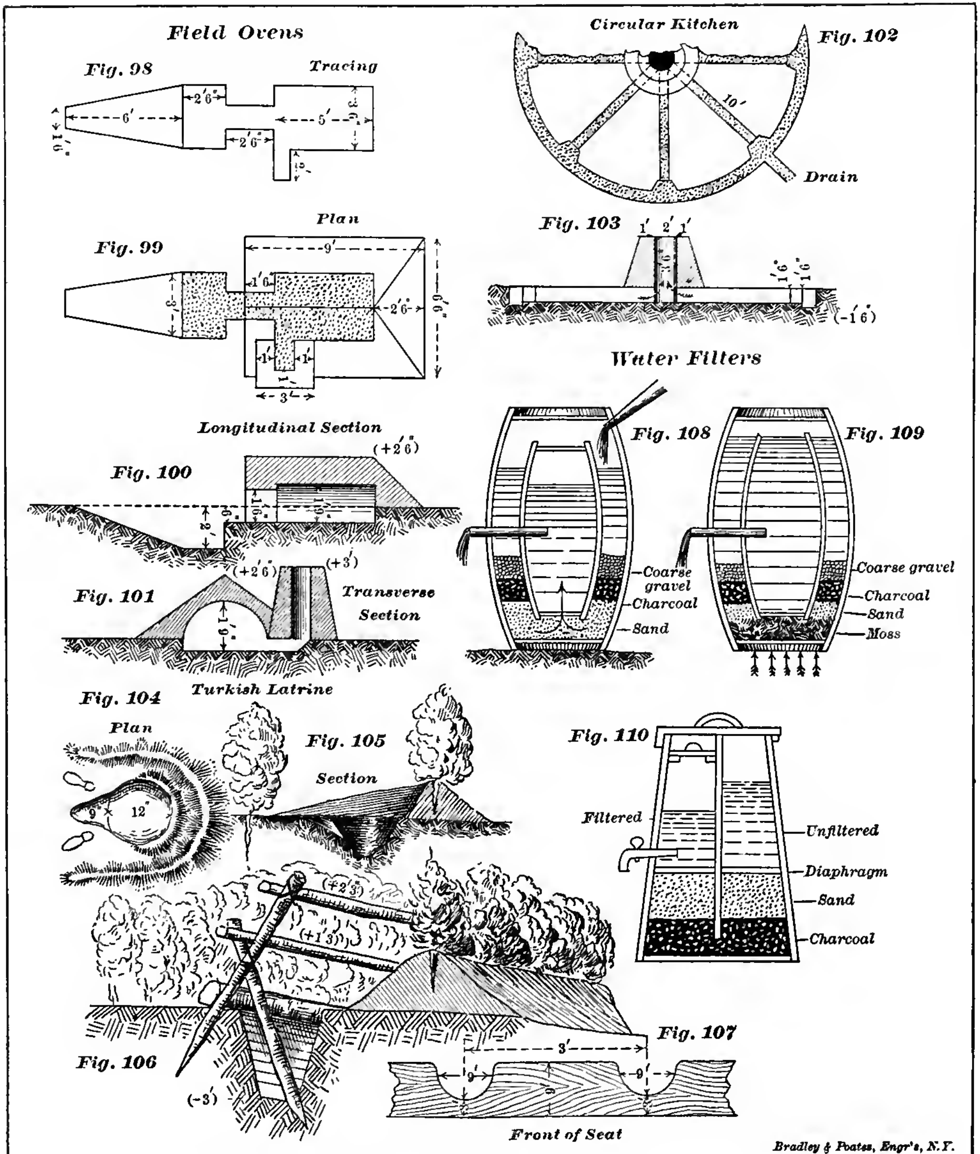
Field Ovens
Fig. 98
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Fig. 100
Longitudinal Section
Fig. 101
Transverse Section
Circular Kitchen
Fig. 102
10′
Drain
Fig. 103
Water Filters
Fig. 108
Fig. 109
Coarse gravel
Charcoal
Sand
Moss
Fig. 104
Turkish Latrine
Plan
Fig. 105
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Fig. 106
Fig. 107
Front of Seat
Fig. 110
Filtered
Unfiltered
Diaphragm
Sand
Charcoal
Bradley & Poates, Engr's, N.Y.

