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CONTENTS.

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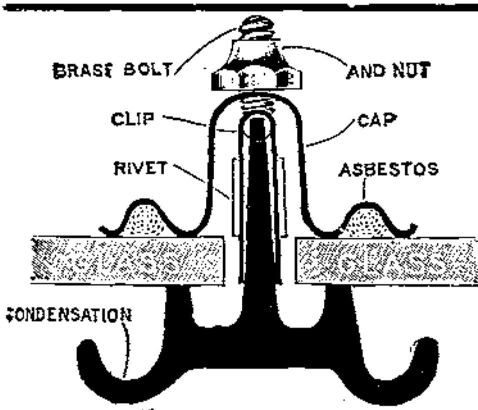

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CONTENTS.

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AN EXTEMPORISED HAND GRENADE.

By Bt. Major R. L. McClintock, d.s.o., R.E.

The hand grenade is a military appliance which, albeit of oft and well-proven utility in both savage and civilized warfare, is specially prone to oblivion during any protracted spell of peace. To the ordinary range-bred soldier it naturally seems incredible that men armed with magazine rifles should ever either desire, or be, in a position to hurl bombs at each other by hand. So, between wars, the use of grenades receives scant attention, and the fruits of laboriously acquired experience are thus gradually lost. Sooner or later, however, the need for the employment of this weapon once more arises, and a suitable type has forthwith to be re-discovered at the expense of much time and trouble.

Hand grenades are essentially articles which lend themselves to improvisation. The opportunities for their use are so rare, and they are so weighty, bulky and so costly as compared with rifle ammunition, that carting them about with an army in the field would seldom be worth while. They are accordingly most unlikely to be found on the spot when suddenly required.

The remedy for this probable deficiency is to arrive at an efficient type of grenade which need not be of Arsenal manufacture, but can be turned out in large numbers when required by the Sapper companies and Engineer Field Park. Such a type, however, demands :—

(1). That no materials or explosives should be required in its manufacture which are not already carried by the Companies or the Field Park.

(2). That the design should be of the utmost simplicity, and only require the use of tools already carried by a Sapper Company in the field.

(3). That full working drawings should be readily accessible to all.

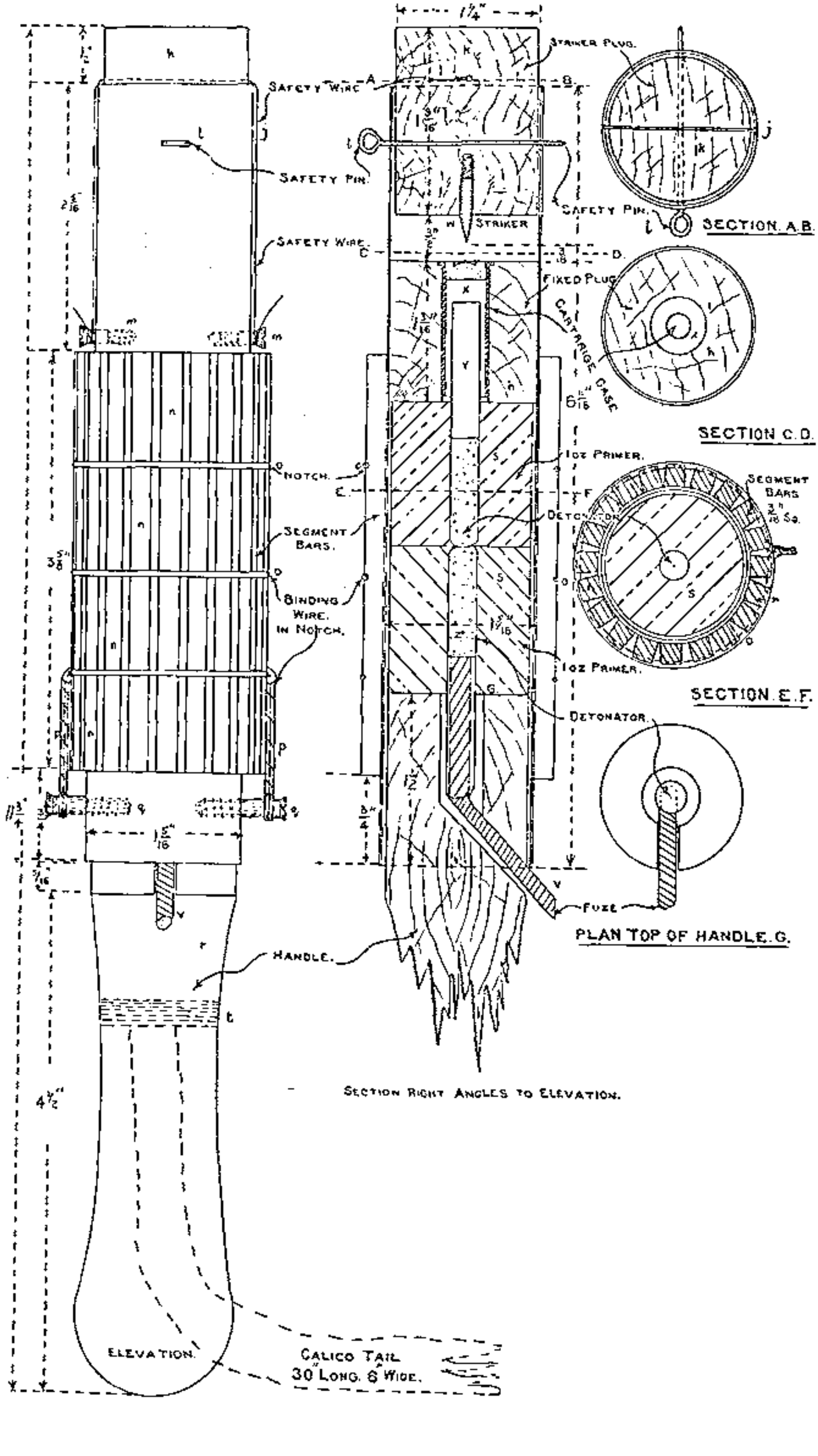
At present there is no such approved design. The official grenade is a costly and complicated machine-made affair of a pattern quite impossible to improvise in the field, and there is no other information on the subject of grenades available to the ordinary man, except such as may have been published from time to time.

To supply this deficiency the three Corps of Sappers and Miners in India (who are faced with the need of a hand grenade more frequently than their confrères at home) have been at the pains of devising various patterns for their own private uses. The following is an account of that adopted by the "Queen Victoria's Own" at Bangalore, and the description and drawings thereof are offered in the hope that they may serve to supply the want referred to above. The grenade in question is the outcome of experiments lasting over nearly a year, and it is claimed that while conditions (1) and (2) have been fulfilled, the grenade is both safe to handle and of extremely destructive effect when fired.

(*a*). *Body*.—The body of the grenade consists of a metal tube $6\frac{11}{16}$ in. long and of $1\frac{5}{16}$ in. internal diameter, or just big enough to admit the ordinary 1 oz. dry guncotton primer. The material of the tube may be block tin sheet, or that obtainable from biscuit, cartridge, or kerosene oil tins, the latter serving the purpose admirably.

(*b*). *Fixed Plug*.—This is a cylindrical plug of wood (*h*) $1\frac{3}{16}$ in. long, and of diameter sufficient to fit the inside of the body tube closely. This is placed within the tube, with its top $1\frac{7}{16}$ in. from one end, and secured in place by two $\frac{3}{4}$-in. screws (*mm*). Through the axis of this plug a hole is previously bored, just large enough to admit and hold a L.M. cartridge ("*x*," *vide* Section C.D.).

(*c*). *Striker Plug*.—Another cylindrical plug of wood (*k*), $1\frac{9}{16}$ in. long and $1\frac{1}{4}$ in. in diameter (*i.e.*, just large enough to slide easily in the body tube) has a nail or screw (*w*) fixed axially in one end, and the head then filed off to a point projecting $\frac{3}{16}$ in. from the wood. This forms the striker (*w*). Now, if the plug (*k*) is dropped into the top of the body tube, the point of the striker (*w*) will rest on the cap of the cartridge (*x*) held in the fixed plug (*h*). The other end of the striker plug (*k*) will still project from the top of the body tube, and a blow on it will explode the cartridge. The point of the striker (*w*) however, is kept $\frac{3}{16}$ in. clear of the cap (*x*) by the striker plug being raised that distance and secured there firstly by the safety pin (*l*), and secondly by the safety wire (*j*). The former, a piece of stiff iron wire, (such as telegraph wire, S.W.G. 12) passes through two



Safety Wire
Safety Pin
Segment Bars
Notch
Binding Wire In Notch
Handle
Elevation
Calico Tail 30" Long. 6" Wide.
Striker Plug
Striker
Fixed Plug
Cartridge Case
1 oz Primer
Detonator
Fuze
Section A.B.
Section C.D.
Section E.F.
Segment Bars 3/16" Sq.
Plan Top of Handle G.
Section Right Angles to Elevation.

holes in the opposite sides of the body tube and through the striker plug between them. Accordingly the latter cannot move till the safety pin is withdrawn. The safety wire, which is made of thin copper wire about S.W.G. 20, similarly passes through a second hole in the striker plug, above and at right angles to the first (*vide* Section A.B.), crosses the opposite edges of the top of the body tube, and is finally secured to the two screws (*mm*). A sufficient blow on the top of the striker plug (*k*) after the safety pin (*l*) has been withdrawn, will cause the safety wire (*j*) to shear against the sharp edges of the body tube, allowing the striker (*w*) to impinge on the cartridge cap (*x*). A drop of *two feet* on ordinary hard ground is sufficient to produce this result.

