

NOTES ON THE WORK OF AN AUSTRALIAN TUNNELLING COMPANY IN FRANCE

By O. H. Woodward:

Foreword

It is intended in this paper to present in broad outline to the members of the Institute a short account of the conditions and operations that constitute what is variously known as Subterranean Warfare, Military Mining, or Tunnelling.

Realizing the magnitude of the operations, and the varied and minute details met with in them on the Western Front, it is the writer's intention to confine these notes to operations carried out by the First Australian Tunnelling Company. In so doing there is no wish to detract from the very fine records of the Second and Third companies. It is to be hoped that members of the Institute (or Others) who were with these companies will write accounts of their doings – the former in the water-logged areas to the south of Armentieres, and later in the sand-dunes at Lombardzee, and the latter in the chalk area of the Lens coalfield. The conditions under which these companies worked were very different from those the First Tunnelling Company, and it would be presumptuous for an officer of any individual company to attempt to describe the operations of all three.

Historical

The student of the Great War is forced to realize that "the spade and the power of the spade have played a leading part from the very first day." It was very early in the war that General Lemain had to cut trenches across the sectors between the Liege forts. Trench warfare may be said to have commenced in deadly earnest after the battle of the Aisne. Once this phase of warfare had been reached conditions began somewhat to resemble fortress warfare. We find that all points possessing natural tactical advantages in that practically continuous line of trench from the flats of Western Flanders into Alsace, to within sight of the Rhine, were converted into veritable fortresses by the enemy. As the result of this, and to cope with his advantageous position, the Allies commenced their mining operations on a very elementary scale compared to that into which they eventually evolved. It was about the middle of 1915 that the Imperial authorities accepted Australia's offer to send over mining men. The establishment of the Mining Corps was the result.

This corps was in active training in the latter part of 1915 under the command of Lieut.Col. A. C. Fewtrell, with Major T. W. E. David as Officer in Charge of the Technical Headquarters Staff.

The Corps embarked at Sydney on 20th February, 1916, and landed at Marseilles on the 5th May, where it entrained and finally reached Hazebrouck on 8th May. On arriving at Hazebrouck the corps came under the administration of the Controller of Mines of the Second Army B.E.F. It was then found that the establishment of our corps did not conform to that of existing tunnelling units on the western front. To conform with these, we found that we had to forfeit our status as a corps. Lieut.Col. Fewtrell was transferred to an A.I.F. Pioneer Battalion as C.O., and Major David to general headquarters, where he took charge of the whole of the geological work of the British army; and the three companies comprising the corps were formed into sperate companies, operating entirely under the control of the Mines Department.

No. 1 company was allotted the sector on either side of the River Lys, from Ploegstraat Wood on the north to Houplines on the south, with headquarters at Armentieres.

No. 2 company was allotted the sector in the water-logged area to the south of Armentieres, with headquarters at Sailly.

No. 3 company was allotted the chalk area in the Lens coalfield, with headquarters at Neux la Mines.

The three companies were actively engaged in military mining by 15th May, 1916.

From this date reference will be made only to the work of the First Tunnelling Company, A.I.F.

From the 15th May to 26th May the company was attached to the First Canadian Tunnelling Company for instruction in underground warfare. On the 27th May it assumed control of mining operations on the front extending from Ploegstraat Wood to Houplines – a distance of about three miles. The operations were

largely confined to defensive mining, though in Ploegstraat Wood a combination of offensive and defensive mining was in operation, with large mines under the German positions at Factory Farm and The Birdcage.

The company remained on this sector until the end of October, 1916, when it was moved north and relieved the Third Canadian Tunnelling Company at that historic spot, Hill 60. It speaks well for the Australian miners that, after such a short apprenticeship, the Higher Command could entrust them with the care of one of the largest and most important mining systems on the western front. Here we remained until after the battle of Messines Ridge, in June, 1917, which practically ended the mining operations of the Second Army B.E.F. Hill 60 had such a sinister reputation that tunnelling companies generally remained for only six months on the work. However, as the handing over of such a mining system as that existing here was a difficult task, and not without risk to the safety of the system, our company remained in charge until the mines were fired.

It is not the wish of this company to claim more than a fair share of the success of these mines. The credit lies with every tunnelling company which, at various times from 1914 to 1917, had control of the system. The excellent supervision of the Mines Department of the army resulted in a continuity of operations which culminated in an awe-inspiring explosion at 3.10 a.m. on 7th June, 1917. At this hour the formidable fortress of Hill 60 was blotted out, and that well-remembered and well-hated Ypres salient ceased to exist.

There is little doubt that the rapidity with which the German fortress area on the Messines Ridge fell into our hands can be laid to the credit of the tunnelling companies, with their 19 mines charged with over 600 tons of high explosive.

After the cessation of active mining in 1917 the tunnelling companies were allotted duties similar to those of the field companies of engineers and Pioneer battalions; but these operations are not within the scope of the present article.

Tunnelling Company Organisation

The original establishment of a tunnelling company was 360. all ranks. Later it was increased to 750, all ranks. This was the reason why the 4th, 5th, and 6th tunnelling companies were absorbed by the 1st, 2nd, and 3rd companies respectively.

Command	Rank
Officer Commanding	Major
Second in Command	Captain
Adjutant and Quartermaster	Captain
Officers commanding sections	Captain
Section officers	Lieutenants
Section Sergeants	Staff Sergeants
Squad Sergeants	Sergeants

Each section was an independent unit, with a strength of One captain, three lieutenants, and 170 other ranks.

When operating as a whole, as in Hill 60, the company was divided into a right and left half-company, two sections in each; one half-company operating in the trenches and the other resting and training in headquarters camp. The tour of duty in the trenches was for four days, and each section comprising the half-company in the line relieved each other every six hours.

Military Mining

Military mining may be divided into two sections, though the line of demarcation is never really clearly defined.

Section 1, Defensive Mining – As the name implies, this class of mining aims chiefly at the construction of an underground mine-system with the primary object of protecting our own system of defence-works. The section of trench to be defended is chiefly governed by information gained of the enemy's operations by aeroplane photos and by careful watching of his front with the aid of the periscope. The transition from a system of defence-mining to a combination of defensive and offensive mining

depends solely on the operations of the enemy, provided, of course, that our own tactical requirements do not call for offensive mining.

Briefly stated, defensive mining consists of constructing a main lateral gallery running approximately parallel to our own front trench, and situated in "No-Man's Land" at such a distance as to prevent mines having effect on the trench system proper.

From several points in the front line trench or communication trenches, shafts (either vertical or inclined) were sunk at from 100 to 200 ft. intervals, and from them drives were put out towards the enemy lines. These drives were then connected by crosscuts, which formed the main lateral gallery. Then at intervals of about 50 ft. listening posts were driven off this main lateral gallery towards the enemy lines and carried out to such a distance as to ensure the protection of the main lateral from the effect of enemy blows. When this point was reached the listening post was driven at right angles to the left and right, and these T heads were carried towards each other to ensure that the area between should be under control by a counter mine fired from either listening post. Generally, to further ensure this, four holes about 8 in. diam. were put in to carry a charge of from 100 to 200 lb. of high explosive placed in a torpedo.

The depth of this defence system in Flanders was governed by the water-level, and was usually about 18 ft., leaving a head cover of from 14 ft to 15 ft.

The morale of all troops is greatly affected by enemy mines being blown under their trench system, even though with shallow mines the result obtained may not be greater than an enemy shell of large calibre. Fig. 1 gives the lay-out of a theoretical system of defensive mining.

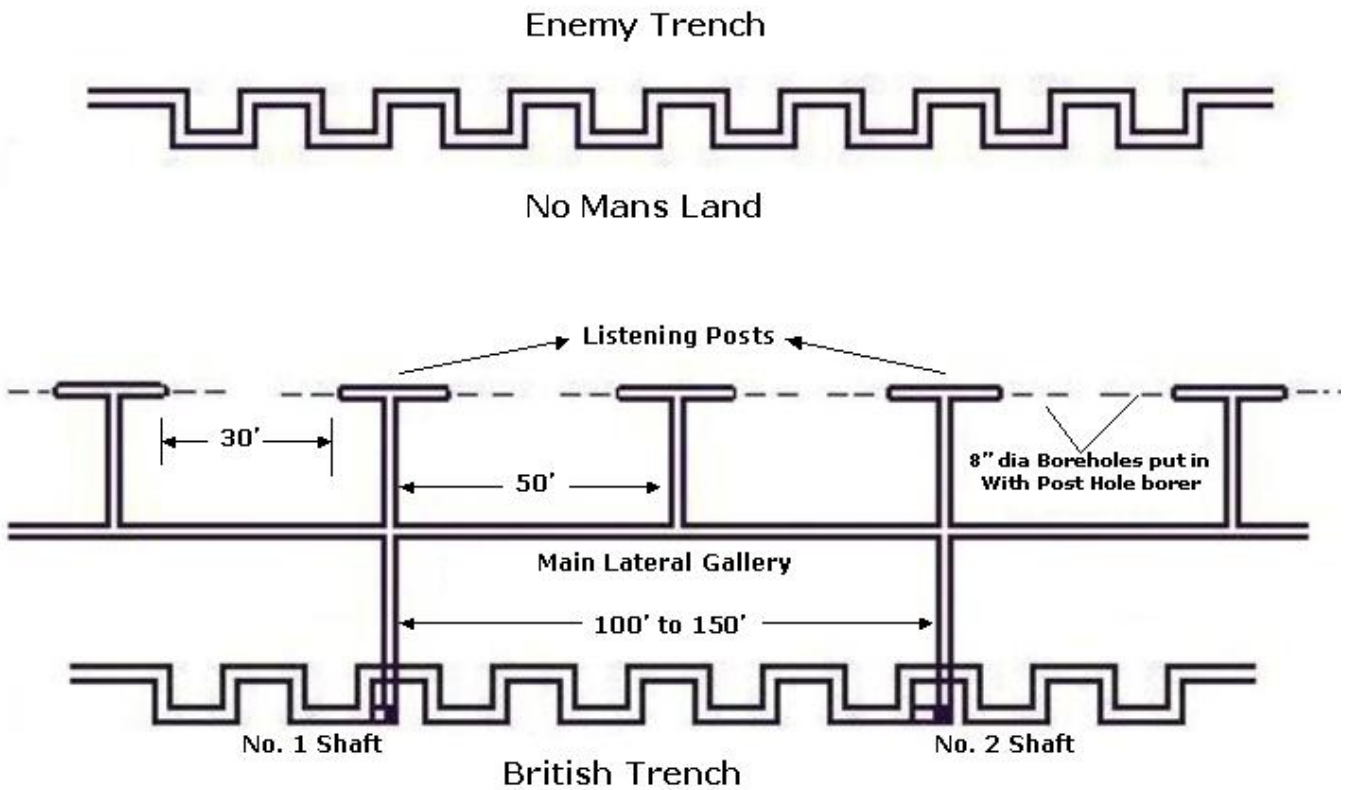


Fig. 1
Ideal Lay-out of Defensive Mining System

Section 2, Offensive Mining. - Offensive mining has for its aim the penetration of the enemy's line and the lay

ing of charges under important tactical positions of such size as to completely wreck them and form craters for the attacking infantry to consolidate.

It naturally follows that depth is an essential to the production of craters of large dimensions and to a large horizontal area of rupture. With offensive mining it is always essential to have a defensive system

above ground-water level, and, it is general - as was the case at Hill 60 - to establish an intermediate level between the defensive and deep offensive systems. This level is referred to as "the fighting level," and it is generally attempted to confine counter-mining to this level in order to mask the work in the deep offensive level. This plan of attack proved highly successful at Hill 60, as information since gained shows that the enemy did not suspect the existence of the deep mining system until too late.

General Mining Tactics. - Broadly speaking, these very closely resembled the fighting tactics of above-ground offensive tactics.

Case I. :- Having blown the enemy in a position previously located by means of careful listening, all effort is made to recover the portion of our own damaged gallery (the result of the blow), and to drive forward, skirting the disturbed ground, with the aim of reaching the enemy gallery before he has organized for its recovery. In this case the initiative is in our hands, and considerable time may be gained.

Case II. :- in the event of an enemy blow wrecking our own gallery, the object is to rapidly form an intermediate lateral gallery behind the disturbed zone, in order to prevent the enemy getting through. This accomplished, the next step is to drive a new gallery and attempt to reach the area in which the enemy had blown.

Briefly, Case I. can be likened to storming the enemy position and Case II. to forming a support line, and from there attempting to recover the lost ground.

Hill 60 - Descriptive

There is not a battalion in the British army that does not know the heap of mud rising on the left of the Ypres-Menin railway line, where that line passes through the Zandvoorde ridge. This eminence derived the name of Hill 60 from the fact that the 60-metre contour line surrounded the crest. In relation to the surrounding country it can scarcely be designated a hill, but it was just sufficiently high to dominate the Ypres salient and obscure our view of the enemy's back areas. Hill 60 lies about 2 1/2 miles in a south-easterly direction from the historic town of Ypres, and almost at the apex of the famous Ypres salient.

Two other artificial mounds of earth rise in this area, both on the right-hand side of the railway cutting. The first, The Caterpillar - so called from its resemblance to that insect when seen on an aerial photo - lay entirely in the enemy lines, and the other, The Dump, lay in ours. These were formed by the spoil from the railway cutting, which is about 30 ft. deep. The Ypres salient was a most dreaded spot to all troops, as in most sectors of its front the enemy could shell from practically three sides. It was the scene of some of the most bitter fighting of the war, and it saw the first use of poison gas by the enemy. The enemy at all points dominated our back areas, and troops moving in and out of our trenches had to do so under cover of darkness.

From its position it was never a rest-home, and when our official reports recorded "all quiet on the western front," it could be assumed without exception that this did not apply to the Ypres salient. It may justly be described as a vast mangled graveyard.

Geology

All tunnelling companies were supplied with accurate geological data compiled by Lieut.-Col. T. E. David and his staff. This data was a valuable guide in mining operations, as by it the variation of winter and summer level of the underground water shown. By this means the depth to which offensive galleries could be sunk without fear of striking water-bearing zone could be estimated. In its geological structure Hill 60 was composed entirely sedimentaries, and an ideal section is as shown in Fig. 2.