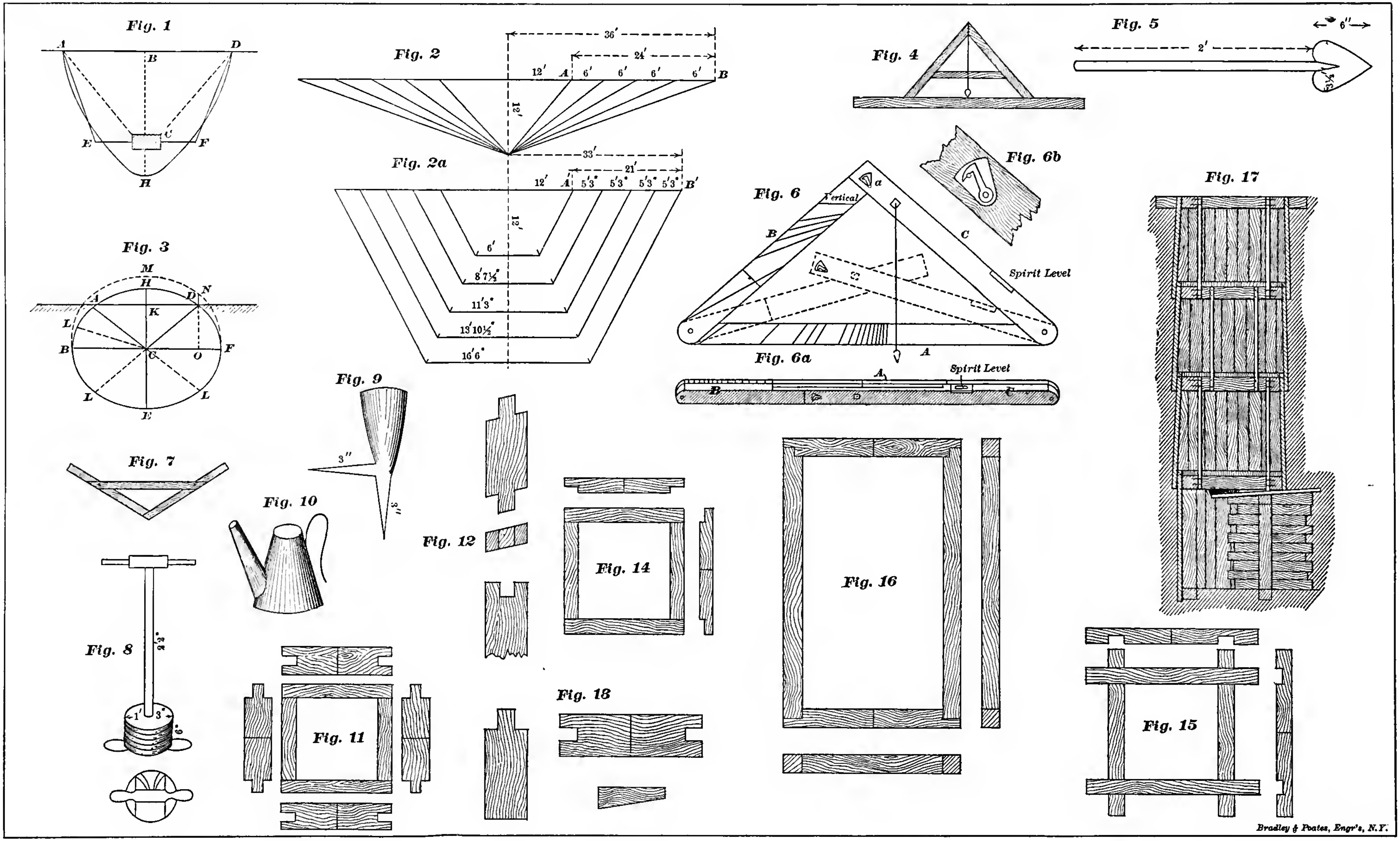
Fig. 1
A
B
D
E
C
F
H
Fig. 2
36′
24′
12′
A
6′
6′
6′
6′
B
12′
Fig. 2a
33′
21′
12′
A
5′3″
5′3″
5′3″
5′3″
B′
12′
6′
8′7½″
11′3″
13′10½″
16′6″
Fig. 3
M
H
A
D
N
K
L
B
C
O
F
L
L
E
Fig. 4
Fig. 5
6″
2′
Fig. 6
Fig. 6b
Vertical
a
B
C
Spirit Level
A
Fig. 6a
A
Spirit Level
B
C
Fig. 7
Fig. 8
Fig. 9
3″
3″
Fig. 10
Fig. 11
Fig. 12
Fig. 13
Fig. 14
Fig. 15
Fig. 16
Fig. 17
Bradley & Poates, Engr's, N.Y.