(*d*). *The Explosive Charge.*—At the lower end of the fixed plug (*h*) comes the charge (*ss*), composed of two 1-oz. dry guncotton primers. That nearest the fixed plug (*h*) has a Nobel's Octuple detonator (*y*) fixed in it, the shank projecting upwards into the interior of the L.M. cartridge (*x*) as far as possible. As the cartridge case is unnecessarily long, and would project below the bottom of the fixed plug, it is better to cut it down with a file to the length of the plug, *i.e.*, $1\frac{3}{16}$ in. The whole of the cordite should be withdrawn from the case, the cap alone being sufficient for the action of the grenade. The second guncotton primer (*s*) has likewise an Octuple detonator (*z*) fixed in it, but this is fitted with $3\frac{1}{2}$ in. of safety fuze (*v*) and points in the opposite direction, *i.e.*, downwards.

(*e*). *Handle.*—The still open bottom end of the body tube is now closed, and the whole charge kept snug by a wooden handle (*r*), $6\frac{3}{16}$ in. long over all. This also is made to fit the inside of the body tube closely, and is thrust in from the bottom end until the guncotton charge (*ss*) is held tightly between it and the bottom of the fixed plug (*h*). The handle is then secured in position by the two screws (*qq*). There is a recess in the handle to admit the shank of the lower detonator (*z*), the fuze of which (*v*) is thus led outside the grenade (*vide* Plan G). This handle is used for throwing the grenade.

(*f*). *Tail.*—Secured to the handle (*r*) by a twine whipping (*l*) is a tail of calico 2 ft. 6 in. long and 6 in. wide. This is required to keep the grenade point first during flight, and is crumpled up and held in the right hand, together with the handle, when throwing the grenade.

(*g*). *Projectile.*—To increase the man-killing powers of the grenade, a segment-projectile (*nnnn*) is added. This consists of 20 "segment-bars" (*n*), each $3\frac{1}{2}$ in. long, made of iron rod $\frac{3}{16}$ in. square. To assist the bars in breaking up into uniform segments on explosion, each bar is notched in three equidistant places with a cold chisel, thus giving 80 segments each $\frac{7}{8}$ in. × $\frac{3}{16}$ in. × $\frac{3}{16}$ in., and weighing 65·6 grs. These 20 segment-bars are placed so as to surround the centre of the body tube like a faggot, and are secured in place by three belts of wire (*ooo*), each passing round the faggot and screwed up tight with pliers (*vide* Section E.F.). The equidistant notches mentioned above afford good seatings for these belts. To give additional security against shifting, the lowest belt can be joined to the two screws (*qq*) by two short pieces of wire (*pp*), but this is not essential.

(*h*). *Weight and Length.*—The total length of the grenade is 11¾ in. Its weight is 1 lb. 4 ozs. when made from kerosene oil tin; this is composed as follows:—Charge (including detonators, fuze, and cartridge) 3 oz. Projectile 12 oz. Envelope, etc., 5 oz. The action of this grenade is alternative, either percussion or time fuze:—

(*a*). *Percussion.*—The safety pin (*l*) is withdrawn, the *tail crumpled up in the throwing hand*, and the grenade cast overhand in an angle of 30 or 40 degrees, precisely as a stone would be thrown. The tail streams out and ensures the grenade pitching on its head. On impact, the weight of the grenade sets it forward on to the striker plug (*k*). The safety wire (*j*) is cut through by the upper edges of the body tube, and the striker (*w*) impinges on the cartridge cap (*x*). The explosion of this ignites the detonator (*y*), which in turn detonates the guncotton charge (*ss*). If the grenade is not used, the safety pin should be replaced.

(*b*). *Time Fuze.*—All that is necessary in this case is the ignition of the projecting end of the safety fuze (*v*), and the prompt hurling of the grenade. The best method is to hold the grenade in the right hand, ready to throw, and ignite the fuze with the left. Fuze of the length shown will burn for about 7 seconds, which is ample for deliberate lighting and careful throwing of the grenade. The safety pin (*l*) need not be withdrawn, nor need the tail be used, as it is immaterial how the grenade falls. A slightly longer range, in fact, will be obtained by dispensing with the tail altogether.

(i.). *Reasons for Dual Ignition.*—Investigations into previously designed grenades show much diversity of opinion as to which form of ignition is preferable. The true solution seems to be to have *both* available if (as in this grenade) it can be done without any special complication of design. Cultivated ground after heavy rain can easily be too soft for a percussion fuze to act with any certainty, unless made so sensitive as to be dangerous to the thrower. Also, in throwing at very short range from the prone position, it is not easy to pitch the grenade up enough to ensure it landing on its head. In such cases the time ignition, whose action is quite certain, can be used instead. Time ignition also enables the grenade to be used for demolition purposes (such as rails) after the removal of the projectile.

(ii.). *Efficiency.*—The weight of charge, and weight and nature of segments given above are the outcome of a large number of experiments. As an example of the action of one of these grenades, the following may be quoted :—The grenade was exploded in the centre of an arena 20 ft. in diameter, whose circumference was formed by a wall of planking 1½ in. thick and 6 ft. high. Forty-three holes were blown clean through the planking by segments. In addition to these there were 140 other hits which did not amount to complete penetration. Of the 63 planks on end which formed the circular enclosure, 12 alone were not touched.

(iii.). *Sensitiveness and Safety of Carriage.*—Experiments have proved that with the safety pin (*l*) in place the grenade cannot be exploded by being thrown or dropped. If necessary, however, still further safety can be ensured by the removal of the cartridge case (*x*) until the grenade is likely to be required. This can be removed or replaced in a few seconds by first removing the striker plug (*k*). The safety pin once withdrawn, the sensitiveness of the percussion arrangement depends chiefly on the thickness and material of the safety wire (*j*). The sensitiveness can therefore be regulated as desired by selection of a suitable gauge of wire. With copper wire of 20 S.W.G., the grenade will explode if dropped 2 ft. on an ordinary road.

(iv.). *Range.*—The grenade can be thrown between 30 and 40 yards by the ordinary unpractised man, and between 40 and 50 by an expert. As some of the segments on bursting go considerably further than this, it follows that the thrower should if possible be behind cover.

(v.). *Time, Labour, Cost and Material.*—Table A is the result of actual experiments at Bangalore. It will be seen from this that the time and labour in the construction of one of these grenades amounts to 4¼ "man-hours." The material required for the construction of any number of grenades can also be ascertained from this Table, always remembering that the various gauges of wire, the size of the segment-bars, etc., etc., are by no means unalterable, but merely those which experiment has shown to be the best.

From the same Table the cost is seen to be approximately Rs.1-6-0 per grenade, complete in all respects. This is a satisfactory result, since the price of the grenade mentioned in M.R., Appendix VI., is quoted as £1 14s. 3d. in *The Priced Vocabulary of Stores.*

TABLE A.—DETAILS OF TIME AND COST OF MANUFACTURE OF 12 HAND GRENADES.

		Hours Work. 1 man 1st rate.	Dimensions L.	B. (Inches)	T.	No.	Quantity. lbs.	oz.	Rate. Rs.	A.	P.	Per.	Amount. Rs.	A.	P.
	1. Carpenters' Work.														
Labour.	Making Striker plugs, fixed plugs and handles														
	Fixing plugs, handles, Safety pin and Wire	20	...	...	...	...	...	...	—	4	—	diem.	—	10	—
	Attaching tails to handles														
Material.	Deal wood—handles...	..	8	$1\frac{1}{2}$	$1\frac{1}{2}$	12	...	...	3	0	0	c. ft.	—	6	—
	Teak wood—Fixed and Striker plugs	...	6	$1\frac{1}{2}$	$1\frac{1}{2}$	12	...	...	3	8	0	c. ft.	—	6	—
	Screws Iron $\frac{3}{4}$ in.—Striker and for fixing handles in tubes...	...	—	—	—	36	...	...	—	7	—	Gross.	—	1	9
	" $\frac{1}{2}$ in.—Fastening fixed plugs in tubes ...	...	—	—	—	24	...	...	—	6	—	Gross.	—	1	—
	Calico, 1 yard wide—Tails	...	72	36	—	1	...	...	—	6	—	Yds.	—	12	—
	String —Attaching Tails to handles... ...	...	12	—	—	12	(inappreciable.)		—	—	—	—	—	1	—
	Wire, Copper, 20 S.W.G.—Safety wires	...	8	—	—	12	(inappreciable.)		—	—	—	—	—	1	—
	2. Smiths' Work.														
Labour.	Cutting to size and notching segment bars														
	Making Safety pins	10	...	...	...	...	...	...	—	4	—	diem.	—	5	—
	Cutting Cartridge Cases														
Material.	Iron rod $\frac{3}{16}$ in. by $\frac{3}{16}$ in.—Segment bars		$3\frac{1}{2}$	$\frac{3}{16}$	$\frac{3}{16}$	240	9	0	8	8	—	cwt.	—	11	—
	Iron wire 12 S.W.G.—Safety pins		3	—	—	12	(inappreciable.)		—	—	—	—	—	1	—
	3. Tin Smiths' Work.														
Labour.	Making body tubes	20	...	...	...	...	...	...	—	4	—	diem.	—	10	—
	Binding on segment bars														
Material.	Kerosene Oil tins—For body tubes		14	9	9	1	...	...	—	3	6	Each.	—	3	6
	Iron Wire, 16 S.W.G.—For binding on bars		24	—	—	12	...	4	—	3	6	lb.	—	1	—
	Solder —For Body tubes, etc.		...	...	...	...	...	3	1	3	0	lb.	—	3	9
	4. Explosives.														
Labour.	Loading grenades, takes about 5 minutes each	1	...												
	This is done by an officer or other responsible person ...		...												
Material.	G.C. Dry Primers 1 oz.—For charge	...	...	..	...	24	...	...	—	6	—	Each.	9	0	0
	Detonators, Nobel No. 8— "	...	...	...	...	24	..	...	9	0	6	1000	2	2	8
	Fuze Safety — "	...	$3\frac{1}{2}$	—	—	12	...	...	9	15	0	100 Fms.	0	1	0
	Cartridges, L.M. 303 — "	...	...	...	...	12	...	...	55	0	0	1000	0	10	7
	Total for 12 Grenades ...	51											16	8	3

Therefore, a single grenade costs approximately Rs. 1-6-0 to make complete with charge, and its Manufacture takes $4\frac{1}{4}$ man-hours. If a large number were made at once, both time and cost would be much reduced.