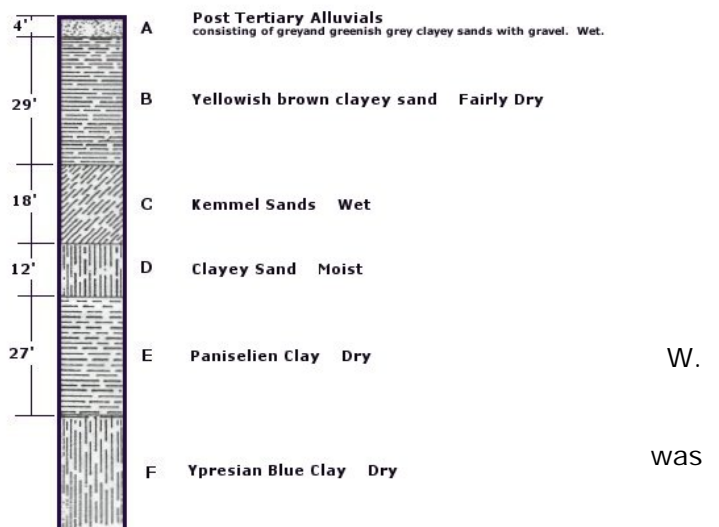


Fig. 2
Ideal Geological Section - Hill 60

A. - Post Tertiary alluvials, "Campinien," consisting of grey sands and greenish-grey clayey sands with gravel : this bed wet.

Lower Eocene.

B.- 29 ft., yellowish-brown clayey sand: fairly dry.

C.- 18 ft., Kemmel sands : wet.

D.- 12 ft., clayey sand: moist.

E.- 27 ft., Paniselien clay: dry.

F.- (?). Ypresian blue clay: dry.

Mining Operations, Hill 60

Hill 60 was the scene of some of the earliest if not actually the first mining warfare. With the opening of the spring campaign of 1915, one of the first British movements was an attack on this Hill. We took it and lost it again, and thereafter each side commenced mining operations in deadly earnest. Unfortunately, the writer is unable to give a list of the various English tunnelling companies whose wonderful efforts pioneered the way to the ultimate grand success of the operations there.

In May, 1916, the Third Canadian Tunnelling Company took over this sector, and to that company is due the credit of having carefully laid the two mines - one under Hill 60 and the other under The Caterpillar.

Not being in possession of the plans of the Hill 60 mining system, it is necessary to attempt to describe its essential details.

Reference to direction will be made in relation to the railway cutting looking towards the enemy lines (see map, Plate I).

Commencing in Bensham Road - our immediate support line - and about 50 ft. from the railway cutting, a main adit 6 ft. 3 in. by 3 ft. 6in. in the clear, and parallel to the railway cutting, was driven for a length of 300 ft., having at this point head-cover of approximately 20 ft. Here a shaft-chamber was excavated, and the main Berlin sap commenced. This sap was the main incline shaft of the system, and was driven for 570 ft. at an average dip of 12° from the horizontal. This point was approximately directly under the enemy front trench.

From here a drive was put in at an angle of about half-left for a length of 240 ft., which brought the end of the drive under the crown of Hill 60. From the same point at the foot of the Berlin sap another drive at a direction half-right was put in for a distance of 510 ft., bringing the end of the drive immediately below the centre of The Caterpillar. In this drive the Canadians experienced trouble, and had to step down about 10 ft. in order to get clear of a band of quicksand. In consequence this mine was under water from the time of charging until it was fired some months later. It speaks well for the careful work of the Canadians that it withstood the long inundation.

At a level about 40 ft. below the surface, and running to the left of the railway cutting and well out under "No-Man's Land," was driven the main intermediate level. This ran for about 400 ft., and formed the main fighting level of the system.

A system of defensive galleries extended from the railway cutting for a distance of about 1000 ft., and approximately parallel to our front line trench. Five shafts connected the front line trenches with this system.

On the arrival of the First Australian Tunnelling Company a deeper system of offensive mining was commenced. From the level of the top of the Berlin sap a vertical shaft was sunk to a depth of 90 ft. This was the first vertical shaft sunk on the Hill 60 system, though not the first attempted.

From this shaft, known as the Sydney, a gallery 500 ft. in length was driven and connected with the foot of the Berlin sap. A pipe-line was installed to convey all the drainage from the old system to the sump of the Sydney shaft, whence it was pumped by an electrically-driven geared pump. The shaft chamber was made as sound-proof as possible. From the Sydney drive, and about 250 ft. from the shaft, a drive to the left, known as Brisbane gallery, was driven for 800 ft., the object being to lay a mine under a German strong post known as The Snout.

From the same position in the Sydney gallery the Perth gallery was driven, with the object of laying a mine under another portion of The Caterpillar. This gallery was driven for a length of 500 ft.

Neither of these mines was completed, although the work was within five weeks of completion. The tactical situation and the danger of the enemy locating the Hill 60 mine decided the higher authorities to precipitate the attack.

On the right of the cutting we had a defensive mining system protecting about 500 ft. of our front trench system.

The activity of mining operations on this sector may be judged by the fact that 34 mines were fired in the 12 months prior to the attack.

During the last few weeks prior to the attack the enemy was particularly active. He seemed to be vainly searching for our deep mines, and seemed to blow at random in the hope of destroying our work.

How close he came to success may be judged by the fact that a mine blown on 25th May crumpled the gallery leading to Hill 60 charge, entombed a listener for 48 "hours, and broke one set of the leads to the mine. About 150 ft. of the tamping had to be removed in order to repair the damaged lead.

This gave us a very advanced listening post, and we were much disturbed to hear the enemy actively working in very close proximity to the main charge. A creaking windlass enabled us to measure his progress in shaft-sinking, and at about the end of May the turns of this windlass were constant, so it was safe to assume that he was driving a gallery towards us, and very nearly on the same level as ours.

As the zero day approached we had to retamp our gallery and trust to luck. Needless to say, those were most anxious days, and practically continuous continuity and resistance tests were made on the Hill 60 leads in order to have earliest information of their being interfered with.

Our luck held, and at 10 minutes past 3 o'clock on the morning of 7th June the switch was thrown over. The earth lifted and rose in two heaving mounds, gently sank back, and as it receded the gases hissed out from countless cracks and burst into two huge tongues of flame.

To those of us who were anticipating the spectacle it was fearsome, and one wonders what were the sensations of the very few of the enemy who escaped from such a hell on earth.

Mining Methods

The actual excavation of the earth was governed by the tactical conditions-

- (a) Defensive or offensive mining.
- (b) Dugout construction and main infantry subways.

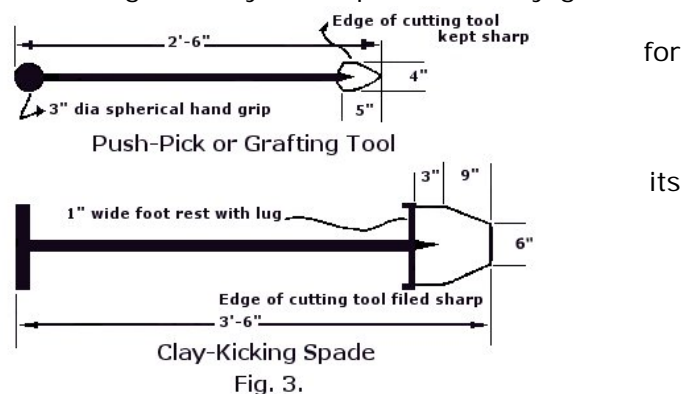
In (a) silence was absolutely essential, so that the use of the pick as a means of excavation was prohibited. This was overcome by the employment of one of two methods - (1) with the push-pick or grafting tool, an illustration of which is given in Fig. 3.

This method was almost universally employed in galleries where a minimum of noise was essential. The pick was pushed into the clay, the spherical end giving good control, and the clay caught in the hand and placed in sand-bags.

It is fairly evident that this method is slow but sure when feeling the way to suspected enemy galleries. Under such conditions a progress of 4 to 6 ft. per 24 hours was satisfactory when cessation of operations listening purposes is taken into account.

(2) .Clay-kicking. - This, to the Australians, was a distinct innovation, and they were not slow to grasp great advantages. It originated with the sewerage-construction workers, in the clay beds of London, and for silence accompanied by speedy progress is unequalled.

Briefly, the operation of clay-kicking can be described as a method whereby the whole of the



power given to the clay-kicking spade (see Fig. 3) is supplied by the legs, the operator being seated on a movable seat and using the handle of the spade as a lever with which to break down the face.

Fig. 4 gives a diagrammatic sketch of the operation.

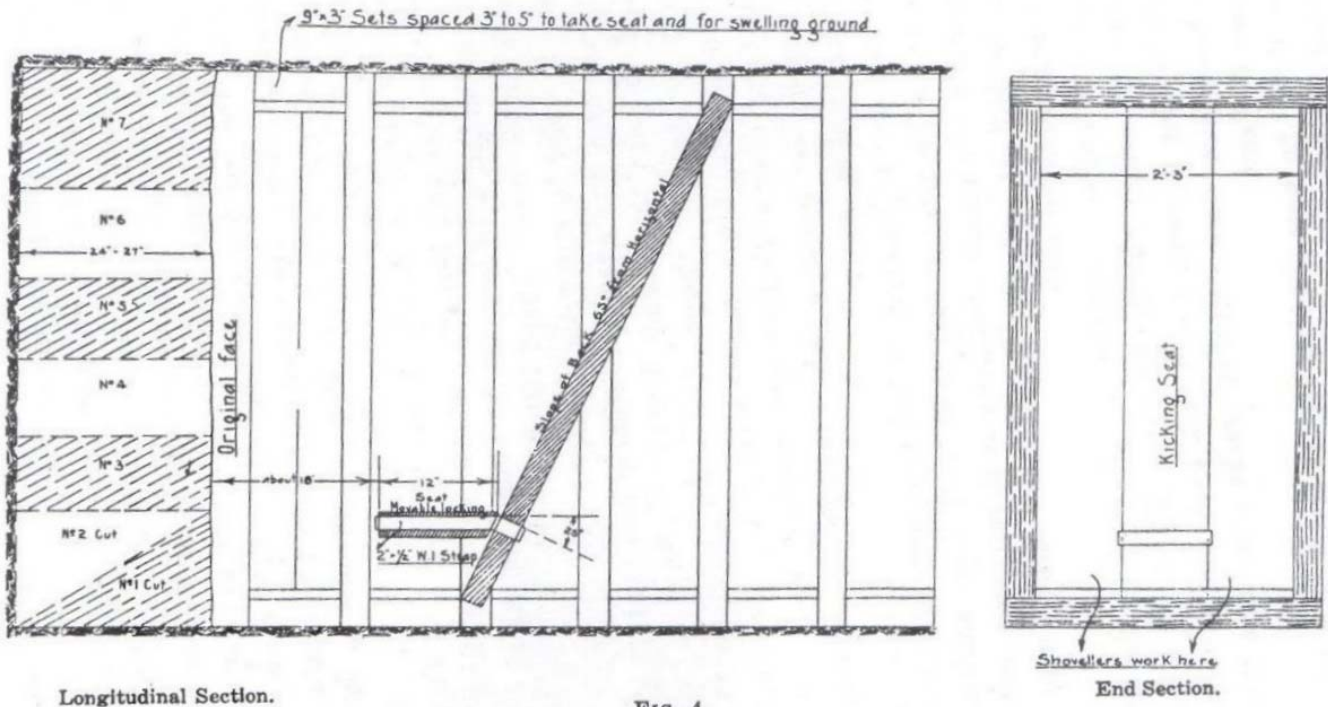


FIG. 4.
GENERAL ARRANGEMENT CLAY-KICKING SEAT.

A sliding seat is fixed to sloping back is set in the centre of the gallery. This seat

is so arranged that it locks automatically at any position. The operator adjusts the seat to his liking, and then, with both feet straddling the spade, undercuts the face for about 2 ft. to 2 ft. 3 in. This operation completed, he takes cuts off the face from the undercut to the roof of the gallery, still using the spade and prying down the slice with the aid of the spade-handle. Throughout the operation the seat is adjusted to suit the varying height. The spoil is removed from both sides of the kicking seat without interfering with the operation of the kicker.

With sharp-edged spade the whole operation is wonderfully silent and the progress remarkable. The following figures illustrate the progress which can be made. The galleries in these cases are the standard mine gallery, 4 ft. 3 in. by 2 ft. 3 in. in the clear, 3-in. space between sets.

No. 1. - Clay-kicking Competition, Second Army Mine School.

Conditions.-Team, 4 men; shift, 4 hours; ground, medium-hard blue clay. Points awarded for speed and silence; latter judged by listening party in an adjacent gallery.

Team No.	Sets timber erected.	Progress.	
		ft.	in.
1	9	7	7
2	8	6	10
3	8	6	9
4	8	6	9
5	7	6	8
6	8	6	7
7	8	6	6
8	7	6	5
9	7	5	10
10	6	5	6
11	6	4	11

No. 2. – These footages were obtained under actual mining conditions. Sets spaced 5 in.; 4 face-men; 8 fatigues for bagging spoils; 6-hour shifts; ground, ideal blue clay.

		Progress	
		ft.	in.
No, 2. -	April 24	26	3
	" 25	25	3
	" 26	27	8
	" 27	27	3
	" 28	21	5
	" 29	27	3
	" 30	28	9
	May 1	23	10
	" 2	25	7
	" 3	30	7

With clay-licking the average weekly progress in a standard mine gallery was about 70 ft.

(b) Dugout Construction and Main Infantry Subways. – The galleries in this case were 6 ft. 3 in. x 3 ft. 6 in. in the clear; timber stood close together; ground, clayey sand, fairly dry; shift consisted of 2 face-men, 3 shovellers, and 7 infantry fatigues, working 6-hour shifts. Method of excavation, pick and shovel.

Figures for a week's progress : -

		Progress	
		ft.	in.
May	22	20	0
"	23	20	4
"	24	33	2
"	25	36	2
"	26	40	0
"	27	20	4
"	28	42	0

The low footages of 22nd, 23rd, and 27th May were due to long interruptions for "Stand to" on those days.

Shaft Sinking

Shaft sinking was confined to –

- (1) Sinking with steel cylinders through water-bearing strata, and continuing with framed sets in the dry clay.
- (2) Sinking with crib timber through surface strata.
- (3) Underlie shafts.
- (4) Stepped incline shafts for dugouts and machine-gun emplacements.

Figs. 5 and 5A give details of the Sydney shaft sunk on Hill 60 by this company.

A shaft chamber with 18 ft. of head cover was excavated. The dimensions were 10 ft. square and 6 ft. 6 in. high. The roof was reinforced with 5 in. x 3 in. rolled-steel joists for safety, as well as to supply a solid base for four 5-ton lifting-jacks, which were employed to drive the steel cylinders down.