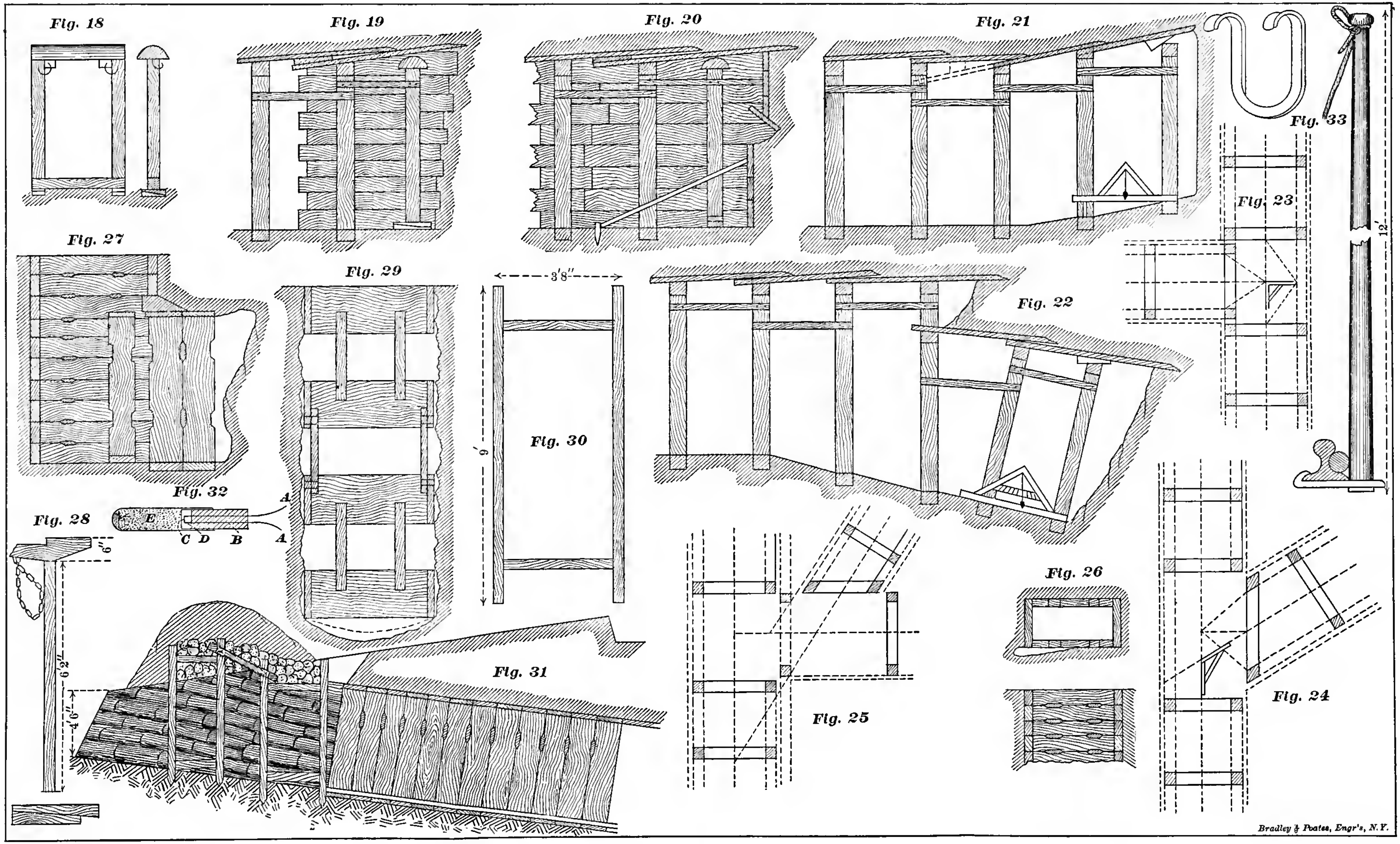
Fig. 18
Fig. 19
Fig. 20
Fig. 21
Fig. 27
Fig. 29
3'8"
9'
Fig. 30
Fig. 22
Fig. 33
Fig. 23
12'
Fig. 32
E
C
D
B
A
A
Fig. 28
6"
6'2"
4'6"
Fig. 31
Fig. 25
Fig. 26
Fig. 24
Bradley & Poates, Engr's, N.Y.