FORTRESS DEFENCE—CONVENTIONS OPPOSED TO THE OFFENSIVE SPIRIT.

By MAJOR J. W. S. SEWELL, R.E.

IN a recent R.E. Professional Paper (R.E., IV. 3) Major Matheson traces the evolution of the modern fortress, with especial reference to the growth of the offensive spirit.

A study however, of this paper, and of other recent articles on permanent fortification, leads to the conclusion that in the region of fortress design the offensive spirit is only nascent: it has not yet attained to the stage of maturity which will give it strength to burst the last shackles of convention.

It is proposed in this article to deal with a few remaining conventions of permanent fortification, which appear to be accepted too frequently by engineers as axioms; they are:—the geometrically traced work or "fort," the defensible gorge, the continuous-line idea, as indicated by works between key points, and the retrenchment.

The *Rôle* of Fortresses is to Economize Detachments.

In order to examine the extent to which these ideas impair the offensive spirit, it will be necessary to consider first the *rôle* of fortresses themselves, and then, more fully, the function of a key-point, by whatever name it be called—*point d'appui*, fort, group, or feste.

In the States of Western Europe, with their vast trade based almost entirely on credit, it is hardly conceivable that a war can be carried on for more than a few weeks. Even so, the dislocation of trade must be so great that the loss to the conqueror will only be exceeded by that of the conquered.

Strategy will therefore obviously be directed to fighting a decisive action at the earliest possible moment, and the design and defence of fortresses must conform to such strategy. A defeated state, frequently in the past, has embarked on a *résistance à outrance*, and no doubt will do so in the future, hoping perhaps for a change of fortune, or that internal disorder or foreign intervention will compel the withdrawal of the hostile armies; a vain hope, if history teaches anything. In such resistances, and in certain cases where true strategy has been obscured by political considerations, or by sentiment, stubborn and protracted defences of fortresses have frequently been carried out, honourable indeed to the defenders, but of little eventual avail to the State.

In designing fortresses are we to legislate for such deplorable conditions? Is it quite clear that the defenders of such fortresses would not have done more damage to the enemy if they had relied less on a passive defence behind trenches, and more on offensive tactics? if they had not yielded all initiative to the enemy, if they had sought to impose their will on him, not merely to place consecutive obstacles in his path?

Too many fortress designs appear to have been prepared as an answer to the query "How can the garrison best be protected?"

The true conundrum for the designer to set before himself is "How can the maximum of damage be inflicted on the enemy?"

In order that the design of the defensive works of a fortress may be treated with due regard to the offensive spirit, it is essential that the designer should divest himself of the idea inculcated in many treatises on fortification, that the *rôle* of a fortress is to cover a locality. For a country that means to win, not merely to resist, the primary *rôle* of a fortress is to cover an offensive movement. As in the case of all defensive works, its function is to economize the defenders' forces and to enable the garrison to "contain" a larger body of the enemy.

Frontier fortresses, for example, behind which the initial concentration of an army is made, enable that army to economize its covering detachments.

Sir G. Clarke points out that the great difficulty in considering permanent fortification is to get away from the conventions of professors, to get soldiers to realize that this subject is not one to be treated as an abstruse science, but is a matter of common sense, and of the fundamental principles of the art of war. The principles which govern the fortification of a defensive position in the field, apply equally to the fortification of a fortress. Thus *Field Service Regulations*, I., 116, says "Since the object of war can only be attained by the destruction of the enemy's field armies, all fortress warfare must be considered as subsidiary to that end." It follows, that the only justification for detaching, to hold a fortress, troops which might otherwise strengthen the field army, can be that those troops should force the enemy to detach troops of greater strength than themselves. Further it follows that if for any reason, such as distance from the immediate theatre of war, a fortress does not compel attention from the enemy, it should ruthlessly be denuded of a garrison.

In order to effect this purpose of "containing" a larger force, the garrison must be prepared to adopt a vigorous offensive. That this fact is not more thoroughly realized—judging from the extravagancies in fortress design which are frequently published—is perhaps due to the extraordinary fascination which has in all ages been exerted by fortresses over hostile armies. For some reason the mere existence of a fortress in a theatre of war appears to have compelled an enemy to detach a large proportion, if not the whole, of his field army, in the endeavour to capture it. Again and again bloody sieges have been undertaken, and the main operations delayed for months, in order to effect the capture of a fortress, which, to all appearances might equally well have been "masked." In modern times there may be quoted as cases in point the Siege of Plevna, the total abandonment by the Boers of all active operations in order to prosecute the Sieges of Ladysmith, Kimberley and Mafeking, and in a lesser degree the Siege of Port Arthur. In this last case, it was certainly of vital importance to render the harbour untenable to the Russian fleet, but this could have been, and was eventually accomplished by the capture of 203-Metre Hill, an operation which did not require the 60,000 men of General Nogi's army for six months, nor the loss of many thousand men expended in the capture of the fortress itself. The absence of this army from the main theatre of war might well have decided against the Japanese the hard-fought battle of Liao Yang.

The siege of a fortress moreover appears to dominate the minds of Governments to an extraordinary degree, and causes the principles of strategy to be subordinated to political considerations on the side of the defender as well as of the besieger.

For examples we have the sacrifice of McMahon's army in the mission to relieve Metz, regardless of the German field armies; the concentration of the whole efforts of both sides on the Siege of Sebastapol; and finally the abandonment of all other operations for three months in the attempt to relieve Ladysmith.

On the other hand, the Germans in 1870 proved themselves wonderfully clear headed in this respect, and never allowed themselves to be deflected from, or even delayed in effecting, their main objective, the destruction of the enemy's field army, by the resistance of a fortress.

In considering the defences of a fortress the garrison have no right to assume that an enemy will ignore his true objective, and by attacking the works of the fortress, permit the defenders to impose their will on him. On the contrary, whilst the defenders must be prepared to compel an enemy to submit to all the delays involved in a regular siege, should he design to capture the fortress, they must also be prepared to attack him vigorously should he try, in his turn, to mask the fortress, that is to contain the garrison with inferior forces. The object must in fact be to compel the enemy to detach the maximum possible, and certainly a considerably larger force than is constituted by the garrison, until the decisive battle has been fought. The object of the Engineer must be to produce a fortress which will compel a maximum detachment on the part of the enemy for a given period, not merely a detachment for a period of indefinite duration.

The Offensive is the Soul of the Defence of a Fortress.

We must now consider the means to be adopted to this end. As an example of what to avoid, and the extravagancies into which engineers may be led, when they ignore the spirit of war, we have the fortification designed by a Russian Engineer in the *Injenerni*

Jurnal for December, 1910 (*vide* Lieut.-Colonel Skey's transcript, *R.E. Journal*, July, 1912, *Plate* I.), with its 2,600 guns, a "feste" 12 miles in length, and 4 miles deep, enclosing in an envelope of obstacles 13 first line and 2 second line forts plus batteries, etc. It even has a second line group of forts and an enceinte behind that. This is truly passive defence run riot.

As fundamental principles for fortresses which are to assist in the destruction of the enemy's field armies, we have it laid down (*F.S. Regulations*, I., 128 (1)) : "The general principle which governs the defence of fortresses, is that the offensive is the soul of defence," and again (*F.S. Regulations*, I., 128 (4)) : "The most effectual means of defence is counter-attack."

Let us now see how these fundamental principles are applied in the case of a defensive position in the field, on which subject our training manuals are more expansive :—

Manual of Field Engineering, I. (2) : "Field fortifications . . . must always be regarded as a means to an end, and not an end in itself."

F.S. Regulations, I., 107 (2) : "No natural or artificial strength of position will of itself compensate for loss of initiative, when an enemy has time and liberty to manœuvre. The choice of a position and its preparation must be made with a view to economizing the power expended on defence, in order that the power of offence may be increased."

Section 108 (2) lays down that the offensive force should not be much less than half the total.

Section 108 (9) instructs that a position should be strengthened "with the object of reducing the number of men required to hold it, and of thereby adding to the strength of the general reserve."

In fact a defensive position as conceived in the training manuals of the British Army consists of a strong reserve thoroughly imbued with the spirit of the offensive, and assisted in its attack by the containing action of well-fortified *points d'appui*.

Major Matheson enumerates as one of three offensive methods—"Fire of all kinds."

It is not quite clear what is meant by this suggestion : the mere development of fire from trenches does not constitute offensive tactics.

The essence of the offensive is movement. The offensive movements of a besieged garrison are :—

(1). Counter-approaches (including countermining) designed to outflank the enemy's trenches.

(2). Local counter-attacks against an enemy who has penetrated the intervals between key points.

(3). Sorties.

The first two of the above compel an enemy to employ greater strength in his front of attack and thus to weaken his reserve, or to bring up reinforcements. A sortie compels him to maintain adequate forces to defend his flanks or the containing portion of the investment line: sorties become of course the only available offensive tactics against an enemy seeking to mask the fortress with a weaker force.

It is proposed now to examine the methods by which a defensive section "contains" a superior force in field warfare.