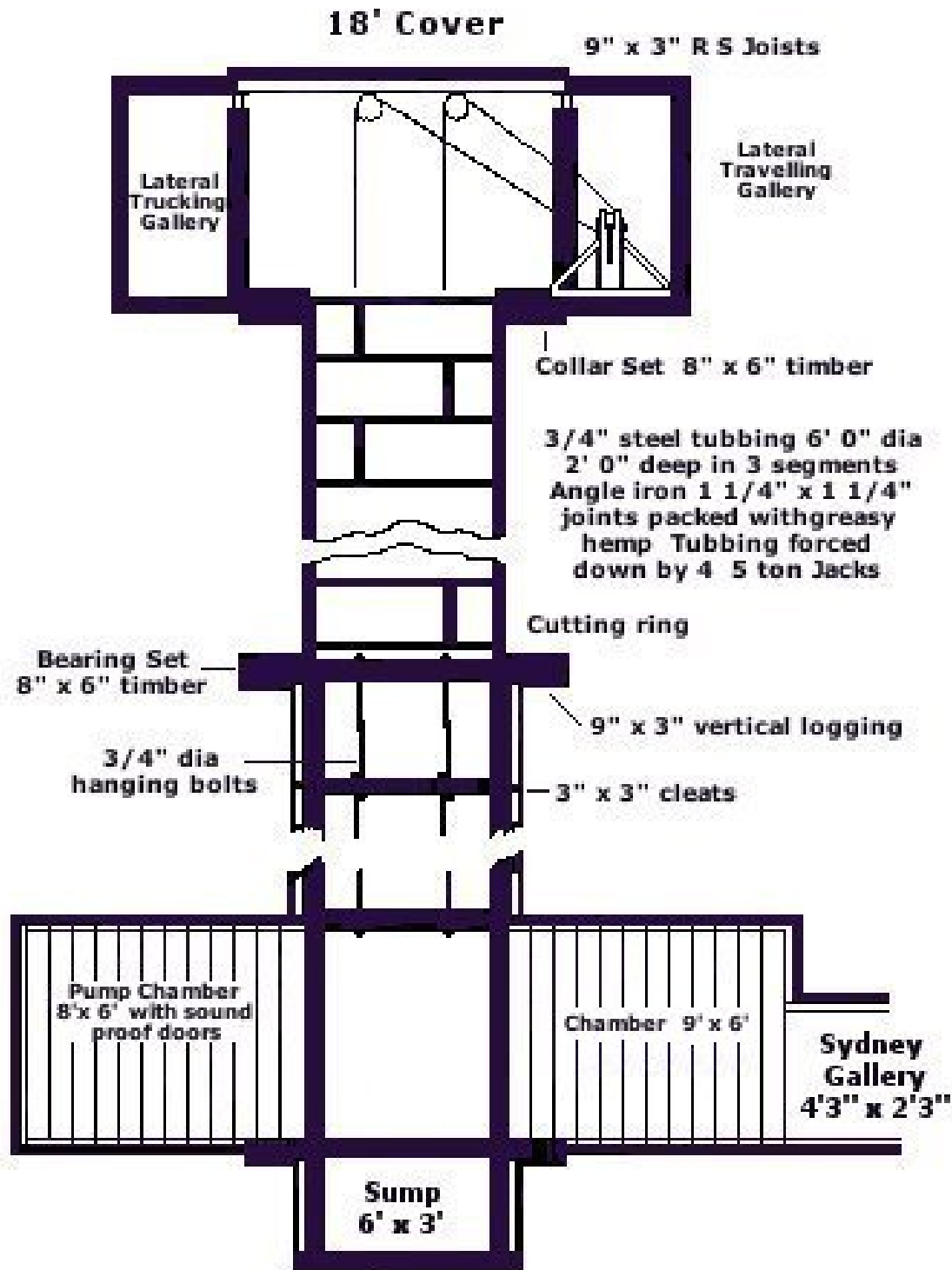


Fig. 5
Details "Sydney" Shaft
Scale - 1/8 in = 1 ft.

A rectangular collar set was placed in position, and the rest of the floor of the shaft chamber securely floored. The steel tubing was 6 ft. in diam. And in three segments; details are shown in sketch.

A cutting ring was placed on the first ring and the ground excavated, and the eased as it was driven down. After passing running-sand strata and reaching a depth of 10 ft below in solid blue clay the steel tubing was dispensed with and frame sets used to complete shaft.

(1) The following figures are of interest, show

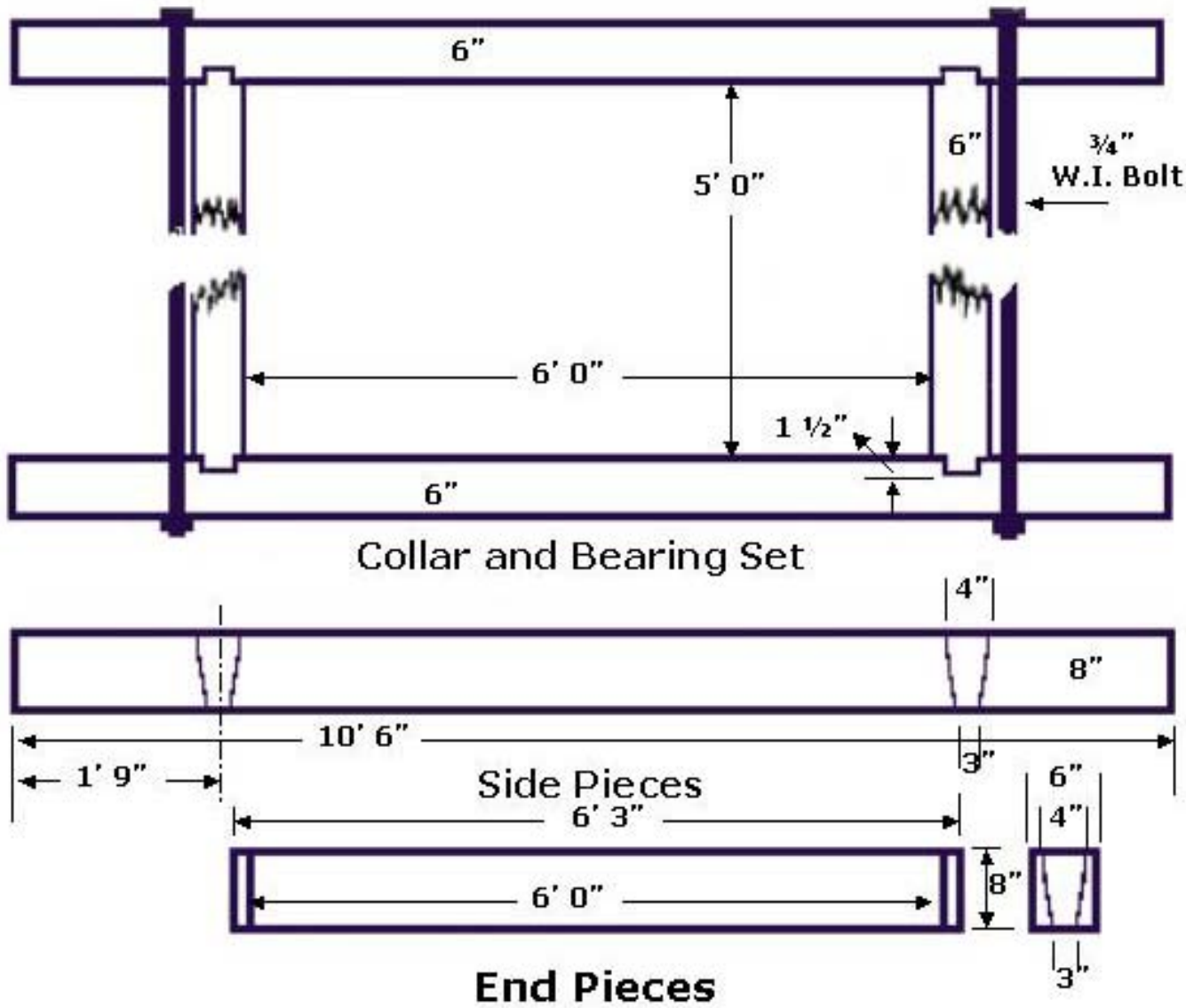


Fig. 5A
Details "Sydney" Shaft

ing progress in this method.

Data- Dimensions of shaft, 6 ft. x 3 ft.
 in clear.

No. of men per shift, 6.

Hours worked, 6 hours on and 6 off.

Date	Progress	
	ft.	in.
Nov. 4	8	0
" 5	11	6
" 6	10	9
" 7	7	9
" 8	4	0

Total, 42 ft. Progress, 3.7 in. per hour

Remarks. – Eight hours lost, due to enemy shelling. Progress included laying collar set, plat set at 36 ft., and boarding bottom of sump.

Nature of country –
 15 ft surface yellow clay (damp).
 2 ft. water-bearing sand.
 Balance blue clay (dry).

(2) Underlie shafts were used in mine systems and in dugouts. In the latter case steps were installed for travelling purposes. The timber sets employed were 5 ft. high at right-angles to the dip and 3 ft. 6 in. wide. This type of shaft presented no unusual features.

(3) Stepped incline shaft. – Fig. 6 shows details for this type of dugout entrance. It has the advantage of using standard subway sets and forms the travelling way at the same time.

Mine

It was that the of the on the Front the

Section

Timber

early seen magnitude mining operations Western necessitated

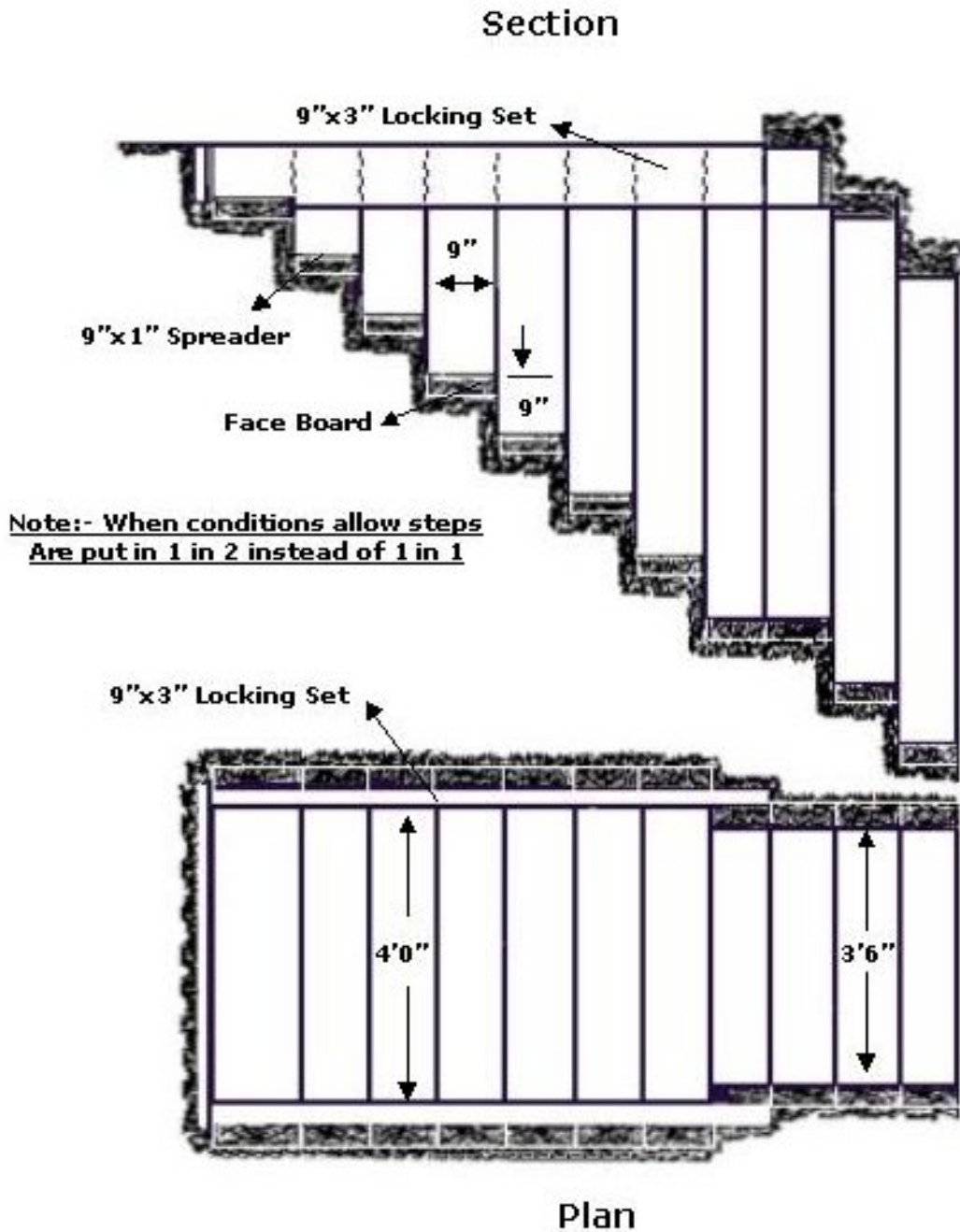


Fig. 6.
Stepped Dugout Entrance

standardization of mine timbers. All timber employed in mining operations was Oregon pine, and size 9 in. x 3 in.

Three standard sets were employed, and Fig. 7 gives the type of construction used –

- (1) Standard mine gallery set; dimensions, 4 ft. 3 in. x 2 ft. 3 in. clear.
- (2) Standard infantry subway set: dimensions 6 ft. 3 in. x 3 ft. 6 in. clear.
- (3) Standard small dugout set: 6 ft. 3in. x 6 ft. in clear.

Special sets, such as those for shaft timbers, collar sets, etc., had to be ordered in advance from the Royal Engineers' park. The quantity of timber used may be judged by the fact that the average progress of this company while at Hill 60 was approximately 300 ft. per week.

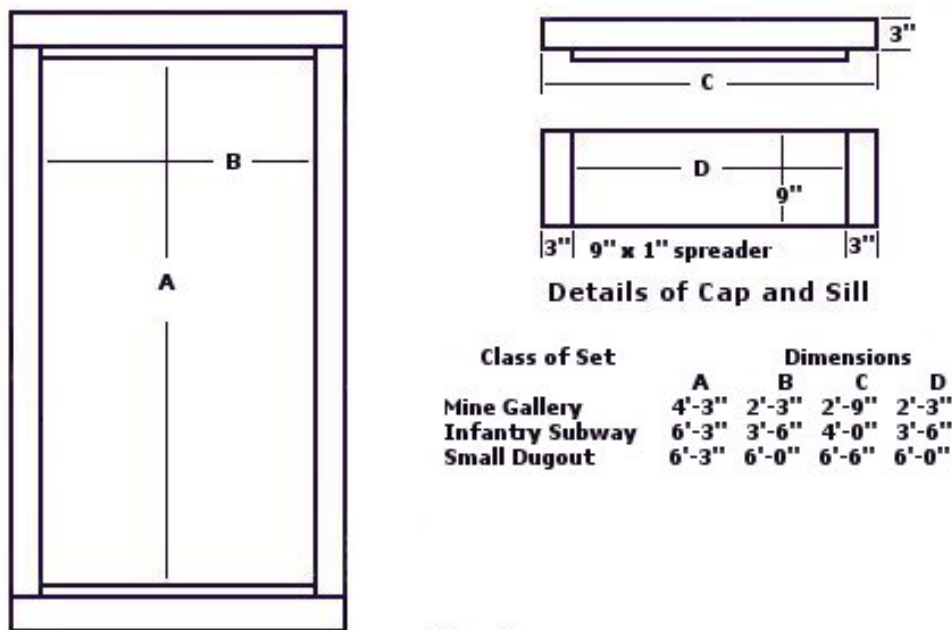


Fig. 7
Standard Mine Gallery Set

Handling and Disposal of Spoil

The dirt, when broken in the face, was shovelled into hempoen bags about 2 ft. long and 10 in. wide and the neck closely tied. In general the tactical situation did not permit of a truck being employed within about 100 ft. of the face, so for this distance the bags had to be man-handled. It was found by experience by our own listeners that slowly dragging the bags along the timbered floor was the quietest method of handling them, and from the face to the truck this system was employed.

Fig. 8 gives the leading dimensions of the truck and type of tracking employed.

This truck could take about 8 to 10 sand-bags. The tracking was very portable, being in 8-ft. lengths and readily laid.

In inclined shafts the truck was hauled direct to the surface. In vertical shafts the bags were put into a sling and hoisted on an ordinary windlass with an up and down rope.

Disposal of spoil was a vital consideration in maintaining the secrecy of the mining operations. The deeper workings being in blue clay, every care had to be exercised in the disposal of the spoil. It had the unfortunate property of discolouring the sandbags a dark blue colour, which rendered them highly visible to aircraft observation.

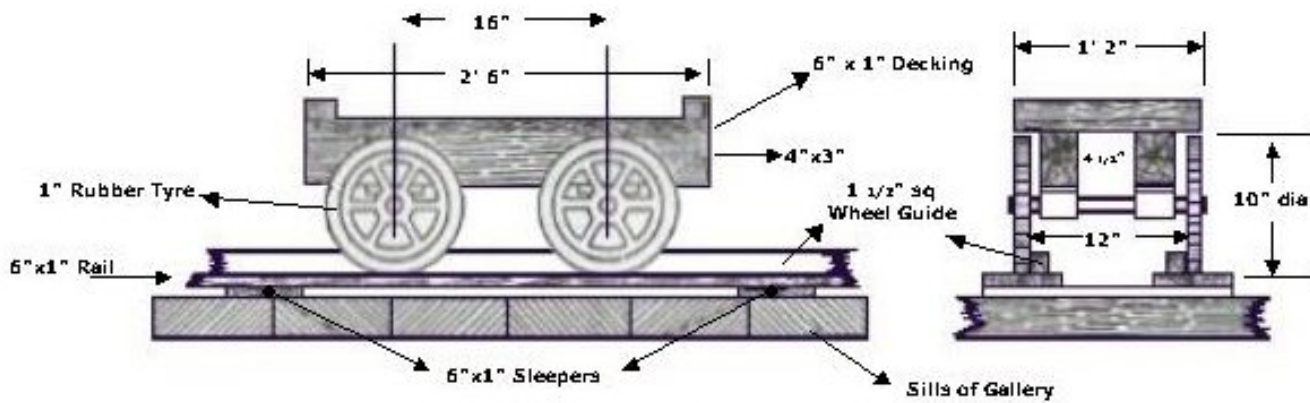


Fig. 8.
Mine Truck and Tracking

The presence of blue clay on the surface was a sure indication to either side of the existence of deep mining.

The spoil in sand-bags was used for revetting trenches, covering dugouts, etc., but the balance was dumped into the railway cutting, which afforded a secure dumping-ground.

Ventilation and Drainage

Small geared rotary fans were usually employed for ventilation. They were worked by two men, and were capable of supplying a strong current of air up to 300 ft. The delivery pipe was rubber hose 3 in. in diam., reinforced with wire-binding to keep it distended.

The gearing on these fans made them very noisy, and the sound carried distinctly along long lengths of gallery.

For more silent working and with equal efficiency 6 ft. blacksmith's bellows were employed. These were generally installed two in series, and gave a good flow of air with a minimum of noise.

For drainage the general service pump was chiefly employed in isolated positions or where the need of silence prevented the installation of power pumps. These pumps were two-stroke 3 in. diam. cylinders operated by two men, and were capable of a lift of about 80 ft., though not generally employed beyond 40 ft. of head. In a mine system such as Hill 60 the pumping absorbed a large number of men.

Surveying and Plan Records

All new work was brought up to date weekly by a theodolite survey. As all galleries were driven as direct as possible, to minimise the problem of disposal of spoil, the surveying was very elementary.

The mine system was kept accurately co-ordinated with the trench system, and as a result, with the aid of aeroplane photos showing both the enemy's and our system, we were able to accurately co-ordinate our positions with the enemy trench system.

The plans were all plotted on the co-ordinate system. The daily progress was plotted, and at the end of each week slip tracings of all gallery progress were forwarded to the Controller of Mines.

A large-scale map showing the listening posts was kept at headquarters, and a daily tabulated sheet showing the listening reports from every post was made.

Direction of enemy progress was plotted from direction listening reports from carefully-checked stations.

Charges and Effects of Mines

For calculating the charge and the probable effect of a mine certain empirical formulae have been arrived at as the result of practical experience. These formulae gave very accurate results in mining operations on the Western Front, and a digest of them is given.

Definitions (Fig. 9)

(1) Mines are charges of explosives placed under the surface of the earth, the position and quantity of the charge depending on the object to be fulfilled -

(a) Whether it is desired to produce a crater at the surface which may be occupied by troops.

(b) or to damage the enemy's works above or below ground.

In the latter case, where no crater is produced, the charge known as a camouflet.

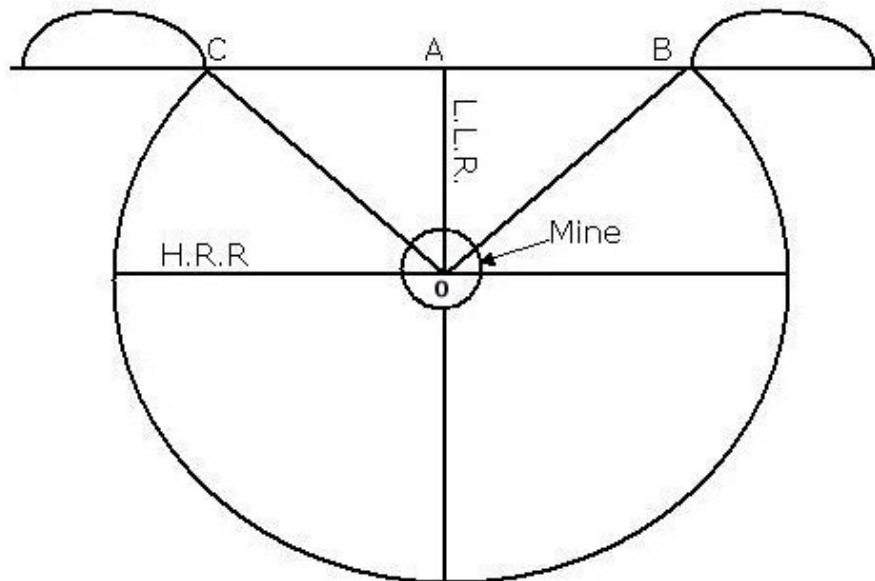


Fig. 9.

Diagram Illustrating Mine Definitions

(2) The shortest distance from the centre of the charge to the surface of the ground - or, in the case of a camouflet, the shortest distance to the enemy's galleries - is known as the "line of least resistance" (L.L.R.), and is measured in feet. It is the line OA in plan.

(3) "Radius of crater" is the radius of the circular opening on the surface of the ground, and is the line AB on plan.

(3) Craters are classified in relation of diam. of crater to L.L.R.

Thus, in a one-lined crater $BC = L.L.R.$
 " " two " " $BC = 2 L.L.R.$

(5) The distance from the charge to which the effect of the explosion is transmitted is called the "horizontal radius of rupture" (H.R.R.).

This is a vital consideration when -

(1) Estimating the destruction of enemy's works underground.

(2) Estimating the destruction of your own works underground.

Formulae for calculating charges: -

- If $L = L.L.R.$
- $r =$ radius of crater in ft.
- $c =$ powder charge in pounds.
- $s =$ variable, dependent on nature of soil,

Then in a common mine

$$c = S L^3$$

and the H.R.R. = $\frac{7}{4} \sqrt{\frac{10c}{s}}$

The values given to s are shown in the following table: -

Nature of Soil	Value of s
Very light earth	0.80
Common earth	1.00
Hard sand	1.25
Clay mixed with loam	1.50
Blue clay, Hill 60	1.60
Hard chalk	2.00

Crater Effects in Blue Clay – These figures are the result of six mines fired in blue clay. The explosive was laid in kinked galleries, with the detonator inserted in 1-oz. Gun-cotton primer surrounded by auxiliary detonators.

No. of Mines	Charge ammonal in lbs	Estimated L.L.R.	Dia. Of crater in feet
1	31,000	60 ft	180
2	15,000	45 "	150
3	13,500	42 "	140
4	12,000	42 "	140
5	1,800	30 "	70
6	600	16 "	46

These tests showed ammonal to be 3.6 times as effective as formula gunpowder. The above results, taking s to be 1.7, show the following efficiencies for ammonal in relation to c of the above formula.

No. 1	3.61
No. 2	4.23
No. 3	3.82
No. 4	4.30
No. 5	3.88
No. 6	3.14

Radius of Rupture for Ammonal in Clay – The relationship between a given charge of ammonal and its radial rupturing effect must be determined when estimating –

(1) Distance within which (a) enemy galleries or (b) our own galleries will be destroyed.

(2) Distance to be tamped for full efficiency of explosive.

The following equation has been deduced from over 100 mines to provide a simple estimation : -

For Clay – Charge of ammonal in lbs. = $(H.R.R.)^3 \div 150$.

Transmission of Explosion – The transmission of the explosion between neighbouring charges was a subject of experiment.

(a) The influence of a neighbouring blow upon detonators in a mine charge showed that in a No. 13 Mark IV detonator the fulminate was more liable to explode than the bridge to fracture. Neither result should be experienced when the detonator is over $1/5$ of H.R.R. from charge fired.

(b) The distance through which explosions can be transmitted between adjacent charges of ammonium nitrate explosives.

Three tests :-

No. 1. – 50 lb. Ammonal at about $1/5$ H.R.R. from an initial charge of 50 lb.: result – fired.

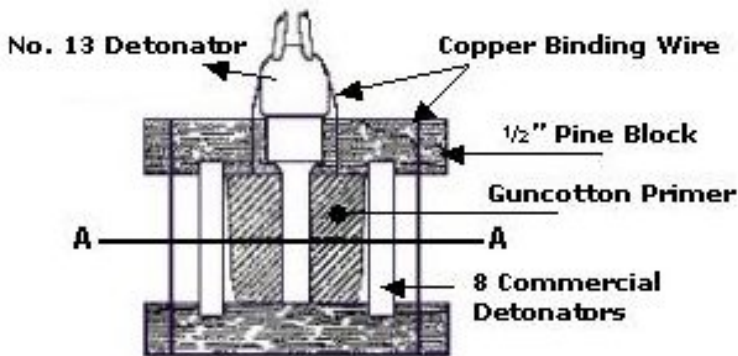
No. 2. – as above, but charge at $1/2$ H.R.R. : result – nil

No. 3. – Initial charge of 400 lb with H.R.R. of 27 ft. at a distance of 5 ft. in solid chalk from a secondary charge of 1500 lb; result – fired, producing a crater of diameter and depth equal to a charge of 1900 lb ammonal.

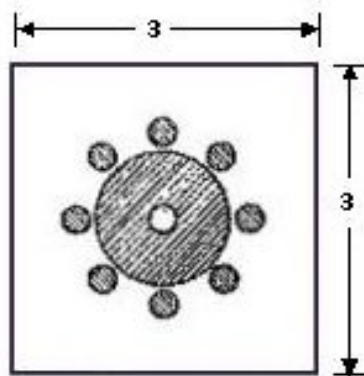
A further demonstration on mine of 84,000 lb. Ammonal at a depth of 52 ft. in chalk, including overburden of 27 ft. of clay and sand, gave a crater 115 ft. in diam., showing ammonal to be 3.75 times as powerful as formula gunpowder.

Charging and Firing of Mines

The standard mine gallery set was 4 ft. 3 in. by 2 ft. 3 in. inside of timber. Consequently, for any charge of explosive over 1000 lb., it was generally advisable to construct a chamber to receive the charge.



Sectional Elevation



Section A A

Fig. 10.

Arrangement of Detonator

cable, while the third circuit had E.I. Mark II. cable. This had six strands of copper and one of steel, covered with vulcanised india-rubber.

Table No. 1 gives all the details of the firing circuits in each mine. The leads were brought to a central terminal testing station. Here each set of leads was attached to brass terminals mounted on a well-insulated board.

This could be accomplished for the average camouflet in the standard gallery by making a T head at the end of the gallery.

In the large mines the standard gallery was enlarged to a 6 ft. 3 in. by 3 ft. 6 in. in the clear, and sufficient galleries of similar size were put in at right-angles to this new enlarged gallery to contain the charge. The only guiding factor in the design of charge chambers was to keep the charge as concentrated as possible.

The detonators used were Electric No. 13 Mark III., containing 43 grains of fulminate of mercury. The detonator was placed in a 1-oz. dry gun-cotton primer.