Briefly, a defensive section consists of a series of fortified localities or key points, covering the intervals between them with flanking fire, and in themselves capable of great resistance to direct attack (*vide Infantry Training*, 143 (1)). The section has its own mobile reserve, whose duties are not to reinforce threatened works, but are strictly offensive. It is charged with local counter-attack against any hostile force which penetrates the intervals or the key points. As is normally the case with all covering forces, if not itself attacked, it will have to attack, in order to prevent diversion of the hostile troops away to the decisive point. In this attack it will be supported by fire from the key points. All this is clearly laid down in the Official Manuals, and it is precisely the same methods which should be adopted in defending a fortress. In the latter case our works will be improved in details (overhead cover, accessories, and obstacles) within the limits of time and finance, but will be modified in trace merely by considerations connected with the more powerful armament at disposal. In general the effect of this will be to reduce the number of key points, whilst increasing the frontage of each point.

Before considering in further detail the design of the key points, a retrospect of the evolution of ideas during the last 50 years may tend to clarify our thoughts. The Evolution of Modern Fortress Design.

As the range of weapons increased, it was necessary to obtain greater depth for the distribution of the defenders, and the old key points or bastions were pushed out to a radius which represented a great advance from the old enceinte. But the engineer of those days took out with him his fixed ideas of a conventional trace, and continued to adapt the ground to his conventional bastions; to make matters worse he regarded his new work not as a key point, but as an advanced work, and therefore made it a closed work.

Difficulties immediately arose over the positions for artillery, and the true spirit of offensive war was to a large extent obscured by the controversy which raged over this point. It is clear that guns of position must be covered by a protecting force, itself entrenched. Continental engineers therefore put their guns in the conventionally traced key points, then called forts. The protecting infantry lined the outer lines of these forts as best they could. But the engineers maintained the geometric trace of the obsolete bastion which did not give good resisting power against attack from the front; for it presented salients which were not covered by flanking fire. Moreover, whilst it was apparently recognized that such a work presented an admirable target to hostile artillery, and the guns themselves were therefore protected by masses of concrete or steel cupolas, the infantry were badly exposed, and all the principles governing the choice of an infantry fire position were vitiated. Thus the trenches were conspicuous, and exposed to enfilade—and in some cases reverse—fire: there was no overhead cover, and little attempt at covered communications: the field of fire was clear certainly, to this extent—that the ground was altered to a true slope, but on the whole, field of fire was sacrificed to a commanding position, with the result that the defenders were much exposed in order to fire down a steep slope: there was usually inadequate provision of cover for supports, and fire control was hardly considered. To adapt such a work to infantry requirements on the outbreak of war involved almost as much labour as a new work would have involved, and then it was a case of making the best of a bad job.

Against these erroneous ideas Sir G. Clarke led the British School who argued that the key point should be a simple type of work for infantry only, and designed with more consideration for the true principles of an infantry work. Guns were to be in the intervals.

Whilst these ideas certainly tended to shake off the vicious shackles of obsolete conventions, they possessed in themselves certain disadvantages which were in opposition to the true offensive spirit. Thus in order to flank intervals with infantry fire alone, it was necessary that the key points should be close together, with intervals of 1,500 to 2,500 yards. This involved the creation of an excessive number of key points. On a radius of 5 miles there would have to be some thirty of these redoubts, which would break the defence into too many sections for the due fostering of the offensive. Moreover the position of the artillery in the intervals was exposed to *coups de main*, and to protect the guns further infantry trenches were to be put in the intervals. The perimeter thus tended to become a continuous line of infantry works, manned at the expense of the reserve, thus sapping the offensive power and spirit of the defenders.

The fortress of this school is thus described by Colonel Jackson, C.M.G., in the *Encyclopædia Britannica*, 11th edition:—"A fully prepared fortress would have practically a complete chain of infantry fighting positions and obstacles between the forts, at all events on the points likely to be seriously attacked." The same author expresses the modern spirit when he says in the same article:—"The teaching of history is all against immobile mechanical defences. Initiative, surprise, unforeseen offensive action . . . all these, with their influence on the *morale* of both sides, tend towards successful defences. . . ."

The great development of the indirect fire of artillery during recent years has assisted greatly in overcoming the apparent difficulties in the way of evolving a fortress key point in consonance with the spirit of war: whilst yet further assistance may be obtained from the improvements in quick-firing ordnance. Thus the conception of the modern key point begins to shape itself. In the first place the means to flank the intervals, and for this purpose quick-firing guns appear to be clearly indicated. Secondly the means by which such guns are covered and the key point itself is rendered proof against direct attack, that is to say infantry works adapted to the ground. Thirdly, the economizing of troops by providing that such protection shall also cover the heavy and medium ordnance designed to assist in the destruction of the attackers, and to oppose hostile artillery, which seeks to assist the advance of the attackers. Lastly, the provision of protected communications, stores, magazines and accessories requisite to the mobility, security, and comfort of the defenders.

"Un pionnier" in *Des Forts et la Mélinite* was apparently the first to suggest such a "group" as being the ideal key point: but Sir G. Clarke (*Fortification*, 2nd edition, p. 158) presents the same idea with admirable conciseness:—". . . in the case of an extended line of defence, where the ground offers marked tactical features, the idea of a continuous chain of permanent works may be abandoned in favour of groups of redoubts guarding the artillery positions." The Germans appear to have adopted this conception of a key point in designing the "feste" of Metz.

There is very much danger in attempting to indicate "types" for *points d'appui*. So sure as there are types laid down, so surely will some "professor" allow common sense to be dominated by systems. The designer of a fortress must be thoroughly imbued with the fundamental principles of war, and his aim will be to get the best advantage out of the ground at his disposal. Many of the finest defences of fortresses have been made by defenders who had only earth works to assist them; the reason lying in the fact that those earth works were made by soldiers for soldiers, in accordance with the true principles of defence. Thus the true method is to adapt the trenches to the ground as indicated in the *Manual of Field Engineering*, and then as far as time and money permit to render them more durable, more shell-proof, and more comfortable. In discussing such matters on paper Major Matheson adopts a very sound line, when he chooses a definite piece of ground and shows how he would defend it. It must be regarded as regrettable however that he selected such a site for his work at all. Such a position as the forward slope where he has sited his trenches is one to avoid if it is by any means possible to do so. On such a slope, if the trenches are put at the top, the defenders must be terribly exposed, in order to fire down so steep a slope. If they are placed lower they are badly dominated from the hills opposite, and also lose field of fire. Wherever they are put on this slope, they must be conspicuous, and there is dead ground on the right front at short range.

It would have been better to have sited the work either further forward beyond the valley, using the latter for lateral communications, or else some 400 or 500 yards back from the crest, whilst covering the valley by artillery fire, either from a flank, if the surrounding country admits of such a course, or with indirect fire if this can be observed. As regards observation of fire, it may be worth noting that whilst air craft may assist artillery by such observation, it is not right to assume, as is often done, that they will be permitted to do so unmolested. Both sides will make use of air craft, the casualties will be very heavy, and as regards a siege, the balance of advantage should lie with the besieger, who is able to bring up fresh supplies of material and pilots.

The inherent errors of the geometric trace are not obviated by siting a conventional fort in the gorge line of the key point as a species of "keep." This is altogether contrary to modern ideas. The *Manual of Field Engineering*, 50 (6), says: "There must be no idea of using trenches arranged in depth as successive lines of defence." Colonel Jackson in his *Encyclopædia Britannica* article is very sweeping: referring to the defence of Arcot by Clive he says:—"Such feats as this make arguments about successive lines of defence and the necessity of keeps seem very barren. History . . . shows no instances where successive lines have been held with such brilliant results." Sir G. Clarke is unsparing in the scathing scorn which he pours upon second lines and keeps. Major Matheson himself says:—"Successive lines of defence lead to false ideas, and almost inevitably to starvation of the main line." He endeavours to forestall criticism by contending that the fort cannot be considered a second line because:—"the position must have depth."

This argument will not hold water; true, a position must have depth, and the supports and reserves must be protected from fire, but the normal action of both supports and reserves takes place in the one (front) line. An argument for a double tier of fire under certain circumstances would be intelligible, but there is no question of that in Major Matheson's design for a *point d'appui* (*Plate* XVIII.).

The argument for a retired defensive line—*i.e.* withdrawn behind the crest line, will appeal to many, especially where the defensive line is of the nature of temporary (*i.e.* field) fortification, and even for permanent works in the very exceptional cases where it is possible to bring effective flanking fire to bear on the slopes in front of the crest: but it is the firing line which must be withdrawn.

A fort as sited in Major Matheson's design cannot come into action until the enemy has captured the front line, except in the case of an assault on the gorge, for which event it is unnecessarily strong. Apparently it is proposed to give the fort a permanent garrison, only 200 men certainly: but these 200 will not be available for action in the decisive place (the front line) at the decisive moment (when it is assaulted). In the other alternative of manning the fort with the defeated troops of the front line, it clearly becomes a second line work, and is open to all the objections to a second line.

Now with a view to making a constructive proposal as an alternative, let us enumerate the points to be considered.

Summary of Main Factors to be considered.

(1). A conventional closed fort on the forward slope is objectionable as opening a good target for the enemy's batteries.

(2). It would be seldom possible to site the defensive line on the reverse slope.

(3). Works exposed on the forward slope must be shallow and inconspicuous: whilst sited to obtain a clear field of fire, they must offer a poor target to the enemy's artillery.

(4). A serious obstacle is required in front of the defensive work. All experience points to the value of a deep ditch, well flanked by fire from caponiers.

(5). Accessory works, bombproof as far as possible, are required, such as latrines, cookhouses, look-out posts, C.O.'s post, telephone cabinets, etc.

So far we follow Major Matheson, and we may now add :—

(6). The "returned" flanks of the normal fort are objectionable as they are exposed to enfilading fire. A better flank defence is provided by "refused" trenches, *i.e.* trenches constructed *en échelon*.

(7). Supports and reserves for key points must be provided with bombproof cover, reasonably close to the front line, and with covered approaches giving access to that line. Let us also note that the "feste" reserve will also require bombproof barracks. The *rôle* of the "feste" reserve is similar to that of the fortress reserve, being that of taking offensive action, *i.e.* attacking any hostile troops which may penetrate the "feste."

(8). The forts are the *points d'appui* of the "feste," as the "feste" are themselves the *points d'appui* of the fortress.

As regards (1) the objection lies in the target offered to hostile artillery by the mass of masonry and earthwork enclosed in a compound and well defined by straight lines and angles which constitutes the typical fort of the latter part of the nineteenth century. The solution would appear to lie in a reconsideration of the design of a fort, rather than in siting a fort of obsolete design on the reverse slope.

The "Conventional" Fort of Geometric Trace *versus* Works adapted to the Ground.

Now the engineers of all epochs appear to have clung to symmetrical and geometric designs for their work. In the region of field fortifications we are just shaking off the shackles of such erroneous conceptions. It is now recognized that the fundamental principle of field fortification is to suit the work to the ground; thus the first step is to select the best position for each rifle, and the *point d'appui* of a defensive line in the field becomes a chain of rifle pits connected by lateral and radial covered communications, off which open the (covered) accessories.

In the region of permanent fortification the geometric plan is still dominant, the objections being less apparent owing to the fact that defilade enables us to suit the ground to the work to the extent that each rifle has a good field of fire. But not only is defilade a costly process; it also involves angles and hard lines, which render our work the most conspicuous object in the landscape, and as such an excellent artillery target.

Cannot we shake off the shackles of convention and design our works to suit the ground, regardless of geometric symmetry? In this way the fort would follow the lines of a field *point d'appui*, defilade only being used where by such means alone could fire be brought to bear on portions of the foreground; that is to say small inequalities in the foreground—holes and hillocks would be levelled, and the command of the trench would occasionally be raised to obtain fire over a convex slope.

The difference between field and permanent fortification would thus lie only in the improvements possible owing to time being available, that is :—

(1). Better preparation of the foreground, technically "clearing the field of fire."

(2). Improved cover to trenches, communications, and accessories.

(3). More serious obstacles.

Having then selected positions for the rifles in a similar manner to the method adopted in the field, with the assistance gained from such defilade work mentioned above, as will not produce any hard lines or conspicuously "engineered" slope, we shall have a chain of "rifle pits" offering a very small target to hostile artillery, both on account of their shallowness in the line of fire, and of their inconspicuousness. These rifle pits must be provided with splinter-proof overhead cover, say of reinforced concrete, covered with turf; and also with steel loopholes. It is very doubtful whether the very slight risk of a hostile howitzer scoring a direct hit would justify the provision of bombproof overhead cover: it would moreover be very difficult to render inconspicuous such massive cover as would then be required.

Now as regards cover for lateral and radial communications and accessories; in field fortification we can only provide trenches designed to escape enfilading fire. If time is available and our works become of the semi-permanent type, we should add splinter-proof and weather-proof overhead cover.

In fortress design the conventional fort or redoubt should be abolished and replaced by works whose firing line in general trace is similar to that shown in *Plate* 17, *Manual of Field Engineering*, and with communications and accessories constructed in the manner shown diagrammatically in *Plate* 16 of that manual.

The essential difference between such works and the old fort lies in the fact that whereas the fort consisted of a terreplein surrounded by artificial ramparts raised above the surface, the new work will consist of passages bored in, or dug out of the surface. Such a work has greater resisting power because each rifle is placed in the best position, it is as inconspicuous as it is possible to make a work, as it disturbs the minimum of surface, and it need not be costly. It will however differ from a field work, to the extent that it is found expedient to secure it against the fire of material-destroying artillery—that is heavy high explosive common shells—and this will be decided by considerations of locality, time, and money. A work may be in such a position that it cannot be exposed to any aimed heavy artillery fire; in such a case, splinter-proof protection for the firing line, and weather-proof accessories with a few splinter proofs for supports might be sufficient. This is however improbable in the majority of works. If then it appears *desirable* to render the work proof against all shell fire, considerations of time and money will decide the extent to which it is *possible* to cover in the floor plan with bombproof roofing.

The firing line must have splinter-proof overhead cover in any case. As communications and accessories have been dug out of the ground it will not be an expensive or a laborious matter to roof them in with splinter-proof cover, and it will usually be desirable to do so for the further reason of restoring the natural surface. In some localities this might be sufficient, and the risk might be taken of the occasional common shell which might chance on the invisible roof of a narrow passage.

Proceeding however to the next stage and considering the case of the work which will assuredly have to endure severe bombardment, and supposing that time or money is short, it will be a nice case for the engineer to decide how to make the best of it.

Shall he provide cover all over which will be proof against medium shell, or shall he provide one secure barrack, proof against the heaviest shell, and allow other communications and accessories to have only splinter-proof cover? The former alternative would usually economize more in life, but is risking the moral of the troops if one heavy shell does chance to fall on the barrack, and so produce that heavy concentrated loss which is so deleterious to moral.

Certainly the moral of the troops should be the primary consideration, and this indicates the desirability of providing one spot where they can rest in absolute security. Better lose 50 per cent. of life than 100 per cent. of moral.

A matter worthy of investigation arises in the case in which general bombproof cover is considered essential and time and money permit. To provide cover over our communications, etc., proof against the heaviest shells becomes a matter of great expense if it is sought to construct on the "cut-and-cover" principle. Where the firing trench is sited on the forward slope of rising ground, it would certainly appear that the most efficient and even cheapest method of providing such cover would be to mine the communications and accessories in the solid hill. Steps would then descend from each rifle pit to a subterranean lateral gallery, whose ceiling might be from 10 to 20 ft. below the surface according to the resisting qualities of the soil to the penetration of the heaviest siege howitzers.

From this gallery would run radial galleries to bombproof barracks. If the ridge is narrow and the reverse slope sufficiently steep, the rear face of the barracks might open on to a terrace notched out of the reverse slope. But if, as will usually be the case, it is necessary to site the fire trench well down the front slope, or if the hill top be flat or with no pronounced reverse slope, such siting would either place the barracks in an insufficiently secure position, or too far from the firing line. It would then be necessary to construct subterranean barracks, artificially lit and ventilated, and with a gallery continued underground towards the rear, until it is considered expedient to emerge on to the surface.

These barracks would contain sleeping accommodation for the garrison, magazines, stores, administration offices, cookhouse, latrines, telephone room, and engine rooms for provision of artificial light and ventilation, etc.

Other accessories would open off the radial galleries or the main lateral gallery. This gallery would also be continued to communicate with any refused trenches. The platforms for the light guns and machine guns sited in the work, and any search-light emplacements would open off the lateral gallery or radial galleries.

This system of mining out the defensive work, is now 130 years old, having been adopted first by the British Engineers in the defence of Gibraltar in 1779-82, where works on this principle, first suggested by Sergt. Ince, were carried out in the solid limestone rock, and now constitute the world-famous galleries.

The infantry works depicted above will form the pivots of the main key points. It is proposed now to deal with the remaining conventions indicated at the beginning of this article, in their general application: and subsequently in their local application to the key points.

Before considering the intervals it is necessary to reiterate that the objection of the dispersed school to the continental fort containing artillery did not lie so much in the grouping of batteries under cover of infantry works; but rather their arguments were directed against the geometrically traced conventional fort. In seeking to avoid this we have perhaps swung the pendulum too far over in considering the key point as a purely infantry work. This involved covering the intervals with rifle fire; and therefore the key points were to be sited so close together, that we fell into the error of a continuous line of works, instead of designing a few strong key points on which the more passive portion of the defence could concentrate their attention. With few key points however it is essential that the intervals should be flanked by artillery fire. The gun is the true weapon for flank defence, both on account of its moral effect and because it does not involve the exposure of a line of men to enfilade fire, as in the case of a "returned" infantry trench or "flank." If it be conceded that we may rely on the quick-firing gun to flank the intervals and to afford support to the neighbouring key points, it will follow that as the radius of the perimeter of a fortress is increased, the interval between the key points may increase in the same proportion, for they are both decided by the same factor—the range of artillery. The "Continuous-Line" Convention.

Thus the number of the key points should not be affected by an increase of perimeter. Whilst the tactical features of the ground will decide the sites; so that the precise number of the key points, and the actual intervals will thus be fixed, it may be taken that in a country which is not of a very hilly nature, the number of key points will not vary greatly from 10 to 12, and the intervals will average, very roughly, about half the radius of the girdle of key points. Thus on an 8-mile radius, the average interval would be about 8,000 yards, varying perhaps from 6,000 to 10,000 yards.

As regards the defence of these intervals, it appears to be accepted too much as an axiom that interval works should constitute an integral part of the permanent fortifications of a fortress (compare *The Growth of the Offensive in Fortification*, p. 43, and *Plate* XVIII.). This idea however deserves further consideration. Let us examine the spirit in which the official manuals treat of this point in considering the defensive position in the field. *F.S.R.*, 108 (8), says: "Portions of a position where the conditions are unfavourable to the defence are usually better defended by means of local reserves, than by strengthening the firing line." *Infantry Training*, 143 (1), says: "If these pivot points are naturally strong, or can be made so artificially, and if they are adequately garrisoned, the defence of the intervening ground should not usually be arranged in a continuous line. The Works in Intervals.

object should rather be to utilize the intervening ground for local counter-attacks, while arranging for either direct or flanking fire, or both . . . on all ground over which the enemy may advance." *Manual of Field Engineering*, 50 (3): "If the pivots are strongly held and fortified, the troops necessary for the defence of the intervening ground need not be large, and the defence works themselves may be limited to ensuring that the ground invisible to the defenders of the pivot groups is swept by fire."

The fundamental principle underlying these instructions is equally applicable to fortress war. It is—to free every possible man for the offensive force; defensive works and their garrisons being reduced, with this object, to the minimum consistent with safety.