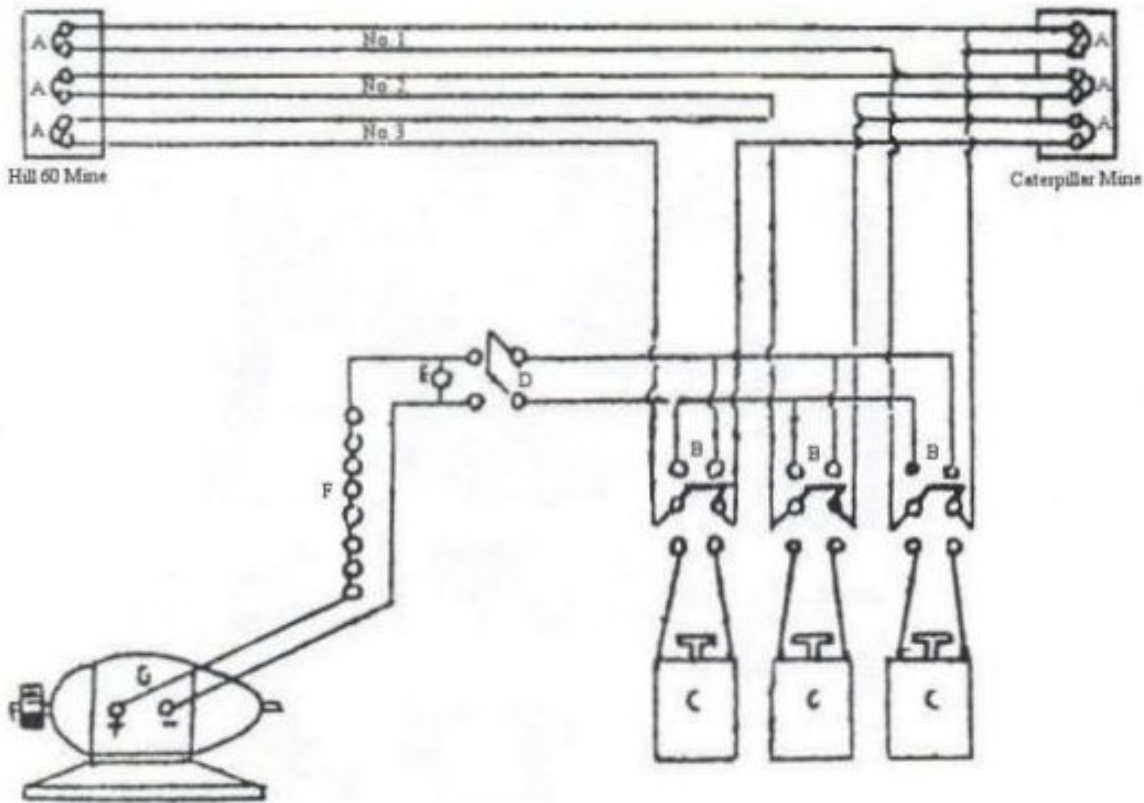
On top and bottom of the primer was placed a wooden cover, as shown in Fig. 10. These were recessed to take eight commercial detonators, which then surrounded the gun-cotton primer.

The whole was then bound together with fine wire. The detonator, thus reinforced with the gun-cotton primer and eight commercial detonators, was placed in a 50-lb. Box of gun-cotton, forming the main primer.

In each of the large mines there were three circuits with five No. 13 Mark III. detonators in series. Two of the circuits had armoured quod

Table No. 1

	Number of Detonators No. 13 Mark III.	Resistance of detonator, cold, in ohms.	Total resistance in ohms of detonators, cold.	Resistance of detonators at fusing point.	Total resistance of detonators at fusion in ohms.	Length of armoured quod cable in feet.	Resistance of quod cable per 100 ft in ohms.	Total resistance of quod cable in ohms	Length of E. I. Mark II. cable in feet.	Resistance of E. I. Mark II. cable per 100 ft in ohms.	Total resistance of E. I. Mark II. cable in ohms.	Theoretical resistance of circuit cold in ohms.	Practical resistance of circuit in ohms by Wheatstone bridge test.	Total resistance of circuit at fusion point.
Hill 60 Mine: -														
No. 1 circuit	5	1.05	6.25	2.6	13.0	1320	.204	2.70	500	.44	2.20	11.15	11.00	17.9
No. 3 circuit	5	1.05	6.25	2.6	13.0	nil	nil	nil	1820	.44	8.00	14.25	14.10	21.0
Caterpillar Mine: -														
No. 1 circuit	5	1.05	6.25	2.6	13.0	1760	.204	3.59	400	.44	1.76	11.60	11.30	18.36
No.3 circuit	5	1.05	6.25	2.6	13.0	nil	nil	nil	2160	.44	9.50	15.75	16.00	22.5



- A. 3 No.13 Mark3 Detonators in series
- B. 3 Double pole throw over Switches
- C. Exploders
- D. Single Pole Firing Switch

- E. Pilot Lamp
- F. Lamp Resistances
- G. 500 volt DC Generator

There were two methods of firing –

(1) The exploder

(2) Power from a D.C. 500-volt lighting set.

Firing Connections - Hill 60 Mines.

The mines were eventually fired by the current from the lighting dynamo, but in case of a breakdown to that set at the last moment three double throw-over switches and one control switch were placed in the circuit. Connected to the three double throw-over switches were three exploders. Fig 11 shows a diagrammatic view of the connections.

The service exploder consists essentially of a small series-wound dynamo. The field magnets and armature wound with insulated wire. The armature is provided a two-part commutator and caused to revolve by means rack and pinion. It is provided with a free wheel so that armature is only rotated on the down stroke. Fig. 12 shows diagram of connections.

There is always some residual magnetism in the field magnets, and the armature revolving on the downward stroke of the handle generates a current. The maximum E.M.F is developed at the bottom of the stroke.

The contact at K is now broken by the end of the rack depressing the spring, and the current flows through the external circuit. The personal factor enters largely into use of the exploder. The rack must be made to descend swiftly and smoothly as possible.

Details of Firing Arrangements, Hill 60 Mines

Fig. 11 shows a diagrammatic arrangement of wiring. It be noticed that the Hill 60 and the Caterpillar mines were in series, and the three sets of leads connected to the dynamo circuit in parallel.

The single-pole firing switch **D** was left open while the three double-pole throw-over switches **B** were closed on

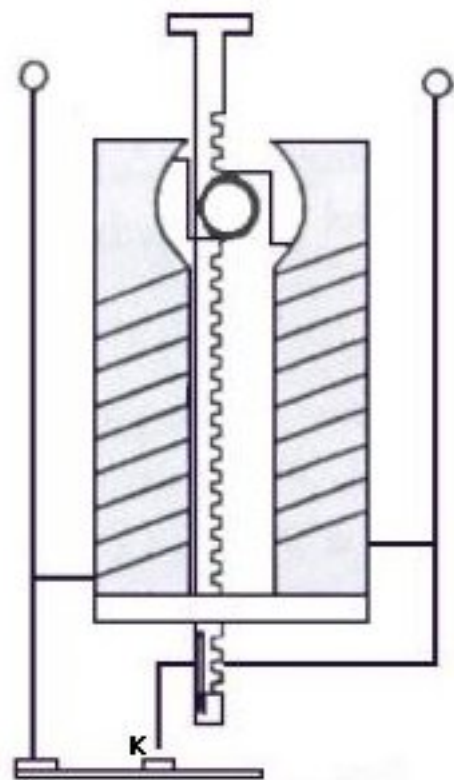


Fig. 12.
Diagram of Exploder
Connections

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dynamo circuit.

To the other terminals of these switches were connected the three exploders.

A pilot lamp, **E**, was installed to indicate that all was correct with the dynamo at the firing station.

Lamp resistances were inserted in the circuit to prevent a flash-over at the generator when the firing switch **D** was closed.

This arrangement allowed the exploders to be used should any failure of the dynamo be met with at the last moment.

An earth was connected to the sparking-plug of the oil engine and dropped when the mines were fired in case the eruption may have damaged this installation.

Explosives and Detonators Used

The explosives used were all high explosives of the shattering type. Only two classes were employed – (1) ammonal and (2) gun-cotton.

(1) Ammonal for general use in military mining was a product of this war. Its composition is as under:-

	%
Ammonium nitrate	65
Trotyl (T.N.T.)	15
Coarse Aluminium	16
Fine "	1
Charcoal	3

From tests described under "Charges and Crater Effects of Mines" it shows a strength about 3.75 times greater than formula gunpowder. It was packed in tins containing 50 lb., enclosed in pine a case.

(2) Gun-cotton was supplied in the form of wet slabs and dry primers. The following are details:-

Slabs – weight, 15 oz; length, 6 in.; breadth, 3 in.; thickness, 1 3/8 in.; remarks – with one perforation for primer.

Primer – weight, 1 oz.; diameter, 1.35 in top, 1.25 in. bottom,; height 1 ¼ in.; remarks – conical, with one perforation for detonator.

Detonators – As all charges were fired electrically, only one type of detonator was used – i.e., No. 13 detonator, Mark III.

Fig 13 shows its construction.

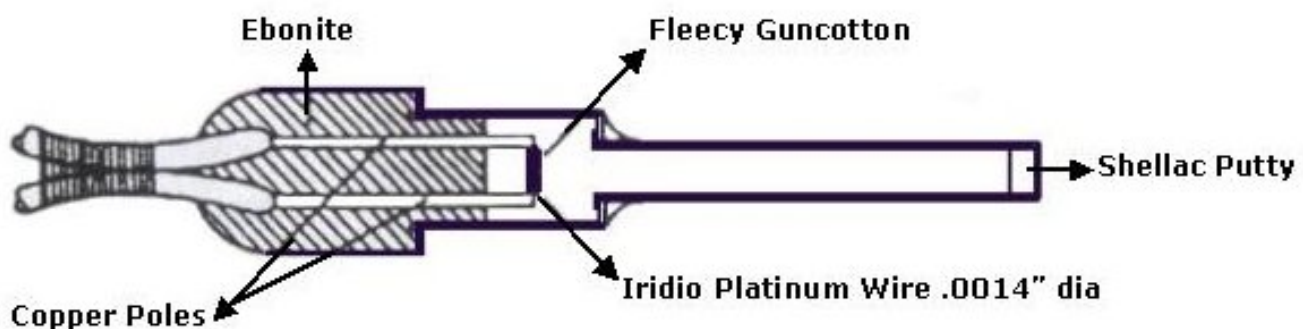


Fig. 13.

Construction No. 13, Detonator Mark III

The attached table gives detailed particulars:-

Material of bridge wire	iridio-platinum
Weight of bridge wire per yd.	.45gr.
Length	.25 in.
Diameter	.0014 in.
Resistance cold at 60° F.	1.05 ohm.
" when just hot enough to start igniter	1.30 ohm.
" at fusing point	2.6 ohm.
Smallest current that can fire	.35 amp.
" " " " fuse	.8 amp.
Smallest current to be calculated for to fire charge	.8 amp.
Largest safe testing current when testing charges	.05 amp.

Details of Charges and Crater Effects Hill 60 Mines

(1) Mine under Hill 60 -

Charge – ammonal, 45,700 lb.; gun-cotton, 7800 lb.; total, 53,500 lb.

Depth from surface, 90 ft., equals L.L.R.

Soil factor, 1.6.

Theoretical radius of crater from charge formulae, 105 ft.

Diameter, 210 ft. = 70 yd.

Actual diameter by measurement = 68 yd.

Depth of crater after debris had settled = 33 ft. from original ground-level. The rim around crater stood about 10 ft. above this.

Radius of rupture to complete obliteration = 140 ft.

Length of 4 ft. 3 in. by 2 ft. 3 in. gallery tamped = 240 ft.

(2) Mine under The Caterpillar –

Charge – ammonal, 70,000 lb.; total, 70,000 lb.

Depth from surface, 100 ft., equals L.L.R.

Soil factor, 1.2.

Theoretical radius of crater from charge formulae, 135 ft.

Diameter, 270 ft. = 90 yd.

Actual diameter by measurement, 273 ft. = 91 yd.

Depth of crater after debris had settled = 51 ft. from original ground-level. The rim around crater stood about 15 ft. above this.

Radius of rupture to complete obliteration = 190 ft.

Length of 4 ft. 3 in. by 2 ft. 3 in. gallery tamped = 510 ft.

The mines were fired at 3.10 a.m. (summer time) on 7th June, 1917.

It was found that the amount of tamping put in with both charges well ensured the L.L.R. being to the surface. The mine system was left practically intact from about 100 ft. from the face of the tamping.

A point of interest is the close agreement of the calculated and actual dimensions of the craters formed.

Electrical Testing and Instruments Employed

As before mentioned, all mines and camouflages were fired electrically. In the large mines the electrical condition of the leads was a vital question, and in order to be well posted as to their condition two series of tests were made –

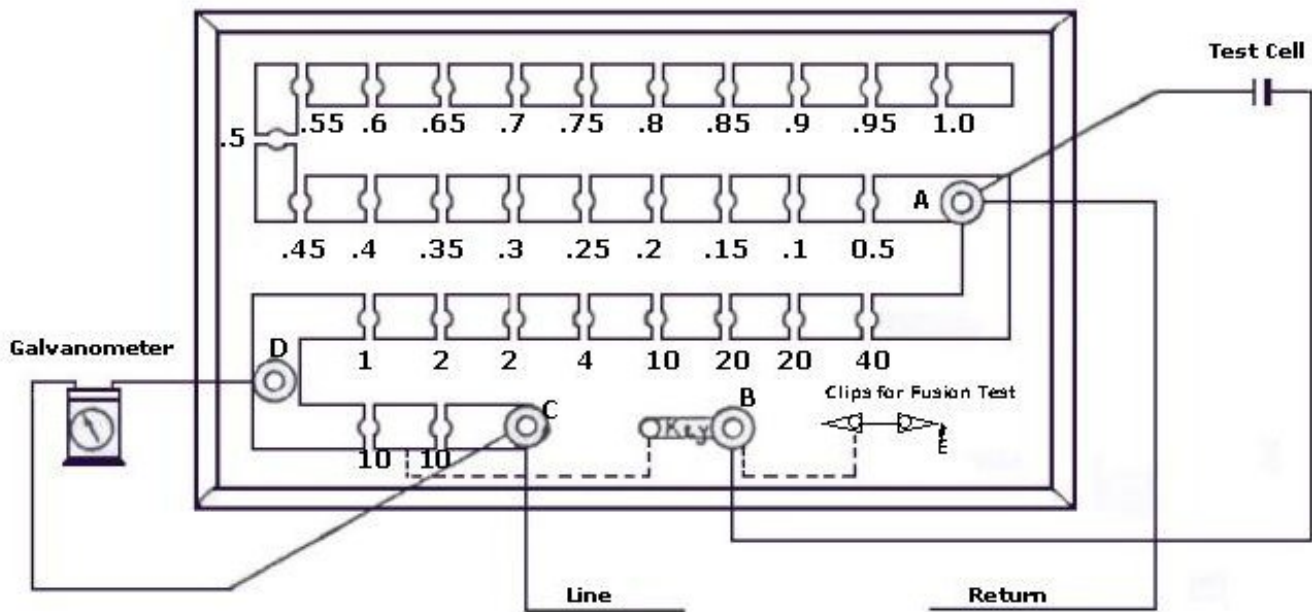


Fig. 14.
100 Ohm. Resistance Coils Showing Connections for Testing
Resistance of Line Fuses Etc.