It is obvious of course, that in such intervals as described above, there will be ground which is invisible to the flanking artillery. There may also be important points such as bridges on the lateral communications, which are open to a night assault. It will probably be necessary to cover such ground or points with small closed infantry works. These should however only be of a nature to check an attack until the reserve can come up and drive back the assailants.

It is also obvious that just as there is a proportion between the main intervals and the radius of the perimeter, so there is a proportion between intervals and the distance of the enemy's trenches. Thus, as the hostile trenches on the front of attack approach to rifle range, the intervals must be decreased by interpolating pivots, so that these pivots support each other with rifle fire. But it would appear to be a faulty policy to construct such works before the enemy has shown his hand, for the following reasons:—

(1). On fronts which are not attacked such works are not required: the construction of such works then involves an outlay of expenditure, which would probably have been better expended on the field army.

(2). If such works are constructed and manned, it involves an unnecessary weakening of the offensive force. If they are not manned, they are a source of weakness, inasmuch as it is very difficult to construct a work which, if captured, will not assist the enemy.

(3). The main objection however lies in the fact that construction of such works before the enemy has shown his hand, constitutes an exposure of the cards of the defenders; when the enemy can call them. If on the other hand the defender waits until the enemy has developed his approaches, he can seek to use his trenches offensively by siting them so as to outflank and enfilade the hostile trenches.

Obstacles in Intervals.

For similar reasons, the intervals are not the places in which obstacles should be placed originally. The chief value of obstacles "lies in the power to deflect the attacking troops into areas most favourable for their destruction by the defenders" (*Manual of Field Engineering*, 42 (1)). At the outset of a siege the object will be to entice the enemy to a premature assault, and to deflect this assault from the key points into the intervals, where the assaulter's troops would find themselves exposed to the enfilading fire of the flanking artillery, and to the full fury of the counter-attack of the reserve, sweeping over ground which is not cut up by trenches and obstacles.

The Convention of Closed Works.

We must now turn to the thorny subject of gorge defence. It appears to be an axiom with all engineers that forts and "feste" must be supplied with a defensive gorge. It is somewhat invidious to raise the voice of criticism in the face of so universally accepted an axiom, but it would appear that it is open to argument. In the days of the great engineers of the 16th and 17th centuries, the *points d'appui* or bastions were not closed. It is true that many fortresses have fallen owing to the enemy penetrating a curtain (interval), and capturing the bastion (key point), but it will be found that in such cases either no adequate reserve was held in hand by the fortress commander, or such reserve had no manœuvring space owing to the town extending right up to the ramparts.

"Closed" works are proper to certain isolated positions, such as isolated posts and barrier forts; the closure of the *point d'appui* may have arisen from the original method of regarding a fort as an advanced post. The idea that a *point d'appui* in the main line may be captured by assault on the gorge appears to postulate the absence or the passivity of a reserve. In either of these cases the secondary element, that is the *point d'appui*, loses its *raison d'être*. And, on the other hand, a defensive gorge cuts both ways. If it is available to repel an enemy who may assault the gorge, it is of equal avail to an enemy who has captured the fort against a reserve attacking with the object of recapture, (*e.g.* the capture of the Malakoff Redoubt in 1855).

On the other hand, there is the moral effect of the feeling of security engendered by a closed work to be considered. Sir G. Clarke in his *Fortification* says: "The principle of retaining closed works for the infantry redoubts forming the key points . . . has been adhered to mainly on moral grounds." That argument certainly held force where the key points were single infantry redoubts. But where the key points consist of groups, there does not appear to be the same reason for enclosing either the whole group or its constituent elements: open gorges are certainly more consistent with the idea of opposing penetration by counter-attack instead of the step-by-step defence of successive lines.

The Convention of Retrenchments.

The same remark applies to the construction of retrenchments, which Major Matheson appears to regard as essential when the attack is being pressed close. The mere fact that a retrenchment is only constructed at so late a stage does not prevent it constituting a second line. Again it may be asked, who is to man the retrenchment? Troops from the reserve? Their proper reply to penetration is vigorous counter-attack before the assailants can form a lodgment.

The defeated troops of the front line? Will they hold a second line after being driven from the first? To reiterate these old arguments against second lines, whether disguised under the name of "fort nucleus," "retrenchment," or any other such appellation, might be regarded as flogging a dead horse, were it not that that hardy but vicious beast periodically shows spasmodic symptoms of a regrettable tenacity to life.

Application of General Principles to Groups of Works.

In designing the groups which constitute the modern key points, these principles are still applicable. Thus the group has its own key points and intervals, and a group reserve, whose function is not to reinforce the firing line but to resist penetration by counter-attack. The "continuous line" idea must still be subordinated to consideration of the strength of the available garrison, and the fire trenches must not be of so extensive a nature as to weaken unduly the force to be kept in hand to constitute the local reserve. But all details will be controlled entirely by the tactical features of the ground. To adapt the works to the ground is the paramount consideration, so as to ensure that all ground within effective rifle range is swept by fire, that the defenders have ample communications, lateral and radial, covered, or at least concealed, and that the key points afford each other mutual support.

Thus the defensive line of the group will consist of two or more infantry works, sweeping the ground to the front with rifle fire, and covering the intervals with either rifle fire from refused trenches, or with machine gun enfilading fire, or most probably with both.

The flanks of the group will be secured by "refused" works, probably of lighter design. The intervals between the key points of this group will be determined by the ground, subject to works being in all cases within effective rifle range of each other. The works themselves will be self-contained as indicated in preceding pages, but it would appear advisable to have open gorges, for reasons given above.

Behind this defensive line will be grouped the siege batteries and their accessories, accommodation for the group reserve of infantry and engineers and the artillery *personnel*, the fighting post and offices of the group commandant, main stores, magazine, etc., etc. As regards all these, engineers agree generally, the main principle being to obtain maximum results for minimum costs. As regards direct fire heavy batteries, rivalry will probably continue to exist between advocates of the steel cupola, and of the barbette of reinforced concrete, until the cupola has been tested in an actual siege. But in the design of these batteries and accessories behind the defensive line, there is no mediæval convention to paralyze our minds. When an engineer can start with a clean slate and no type design he can usually be trusted to produce a good design of his own, and that is in general more desirable than losing time in the search for the elusive best design. The curse of the engineer in more fields than one is the convention inherited from his predecessors, which sometimes possesses its own fundamental errors, but far more frequently is applied wrongly, because the engineer of to-day misses the underlying truth, and is bound hand and foot to unessential details, which were never principles, and with the progress of science, have now become not only out of date, but even vicious.

As regards the obstacle, the arguments adduced above against closed gorges, apply equally to an obstacle continued all round a key point (either major or minor). Further the major intervals between the groups, at any rate in the first instance, should be kept clear of obstacles, for the reasons given above. The one certain site for an obstacle is the immediate front of an infantry work. But should this obstacle be continuous along the whole front of the group? The arguments adduced above against obstructing the major intervals do not apply with equal force to the minor intervals, but the principle of the offensive must not be lost sight of. If the frontage of a group be 1,500 yards or more, this is a somewhat long front over which to advertise clearly that we mean to make no offensive move, and to deny ourselves the advantage of surprise. It is not a matter for any dogma, but is again a matter to be decided according to the ground. On the one hand the engineer will place the certain moral advantage of the feeling of security engendered in the garrison of the group by a continuous obstacle between themselves and the enemy. On the other hand he will consider whether by discontinuing the obstacle in a certain interval or intervals, he can increase the offensive power of the group garrison to such an extent as to outweigh this moral advantage. On the one hand, for instance, the presence of a continuous obstacle might permit a trench directly covering a battery to be abolished. On the other hand a very ordinary feature would be a re-entrant valley, inadequately flanked from the pivot works, and therefore tempting to the attacker. But such a feature can be turned into a very death trap to the assailant, and if it is possible to do so, it would be folly to warn the enemy off by closing the mouth of the valley with a continuous obstacle. It is hardly to be supposed that in practice any engineer would make so faulty and vicious a disposition of an obstacle, but the plans published from time to time of theoretical or actual groups of works are so covered with hatching representing a thick continuous belt of obstacles (which in fact usually constitutes the most conspicuous feature of the plan) that there is some danger lest such a belt become accepted as another convention.

As regards the nature of the obstacle; if time and money permit, it is universally agreed that this should take the form of a deep ditch, flanked by counterscarp galleries or caponiers. In this case the objections to straight lines fail, for judicious manipulation of the exterior slope and the glacis can usually be made to conceal the berm of the escarp without involving any hard lines in the slopes themselves. Even if the returned flanks of the ditch become visible to the artillery of the attack, it should not assist that artillery much in hitting the vulnerable trench, whilst a bombardment of the escarp will not very seriously weaken the resisting power of the fort. On the other hand the ditch must be laid out in straight lines in order to render effective the flanking fire from the caponiers. Galleries as in the existing designs would lead from the barracks to the caponiers and also to the magistral gallery whence start the countermine galleries of communication.

In the event of a continuous obstacle being considered desirable, it is obvious that a continuous deep ditch will be financially impossible, and usually tactically undesirable.

With the normal position of the infantry work on a forward slope, it will in most cases be best to "return" flanking ditches to the rear of the crest, and to form the continuous belt from the end of the flank ditch with a wire entanglement in rear of the crest line, provided that in such position it is within the arc of fire of the rifles or machine guns flanking the interval.

THE WATER SUPPLY OF RISALPUR, N.W.F.P.

By LIEUT. B. T. WILSON, R.E.

As it seems probable that R.E. officers in India may be shortly called upon to design new cantonments and consequently to draw out projects for water supply, practical notes, and plans of a newly installed pumping plant may be of value.

Risalpur was chosen by Lord Kitchener in 1905 as a suitable site for the first cavalry brigade of the then, newly reorganized Indian army. The cantonment, as now built, is situated on virgin sandy soil sloping down to the Kabul River near the old cantonment of Nowshera—the open nature of the surrounding country, which is flat, devoid of cultivation and intersected by deep, dry, ravines makes it especially adapted for the training of cavalry, but at first sight the water supply facilities were not so pleasing to contemplate. In the middle of the cantonment the water was found to contain too much salt to make it suitable for permanent use, but a preliminary well sunk on the banks of a stream called the Kalapani was productive of palatable water. This stream is 1½ miles E. of the cantonment and flows into the Kabul at right angles. This source of supply was approved and the cantonment was put in hand. The original water supply scheme was to pump water from the central well of three wells in the manner shown below :—

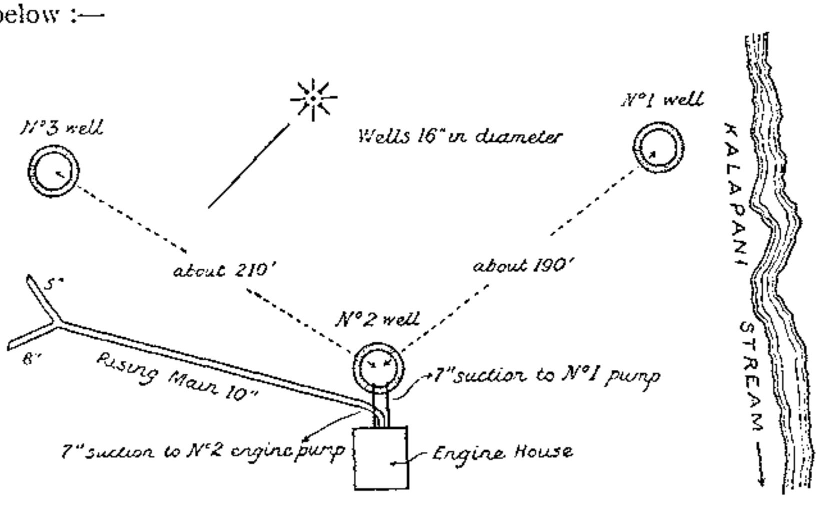


Fig. 1.

The rising main 10 in. in diameter bifurcated into two branches, the larger (8 in.) going to a raised reservoir of 100,000 gallons, the smaller to an existing earthbank reservoir of 40,000 gallons capacity. The pipe resistances and the gravity heads were so balanced, that water would tend to flow equally to both tanks. The two outer wells were to be connected with the centre well by a 9-in. pipe line laid 14 ft. below the level of the water in the wells before pumping, *i.e.* below the normal water level. The amount of water required was 263,000 gallons and with the pumps working a 16-hour shift, the wells were to be called on for a continuous hourly yield of about 5,500 gallons. This is a brief description of the scheme which the Garrison Engineer was asked to carry out.

As regards the yield from the wells, the experience gained in executing and modifying this project shows that the information contained in the P.W.D. paper No. 63, Simla, 1909, is well borne out in practice. The theory expounded in this paper is that the yield of a well at any one moment depends upon the depth to which the water has been lowered at that moment—in other words the velocity of re-entry of water into a well varies directly as the depth, to which the water level has been reduced or V (velocity in feet per hour) $\propto$ H (head in feet) whence $V = cH$, where c is constant. It is shown that for the sandy soils of the Punjab $C = \frac{1}{2}$ and in so-called "clayey" soils $C = \frac{1}{4}$. By pumping any particular well down to the depth desired, recording the recuperation increments in each quarter of an hour and plotting the results, C can be found by actual experiment (*vide Plate* I.).

The limiting factor in gauging the capacity of a well is the velocity at which water can flow into the well without disturbing the sand of the bottom. If this velocity is exceeded, the capillary tubes, formed by the water entering through the sand, will be broken up and sand will come into the well, thus endangering the stability of the well cylinder foundations. This limiting, or critical velocity, will depend on the kind of sand in the well. In the case of a new well in fine sand, it will naturally be less than with an old well resting in coarse sand or gravel. Experience at Risalpur indicates that even with an entrant velocity of $1\frac{1}{2}$ ft. per hour, sand has infiltrated into the well cylinders. At various places in the Punjab the critical velocity has been as high as $3\frac{1}{2}$ ft. per hour, generally in gravel, and in old wells in which the light sand has in the course of time been all removed. The difficulty then in estimating the yield from a well consists in finding out this critical velocity—in the Punjab it lies between $1\frac{1}{2}$ ft. and $3\frac{1}{2}$ ft. per hour—and the finer the sand of the bottom, the less this velocity will be. To commence with it was thought best to assume this velocity at about 2 ft. per hour, and, taking C at the value determined by tests from $V = cH$, we get the working head of the wells, and the height at which the suction strainers must be fixed.

Tests taken at Risalpur show that the factor C in the formula $V = cH$ has decreased in value from ·75 in July, 1908, to ·25 in 1912. This is probably either due to a decreased amount of water in the well area, or to the fact that the latter has become choked up owing to its having been overworked before the importance of not exceeding the critical velocity had been fully realized.

In the second case continual cleaning of the well bottoms may be necessary until the fine and choked-up sand has been finally removed. Tests at intervals will show whether any improvement in "c" is being effected. It is, of course often the case that the amount of water in a well area decreases as additional wells are brought into work.

The work of sinking wells Nos. 1, 2 and 3 was accomplished without any special incident and it was only when start was made with sinking the connecting pipes 14 ft. below water level, that difficulty was experienced. Two lengths were actually placed in position at this depth with some difficulty, elaborate shoring and temporary pumping arrangements being necessary. The cost of laying the pipes 14 ft. below water was evidently excessive nor did it appear necessary in view of the fact that the working head of the wells, determined by the method above mentioned, could only be 5 or 6 ft. Besides this difficulty with the connecting pipes, it was evident that the available yield from the wells had been overestimated. Assuming the normal critical velocity of re-entry of the well area to be as high as $2\frac{1}{2}$ ft. per hour, the discharge would only be $2\frac{1}{2} \times \frac{16^2 \pi}{4}$ c. ft. per hour

$$= 2\tfrac{1}{2} \times \frac{16^2 \pi}{4} \times 6\tfrac{1}{4} \text{ gallons}$$

$$= 3{,}143 \text{ gallons per hour.}$$

In order to obtain 263,000 gallons in 16 hours and allow one well spare, six wells were evidently necessary instead of the three proposed.

These facts being made clear a revision of the well project was asked for in 1910, and the plans in *Plates* II. and III. were drawn out and approved during the winter of 1910—1911.

In the revised scheme six wells were allowed for, to be connected by horizontal suction pipes above water level to a centrally placed suction chamber from which a suction pipe was to join with pump in use. General arrangements were as below in *Fig.* 2.

To provide for the air collecting in the long suctions, an air pump, run off the main shaft of the engine, will be capable of exhausting the suction chamber. This is made by Evans & Co. of Wolverhampton, who specialize in air pumps of this description.

The new scheme was carried out in the summer of 1911 and was complete in all main essentials by the winter. No special difficulties were experienced, and only minor alterations to the first draft plans were made.

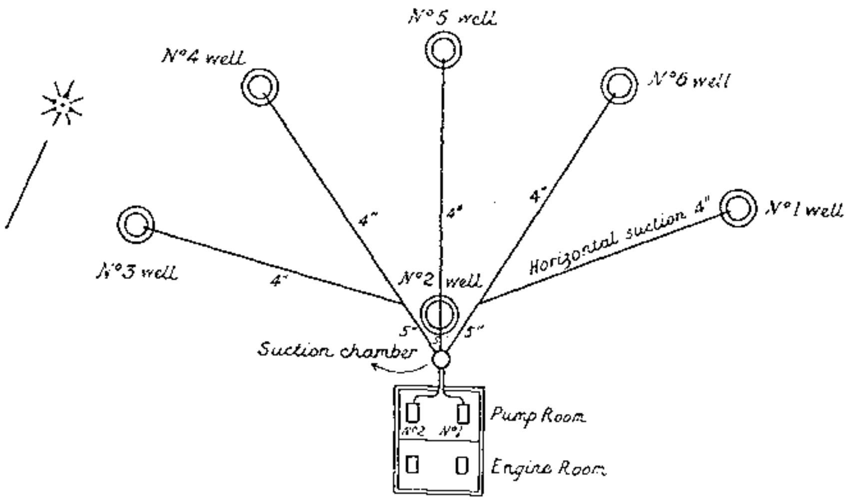


Fig. 2.

The wells were sunk in the manner common to the Punjab. The shaft of the well is excavated at once to water level. The ground usually consists of stiff sandy clay, which will stand up for months in all weathers without any support. Whilst this excavation is in progress the wooden curb of the well cylinder is being made; this is of the roughest description generally of tarash wood with 1-in. bolts and heavy plates. The bolts should project upwards for a distance equal to the amount of water which will be in the well, their ends are fixed into a holdfast ring, fixed in the brickwork of the well steining. The curb complete weighs about 4 tons—a winch, some strong holdfasts and tackle are necessary for lowering it into position. When lowered, it must be accurately centred in the well shaft. This done, 15 or 20 ft. of brick steining are built on the curb and allowed to set for 10 days, after which the actual process of sinking begins. At the start, the water, which has collected overnight is taken out by means of bullocks, and a leather water sack known as a "chursa." Coolies then work about knee deep in water and spade out the sand, the well cylinder sinking gradually as this is done. When the sinking had been done to 15 ft. of water the well is completed by building up the steining, and roofing in. For ordinary irrigation wells the depth of water, which can be obtained in this manner is quite sufficient for all purposes. In the case of water supply wells, it is necessary to pump to obtain depths over 10 ft.

Pulsometers were used very successfully in Risalpur for this purpose. It is important to have enough steam power available and to follow exactly the instructions of the maker's pamphlets, which are fully descriptive and quite clear to follow.