Note: - When testing Explorer it is placed in series between A and Terminal of Fusion Clips E. Between these clips is placed 1/4-in. Standard Iridio-Platinum wire; the Key and C are short-circuited and the two ohm plugs kept in. Galvanometer and cell are disconnected.

(1) For continuity, taken once every 6 hours; (2) for resistance, taken once every day. The testing set supplied to tunnelling units contained a set of resistance coils, to 100 ohm; a three-coil galvanometer; one dry electric cell; two reels iridio-platinum wire, .0014 in. diam., the same as the bridge wire of electric detonators.

Resistance coils are arranged as in Fig. 14, so as to be as easily connected up as a Wheatstone bridge. They are graduated from 1/20 ohm to 100 ohm, and are also furnished with clips 1/4 in. apart for holding the iridio-platinum wire used in the fusion test.

It will be noted that the key is placed in the battery circuit, and that the galvanometer is always in circuit.

The three-coil galvanometer has three coils, the bottom of which are wound to 2, 10 and 100 ohm respectively, any which can be brought into circuit by a brass plug. The end all the coils is connected to one terminal, the others being connected each to its respective brass block.

Fig. 15 shows diagram of connections.

The 1000 ohm coil is used for comparing and indicating small currents up to .005 amp. The 10 ohm coil is used with the Wheatstone bridge.

The 2 ohm coil is used for continuity testing.

The dry electric cell is a special form of dry cell provided with a resistance coil that brings the total internal resistance up to 12 ohm. This obviates the possibility of

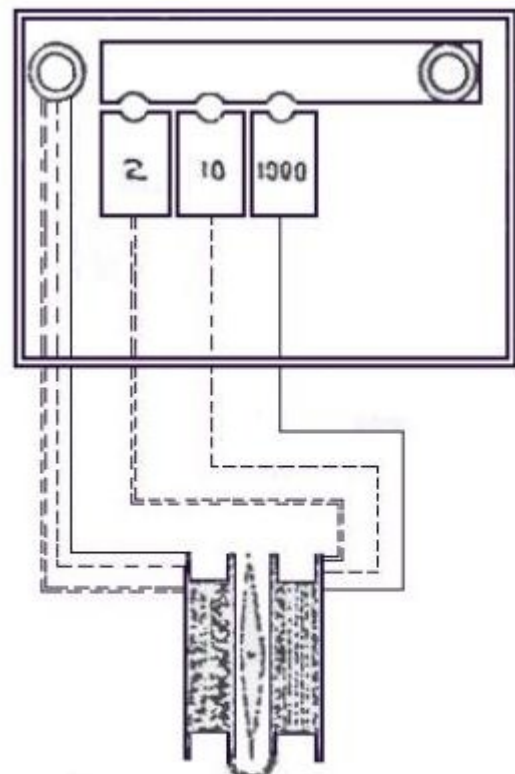


Fig. 15.
Galvanometer

of
of

anything but a very small current being sent out by it under any circumstances; its E.M.F. is 1.5 volts

Fig: 16 shows connections.

The electrical testing may be divided into – (1) testing the firing apparatus, (2) testing the detonators, (3) testing the conducting wires, (4) test ing the complete circuit after everything is ready for firing.

(1) Testing Exploders is carried out with the firing resistance coils connected up as in Fig. 14. The key is cut out by a short lead as shown.

If in good condition the Mark V. exploder should fuse standard iridio-platinum wire through 100 ohm. The exploder should not be tested with a resistance it is unable to fuse through, but should be tried gradually until the machine fails to fuse.

To be safe, the exploder must be capable of fusing through a resistance 25 % greater than the calculated resistance of the circuit at fusing point.

(2) Testing Detonators. - All fuses and detonators should be balanced by the Wheatstone bridge method. The connections are made as in Fig. 14. The two 10-plugs are removed, and, with all other plugs in, depress the key and observe the direction of the throw of the needle. This gives the resistance when too low. Now unplug sufficient resistance to give a throw to the needle in the opposite direction. This resistance is too high, and the correct resistance should be taken as a mean of the resistances which give indications on the galvanometer as being just too high and just too low.

Test of Detonators for Over-Sensitiveness – Detonators should not fire in 4 seconds with a current of .32 amp.

Test of Detonators for Under-Sensitiveness – A few detonators from each box should be fired with .45 amp. If they fail to fire in 4 seconds the whole box should be rejected.

(3) Testing Conducting Wires – The continuity test is made with a galvanometer and battery in the circuit. Resistance tests are made on the Wheatstone bridge.

(4) Testing Complete Circuit – When the mines are laid, the theoretical resistance (cold) of the detonators and cable can be estimated from data supplied with each article. The whole circuit should then be balanced with the test cell by the method of the Wheatstone bridge. If the actual resistance agrees within small limits with the theoretical the circuit can be taken as correct.

Example (Fig. 17): -

	ohm
7 Detonators	7.05
Main leads	4.00
Branch leads	2.00
Leads between charges	<u>1.00</u>
Total theoretical resistance	14.35

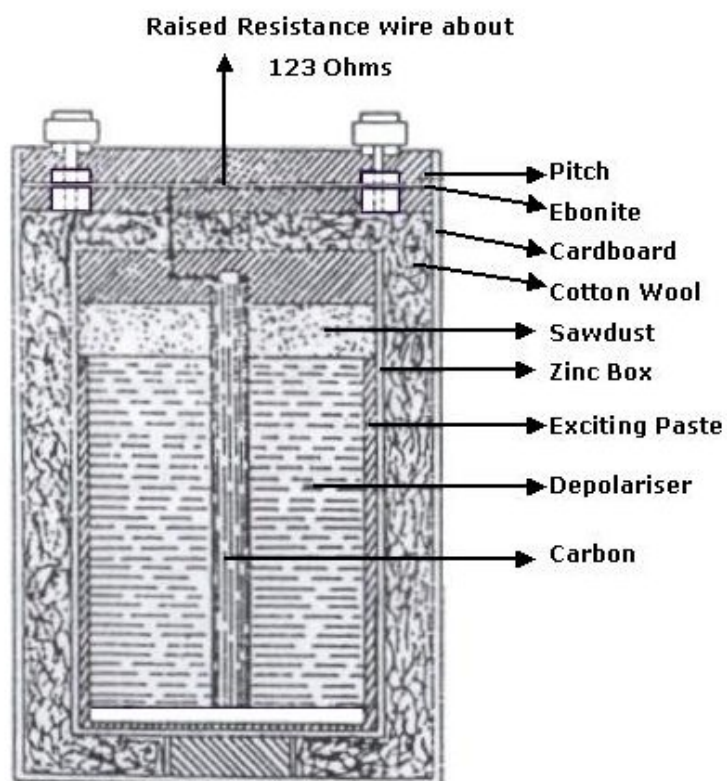


Fig. 16.
Test Cell

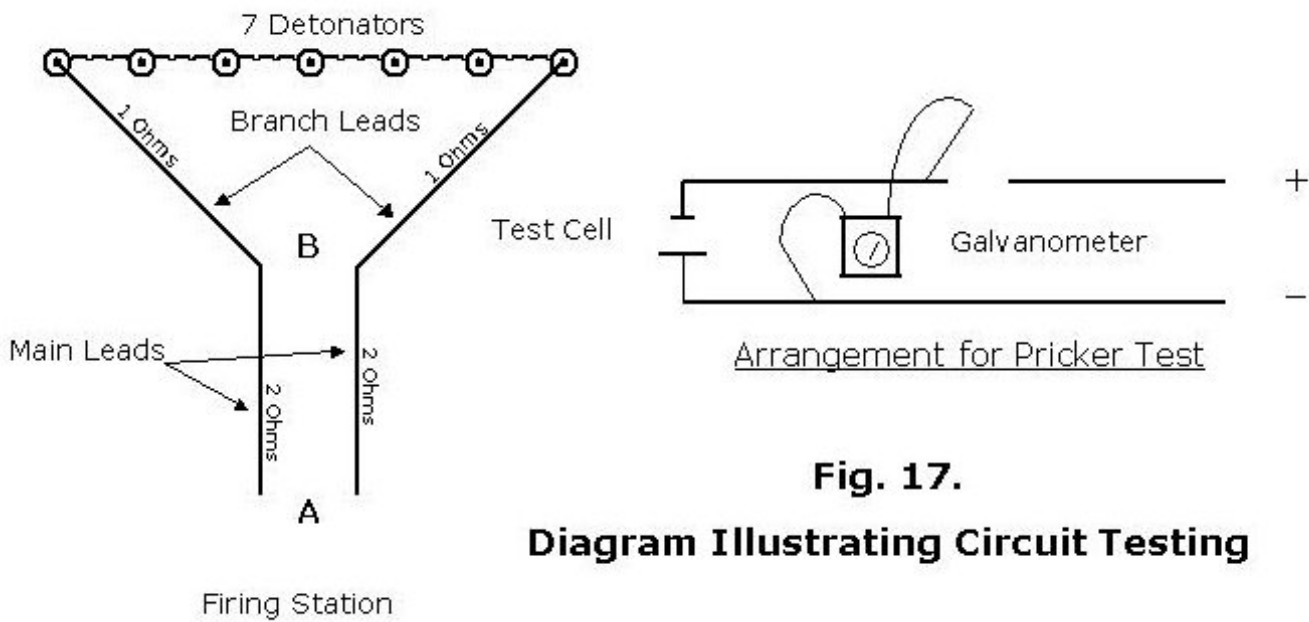


Fig. 17.
Diagram Illustrating Circuit Testing

If resistance measured from A is, say, 18 ohm, there is a bad joint. If infinite, there is a disconnection. If considerably less there is a leakage. If a steady reading is difficult to obtain there is probably a loose connection.

These faults can be generally readily localized by what is known as the "pricker test," which consists of attaching two needles to flexible leads of the galvanometer and making the cross connections by piercing the insulation.

Arrangement of test is shown in Fig. 17.

Mine Listening and Instruments Employed

It can be justly claimed that, in common with the other branches of modern warfare, mine listening developed along very scientific lines. The advance from the stage of listening with the un-aided ear to the use of the most highly specialized instruments was rapid. Yet the general public and journalists seem to have been unaware of this fact. As late as May, 1916, it was common to find illustrated papers depicting the tunneller listening for enemy mining with his ear upon a duck-board or in a stooping attitude with hand over his ear, the better to concentrate the supposed noises. Had such been the true case, the tunneller's lot would have indeed been an "uplifting" one.

However, we were aided by instruments of the most delicate nature, chief of which were the geophone and various types of microphones with electrical connections. The latter enabled listening to be carried out at a great distance from the actual listening post, and also lent itself to the establishment of central listening stations.

The geophone (Fig. 18) was in general application, as it possessed the double advantage of (1) giving a true reproduction of sound, and (2) giving a true determination of direction.

In construction it consisted of a mass of mercury enclosed on either side by a mica diaphragm and surrounded by an annular block of wood. Over the mica diaphragm on top and bottom are placed wooden covers, with an air space about 1/8 in. deep, and the size of the mica diaphragm. Connected to this air-space are two tubes, to which are attached a double stethoscopic ear-piece to convey the sound to the ears. Fig. 18 gives the construction in detail.

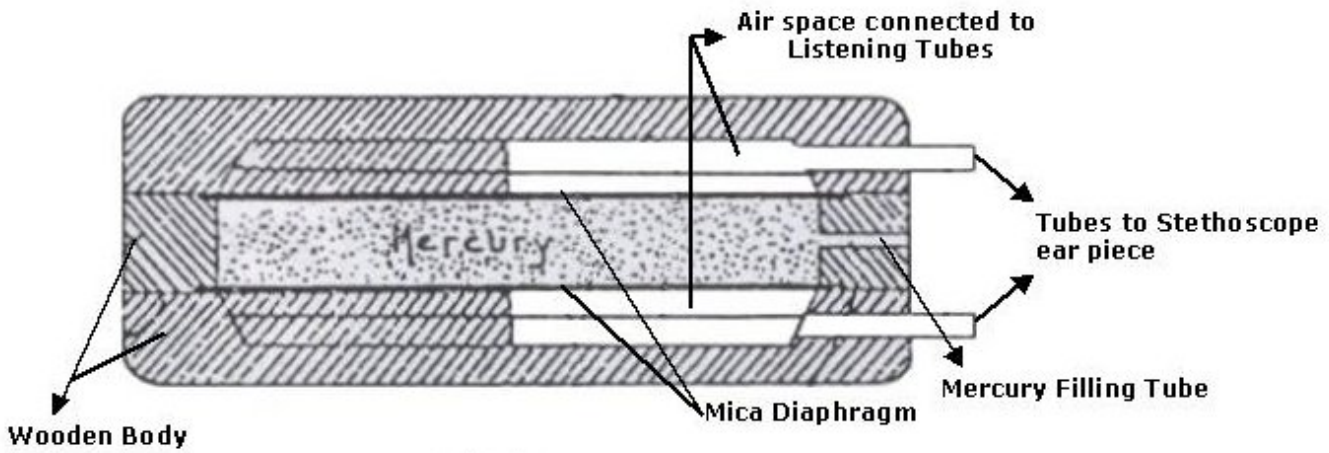


Fig. 18.
Diagrammatic Section of Geophone

Geophones are issued in pairs with a compass mounted on a piece of deal board about 9 in. long, pointed at both ends, to allow finer adjustment to the centres of geophones when these are used in pairs for determining direction.

For magnification of sound only a single geophone is used. At each listening post the listener, when only observing for sounds of enemy mining, uses the single geophone arranged as shown in previous sketch. The geophone is placed on a bench cut in the clay, and the listener, being comfortably seated, adjusts the ear-piece to his ear, and then, with watch and log-book, correlates the sounds heard and describes in detail what he considers to be their nature. It is essential that silence be observed, that the rubber ear-piece tubes hang freely and do not brush against each other, and that all equipment of the soldier be free from the liability of producing creaking sound.

The double geophone is used for determination of direction. The two geophones, previously calibrated, are used in this case, one rubber tube of the stethoscope ear-piece being attached to each geophone. The unused nipple on each geophone is plugged with a rubber stopper. In principle the two geophones now act as highly sensitive ears, and, of course, it follows that the listener himself must possess unimpaired hearing.

As with the natural ear, the direction of sound is arrived at by a wave length striking one ear quicker than the other, whence we get the impression that the sound is to the right or to the left. When the wave length meets both ears simultaneously we get the impression that the sound is directly ahead or behind. The same principle applies to the use of the double geophone.

To be a successful listener one must possess the faculty of discarding all preconceived ideas as to the direction from which the sound comes.

The two geophones are placed on a bench cut in the clay and detailed conditions apply as before mentioned. Let us assume that the sound is from the right. The right-hand geophone will record the noise more strongly, and so the left-hand geophone, or both, are slowly operated until the observer unconsciously notes that the sound is directly ahead. The compass is then placed across the centre of the geophones and the magnetic-reading noted. This is again re-checked as often as desired. For determining the elevation of the sound the same principle is applied, but in this case the geophones are placed along the wall on the clay one above the other, and the angle of dip or elevation noted.

The following table (No.2) will serve to illustrate clearly the sensitiveness of the geophone. These tests were carried out in blue clay similar to conditions on Hill 60.

Table No. 2

Nature of sound	Distance from source	With unaided ears	With geophones
Light picking	175 ft	Just distinguished	Clearly heard

Clay-kicking	125 ft	Sounds of working not heard	All sound distinguished
Shovelling on timber floor	110 ft	Just detected by expert listener	Clearly recognized
Clay falling from face	60 ft	Occasionally heard	Distinctly heard
Falling clay; filling bags; walking in boots	45 ft	Heard, but not usually recognized	All sounds clearly distinguished
As above	40 ft	Recognized	Very distinctly heard
Walking in muffled boots and general gallery sounds	30 ft	Just recognized	Distinctly heard all sounds of
Walking in muffled boots and trolleying with rubber-flanged trolley wheels	20 ft	Clearly recognized	Gallery work distinguished very readily from this distance
Talking and clothes brushing against gallery	10 ft	Just heard	
Talking and bag-dragging	5 ft	Heard quite plainly	

Electrically-connected Microphones.- The only instrument of this class with which the writer has had personal experience is the "western electric mining detector." It consists, briefly, of a microphone connected electrically with a telephone ear-piece, so that earth vibrations are transformed into electrical impulses. In the circuit is a set of five variable resistance coils, which enable the electric impulse to be reduced to zero. The instrument is calibrated by placing the microphone in the same nature of soil as that in which it is intended to be used. Then at regular intervals of, say, 5, 10, 15, 20, 25 ft., and so on, a constant bumping on the ground is made. The person calibrating the instrument now places a resistance in the circuit until the sound can be just heard. This point, of course, need only depend on the personal factor of the observer.

When all the distances have been calibrated we get two factors - (1) distance of sound from microphone, (2) resistance placed in circuit. From these a graph can be derived.

In actual work the sound at an unknown distance is heard; the resistance can be calculated, and from the graph the distance of the source of the noise found.

This type lends itself to the establishment of central listening stations and it is thereby claimed to save labour in listeners. From the experience of No.1 Company this practice possesses many disadvantages, when compared with the system of having a listener in every post using the geophone.

Take the case of the two systems side by side. Assume 50 listening posts.

With the geophone for every minute of the day there is at least one and perhaps three or four listeners capable of picking up any sound made during that period. Now for the listener on the central listening station. Considerable time must elapse before he can plug and unplug connections for the 50 posts and give a reasonable time to listening to each post. Consequently, all sorts of things may happen at the other extreme posts, and vital information may be lost. Again, he does not get such a clear reproduction of sound as does the man with the geophone.

It may be argued that a patrol with a geophone can investigate posts from which noises are reported from the central listening station, but against this procedure can be laid the following general conditions :-

In all mining systems a stage is eventually reached when both sides are fully aware that the other is mining against him. Consequently, it is only correct to assume that both sides strictly enforce silence in their operations, and it may from experience be almost given as a rule that either side only obtains vital information from the carelessness of the other. Consequently, with a geophone at each post these slips on the part of the enemy are noted, and a very true idea as to their nature instantly obtained. With the

central listening station the post may have been recently disconnected, and very valuable information lost.

Training of Listeners. –All listeners were trained at the Second Army Mine School at Proven under the command of Capt. Pollock (of Sydney University). Here a model mine was made, with one gallery in the surface clay and the other in the blue clay. Adjacent to this, and entirely separated, was a second mine running at an angle to the first system.

In-system No. 1 the men being trained for listening were posted from time to time at different listening posts, so arranged in conjunction with system No.2 that the distance from the source of noises could be regulated.

In system No.2 mining was carried out by a party of miners under conditions similar to front line work.

In the early stages of training the listener was given a schedule which showed the nature of the work being carried out in No.2 system, thereby being enabled to associate the noises with their correct origin.

Later, he had to construct a schedule himself from his listening record, noting the time at which the varied operations of mining in No.2 system were carried out and identifying each class.

Still later he was trained in direction of sound by the double geophone.

The course lasted ten days.

The lot of the listener is a most unenviable one, and, unfortunately, as regards the general public and perhaps the other arms of the service, is not truly recognized. It was a branch of duty which entailed constant faithful service without the glamour attaching to the other branches of the service. A listener might be posted hundreds of feet behind the enemy lines, keeping his lonely vigil, his only means of escape being a gallery 4 ft. 3 in. high and 2 ft. 3 in. wide. Once per tour of duty he was visited by his N.C.O. and the officer on duty.

His tour of duty was 6 hours listening, 6 hours rest (in which he obtains his meals), and then back to duty again. The tour of duty in the line is 4 days, after which he was relieved, and went back for rest for 4 days.

The history of the company shows many acts of heroism performed by those trusty soldiers, to whose efforts has to be placed the successful guarding of Hill 60 through months of dangerous and anxious duty.

Mine-Rescue Work

Hand in hand with the scientific advancement of the different phases of underground warfare went that of mine-rescue work. Due to the number of casualties caused by carbon monoxide poisoning - the result of our own or enemy blows - each army had a fully-equipped mine-rescue school, where men from the , various tunnelling companies in the army were trained and then given revision courses at stated intervals.

Equipment of Mine-Rescue Schools. - In the British Army the standard apparatus used for providing the wearer with a supply, of factitious but respirable air and allowing the wearer to work in the most poisonous gases were :-

(1) The proto set.

(2) The salvus set. (This set is really a miniature proto set, with a supply of oxygen for 3/4 to 1 hour. It is very light and portable, and was chiefly used by officers in rapid reconnaissances- after enemy blows.)

In addition to these sets, there was the novita or oxygen reviving apparatus, used for resuscitation work conjunction With the application of Schaefer's method of artificial respiration to the person gassed.

The Proto Set. – Fig. 19 gives a diagrammatic view of this apparatus. Briefly, it consists of two steel cylinders, each capable of holding 5 cub. Ft. of oxygen gas compressed to 120 atmospheres (1800 lb) per sq. in. A reducing valve is fitted to these cylinders, so adjusted as to pass a regular supply of 2 litres of oxygen per minute, no matter what the pressure may be in the cylinders.

The reducing valve delivers the oxygen through a flexible tube to the breathing bag, which is carried on the chest. This bag is of strong rubber contained in an outer bag of canvas. It has two compartments, which, however, communicate near the bottom of the bag through a filter bed of stick caustic soda. This bag is fitted with a saliva trap and a relief valve for allowing excess air to escape. The mouth of the bag is closed with metal clamps and wing nuts. From the oxygen compartment of the breathing bag runs a flexible corrugated tube, fitted with an inhaling valve to the mouth-piece, and from the mouth-piece runs a similar tube fitted with an exhaling valve to the saliva trap and thence to the other compartment of the breathing bag.

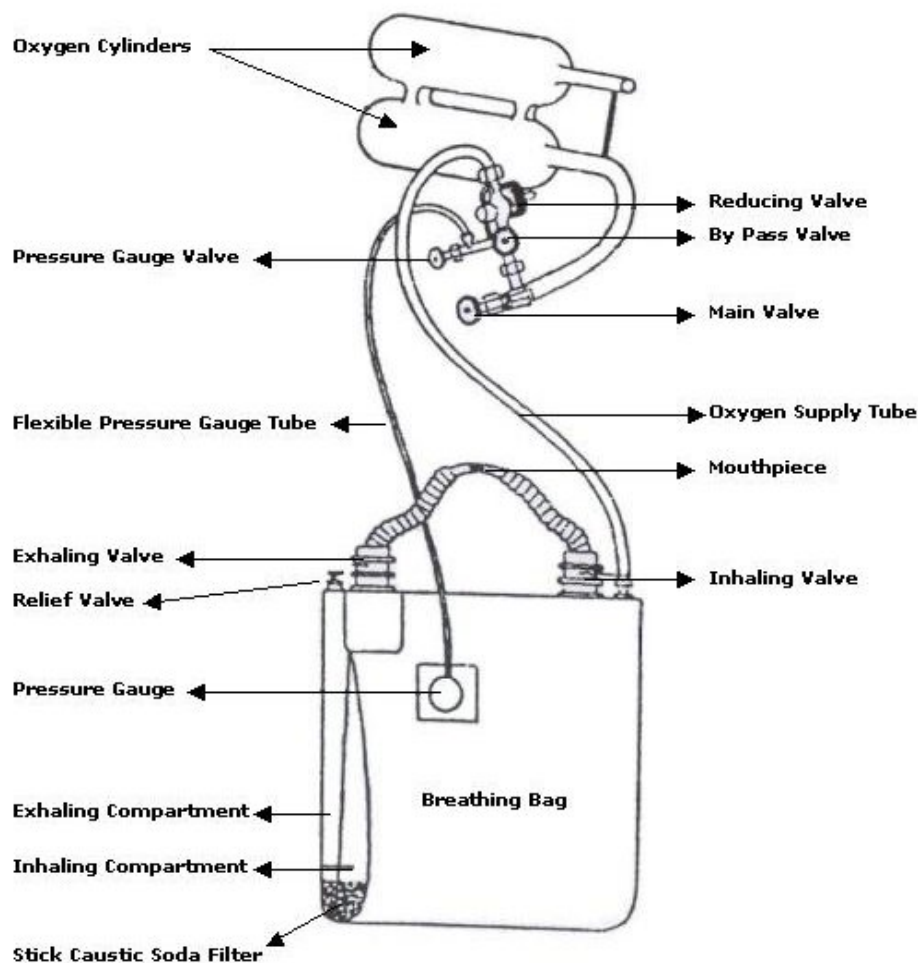


Fig. 19.
Diagrammatic Set "Proto" Apparatus

The mouth-piece has two rubber grips, which are held between the teeth, and a rubber flange held between the lips and the teeth. To ensure this being kept in position it is attached by woven straps to a skull cap.

A nose clip, to prevent breathing through the nose, is also attached.

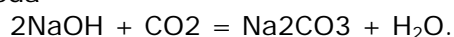
Connected to the oxygen supply pipe is a flexible tube leading to a pressure gauge, which enables the wearer to read off the amount of available oxygen remaining in his cylinders, and a by-pass valve, by means of which oxygen can be admitted to the breathing bag at a greater rate than that supplied by the reducing valve.

The whole is supported, on a broad belt which fits over the shoulders and straps round the waist. The oxygen cylinders are carried on the back, the breathing bag on the chest, and the main valve, reducing valve, and by-pass valves on the left side in such a position as to be readily operated by the right hand.

Operation. - About 4 lb. of stick caustic soda (98.99% pure) are placed in the breathing bag. The apparatus is then adjusted to the body and the mouthpiece inserted. Breathing is then carried on with the main valve opened about one turn, and when the breathing bag is slightly inflated the nose-clip is attached.

Cycle of Oxygen Gas. - When the main valve is opened the oxygen passes through the reducing valve, then through the flexible rubber tube to the oxygen compartment of the breathing bag. From here it is withdrawn by inhaling into the lungs. The exhaled air passes to the other compartment of the breathing bag, whence it slowly filters through the caustic soda filter bed to the oxygen compartment.

In passing through the filter bed the CO₂ in the exhaled air is absorbed by the caustic soda with the formation of carbonate of soda -



This reaction is accompanied by the formation of heat, and to cool the breathing bag from time to time oxygen is admitted to the bag direct by means of the by-pass, the relief valve being depressed at the same time. In order that the formation of the carbonate may not render the filter bed impervious, the sticks should be well rubbed together from time to time by grasping the bottom of the breathing bag in the hand.

With this apparatus the wearer is enabled to work in a vitiated atmosphere for about two hours on end.

The Novita Set or Oxygen Reviving Apparatus. - This set consists of a single oxygen cylinder with a control valve admitting oxygen to a rubber bag of about 1 cub. ft. capacity. From this bag runs a flexible rubber tube (on which is a clip valve), ending in a rubber face-mask fitted with an exhaling valve.

The person gassed is laid face downwards, the rubber mask placed over his mouth and nostrils, and while Schaefer's method of resuscitation is being applied oxygen is admitted, so that, in inhaling, free oxygen is drawn into the lungs.

Air-Testing. - To test the purity of the air the proto men carried canaries or white mice in a wire cage opened on all sides, on the top, and bottom. The rapid heart-beat of these indicators results in poisonous gases being assimilated to their system much more rapidly than would be the case with the human being, thus giving a reliable indication of a danger point.

The scientific employment of these indicators was not always grasped by the rank and file, as the following incident illustrates :-

We had blown a camouflet of 3000 lb., and as soon as the gallery was pronounced clear we commenced to recover our former position. An air-pipe was placed up to the face, and, to prevent danger from gas cavities when driving through the shattered ground, a white mouse was left with the facemen as an indicator. Judge of the officer's surprise, when, later, visiting the face, he found the mouse and cage suspended in front of the air supply! When remonstrated with, one faceman replied, "Why, the amount of fresh air that mouse will breathe won't harm us!"

Training in the Use of the Apparatus. - All officers and specially-selected men went through a course at the mine-rescue school. Here air-tight galleries of standard size were constructed on the surface with windows, so that the operations could be watched by the instructors. These galleries could be filled with smoke or gas from a small furnace, so that actual conditions of the most rigorous type could be enforced. Operations such as bag-dragging, tamping, and rescuing injured persons were carried out.

In addition, ladder-ways and small openings were included in the system, the nearer to approach to actual conditions.

Lectures on the theory and care of the apparatus were given, and one section of the practical examination consisted in localizing the defects in apparatus. A medical officer gave lectures in mine gases and the application of Schaefer's method of resuscitation in conjunction with the use of the novita set.

Organization in the Trenches. - At every separate mine system two protomen were always on duty on each shift, the whole being under the charge of an N.C.O. They kept all the apparatus in good order, and, immediately on an enemy blow, or after one of our own blows, made a complete inspection of the mine system. All men working below were ordered to come on top immediately on an enemy blow, and to remain there until the galleries were pronounced clear of gas.

In order to economize in apparatus, all proto sets, once the pressure had fallen to 90 lb., were sent back to the mine-rescue school to have the cylinders re-charged and a thorough overhaul of the apparatus made.

Dugouts

The construction of dugouts and machine-gun emplacements formed an important part of the work of tunnelling companies.

Figs. 22 and 23 gives a general lay-out of the standard dugout or machine-gun emplacement.

The only special feature in the larger dugouts was the size of the galleries. They were 8 ft. x 7 ft. in the clear, necessitating and excavation of 9 ft. x 8 ft. in the average clay this width was too large to carry one face, as the back invariably bellied.

Fig. 20 shows the details of the method of driving these galleries with the aid of a pilot gallery.

Fig. 21 and 21A show in detail the construction of a 4-way opening-out set used in large dugouts where a centre support was not desirable.

One particular system of dugouts constructed by this company is worthy of special mention, it being the largest of its type constructed by the British Army. The system was known as Hill 63 Dugout. Fig. 21 gives the details of construction. It was constructed at Hyde Park Corner, in Ploegsteert Wood.

The following details show the magnitude of the work: -

Number of working days	63
Average number of men employed, including attached infantry	197
Cubic feet of earth removed	192,588
Average cubic feet of earth removed per man per day	15
Average progress per man per day on the job	.22 ft
Total footage of 8-ft. x 7-ft. gallery, in the clear	2399 ft
Total footage of 6-ft. x 4-ft. gallery, in the clear	146 "
Aggregate footage	2722 "
Sets of timber used	3435
Entire timbering	520,000 sup. ft.
Bunk sleeping accommodation for	1200 men

In addition, accommodation was made for officers' quarters in steel-framed dugouts placed under the spoil dump with about 12 ft. of cover. The system could accommodate a further 150 ranks in addition to 50 officers. A typical example of progress in smaller dugouts is shown. The dugouts were constructed in Hooze crater for Brigade headquarters prior to the Menin Road battle in September, 1917.

Total hours to complete	312
Hours delay due to enemy shelling	23 ³ / ₄
Actual hours worked	288 ¹ / ₄
Average number of men per shift	27.4

Footages -	3 stairways 6 ft. 3 in. x 2 ft. 9 in. in clear	130 ft. in length	120.3 cub. yd.
	Main gallery 6 ft. 3 in. x 3 ft. 3 in. in clear	127 ¹ / ₂ ft. in length	111.8 " "
	Dugouts 6 ft. 6 in. x 6 ft. in clear	140 ft. in length	233.3 " "
	Total excavation		465.4 " "
	Cubic feet spoil removed per hour		1.6 " "
	Ground – blue clay		
	Spoil sand-bagged and hoisted by truck up the three stairways		

Figs. 22 and 23 illustrate this section.

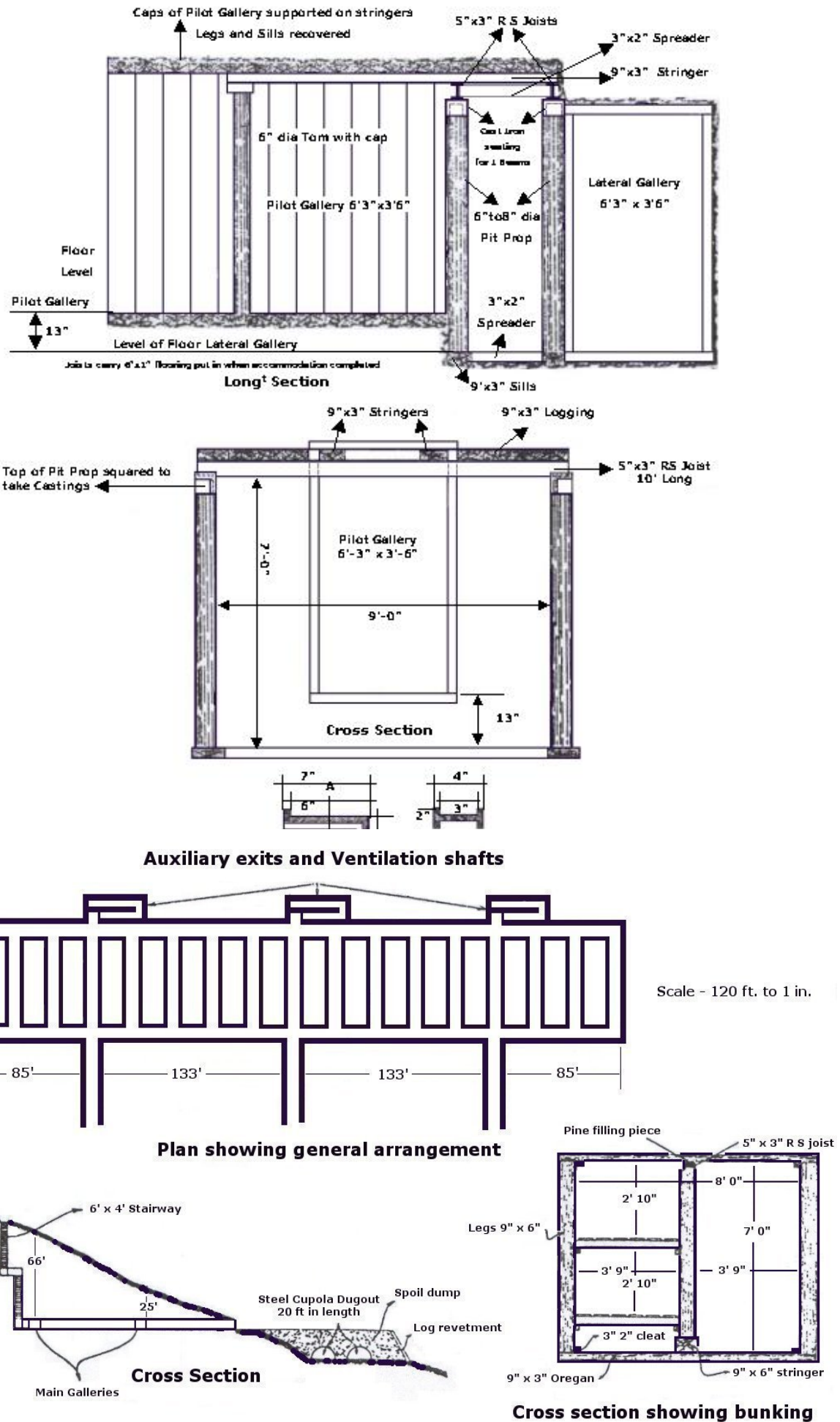


Fig. 21.

Details, Hill 63 Dugouts

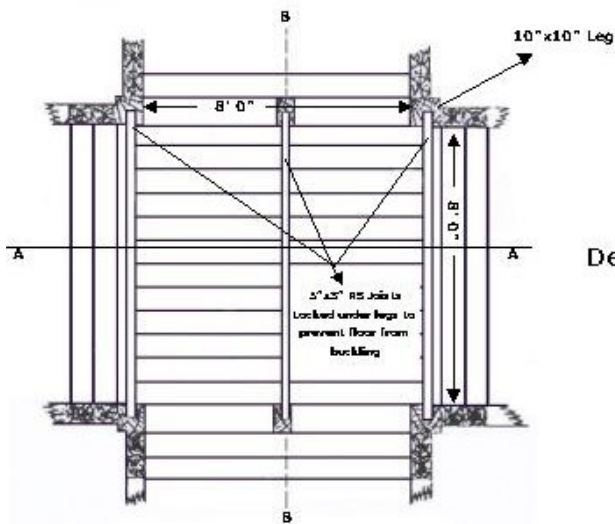
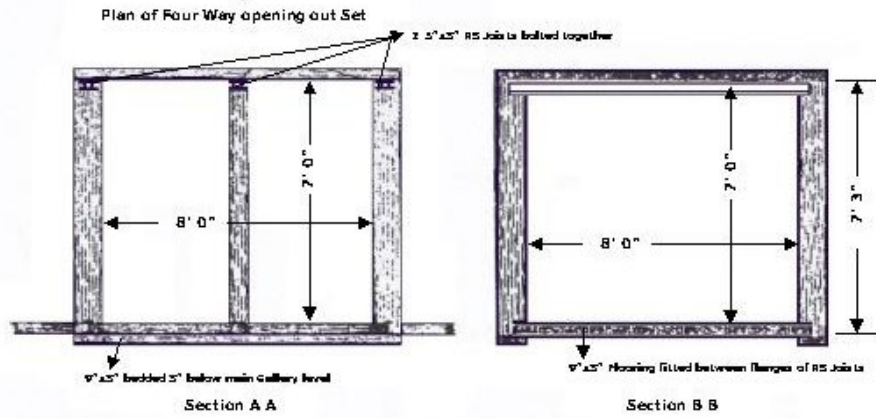


Fig. 21A
Details, Hill 63 Dugouts



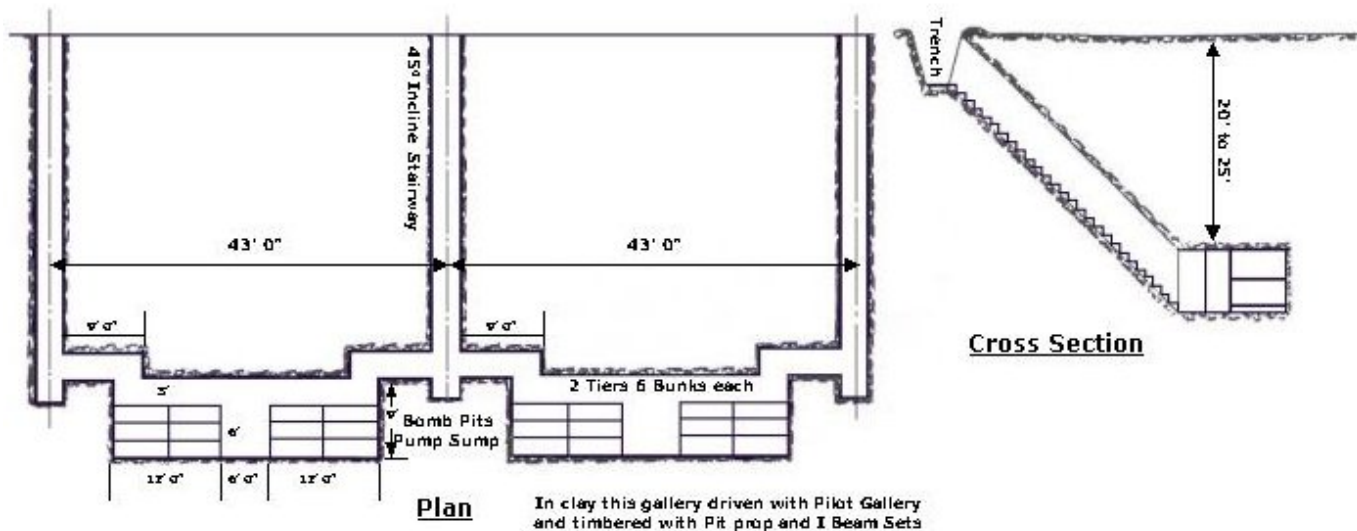


Fig. 22.

Standard Front-Line Dugout; Accommodation, 48 Men.

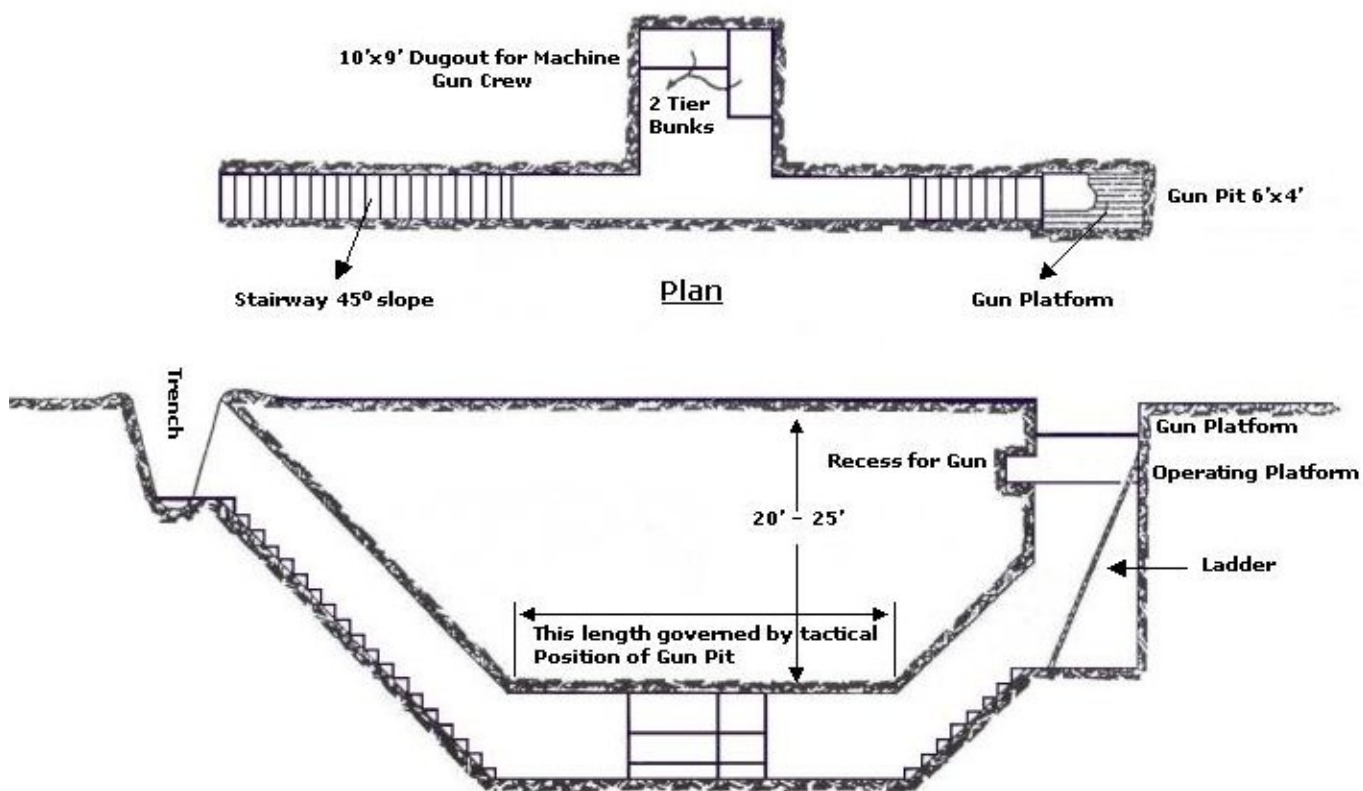


Fig. 23

Standard Machine Gun Emplacement

Source:

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