The air valves require careful watching—any jarring or irregular action of the ball valve is due to these being out of order.

A by-pass connecting the rising pipe and the suction pipe, as sketched below in *Fig.* 3, enables the discharge of the pulsometer to be regulated to a nicety. Without it the steam has to be constantly turned off owing to the sump hole drying up.

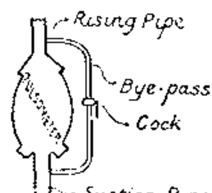


Fig. 3.

In deep wells of 40 ft. to water level and over, or in any special case such as sinking through quick sand, a steel curb is advisable and may be obtained through any of the Indian engineering firms.

These occur at the junctions of the suction pipes of No. 1 and No. 6 wells and of No. 3 and No. 4 wells respectively. Owing to the foundations of these chambers coming where previous excavation had been made in the endeavour to lay the connecting pipes below water level, reinforced concrete slabs were used 4 in. thick, 2 per cent. reinforcement with 12-in. lime concrete over them; they have proved satisfactory. The roofs were the ordinary brick domes well known to Indian bricklayers and mistris.

These call for no special comment. They were built "cut and cover," as earthwork is cheap, owing to Ghilzai labour in the winter.

It will be noted that a 9-in. arch only was used in spite of the heavy filling above (20 ft. average). This latter was put in gradually, and carefully rammed. The ends of the culverts only butted against the wells so as to allow the latter to sink freely, which they do for some time after completion owing to the curbs being founded in sand only. For the same reason the arched openings in the well steinings were cut 1½ ft. higher than the culvert sections.

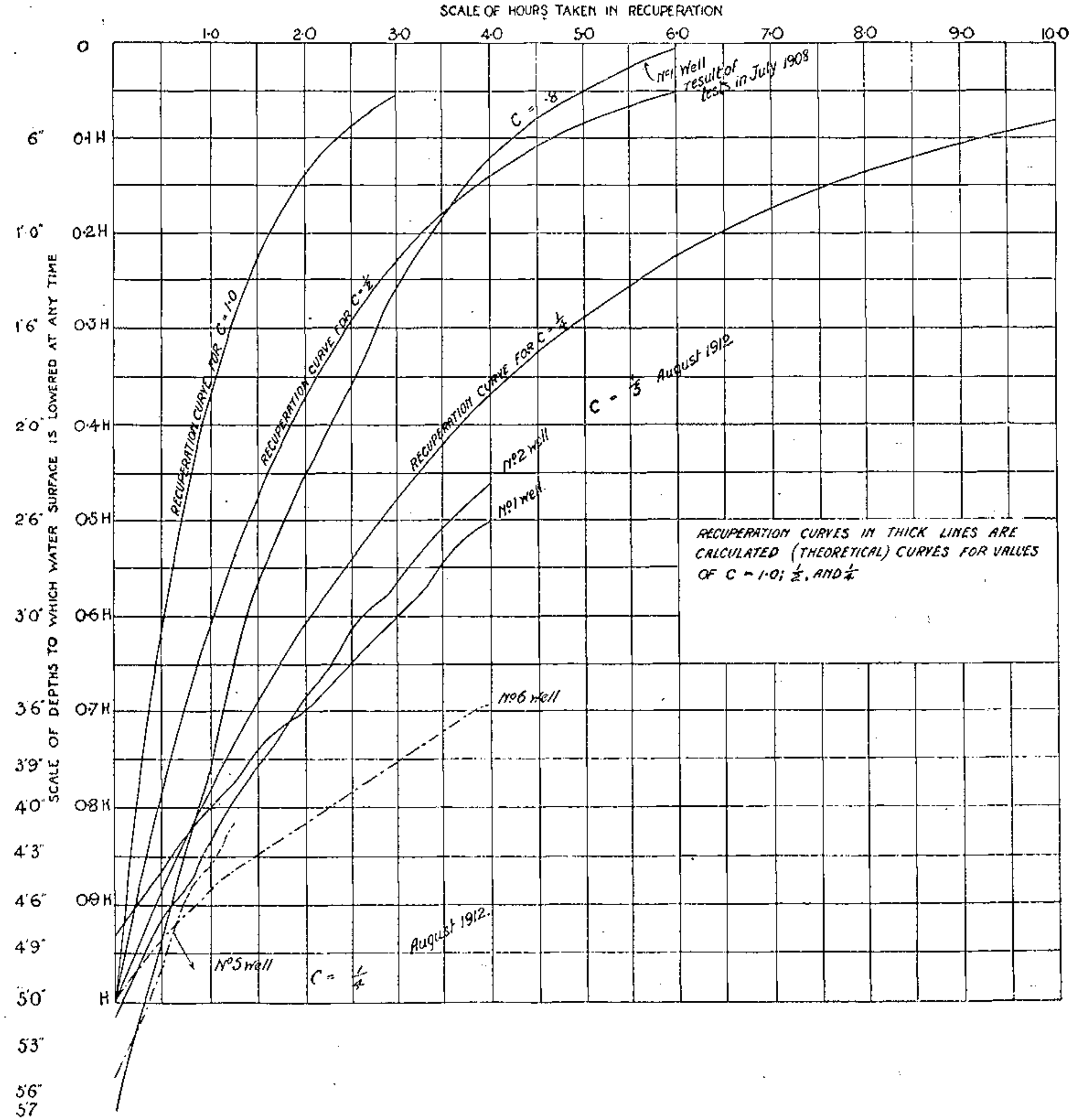
Owing to the tendency, which the suction pipe strainers have of drawing sand into the wells, it is recommended that they be fixed always in the centre of the wells so that as little damage as possible may be done to the well foundations.

The work as a whole formed an interesting study of conditions obtaining in the supply of water from wells. Equally interesting and far more extensive work has been done in this connection at the Punjab stations of Lahore and Amritsar, and no doubt papers are available giving full information of the progress made in these places.

PLATE I.

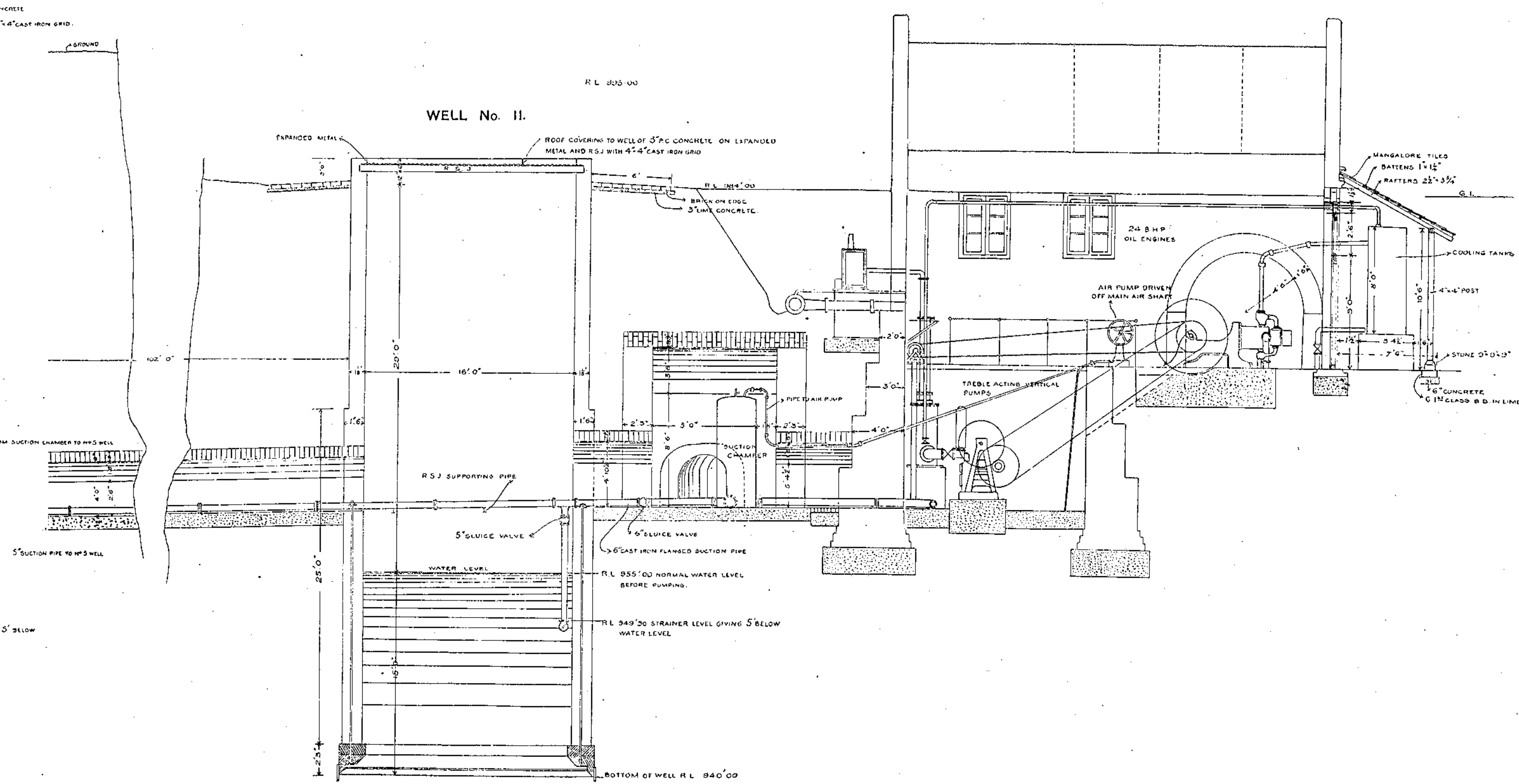
THE WATER SUPPLY OF RISALPUR, N.W.F.P.

RECUPERATION CURVES.



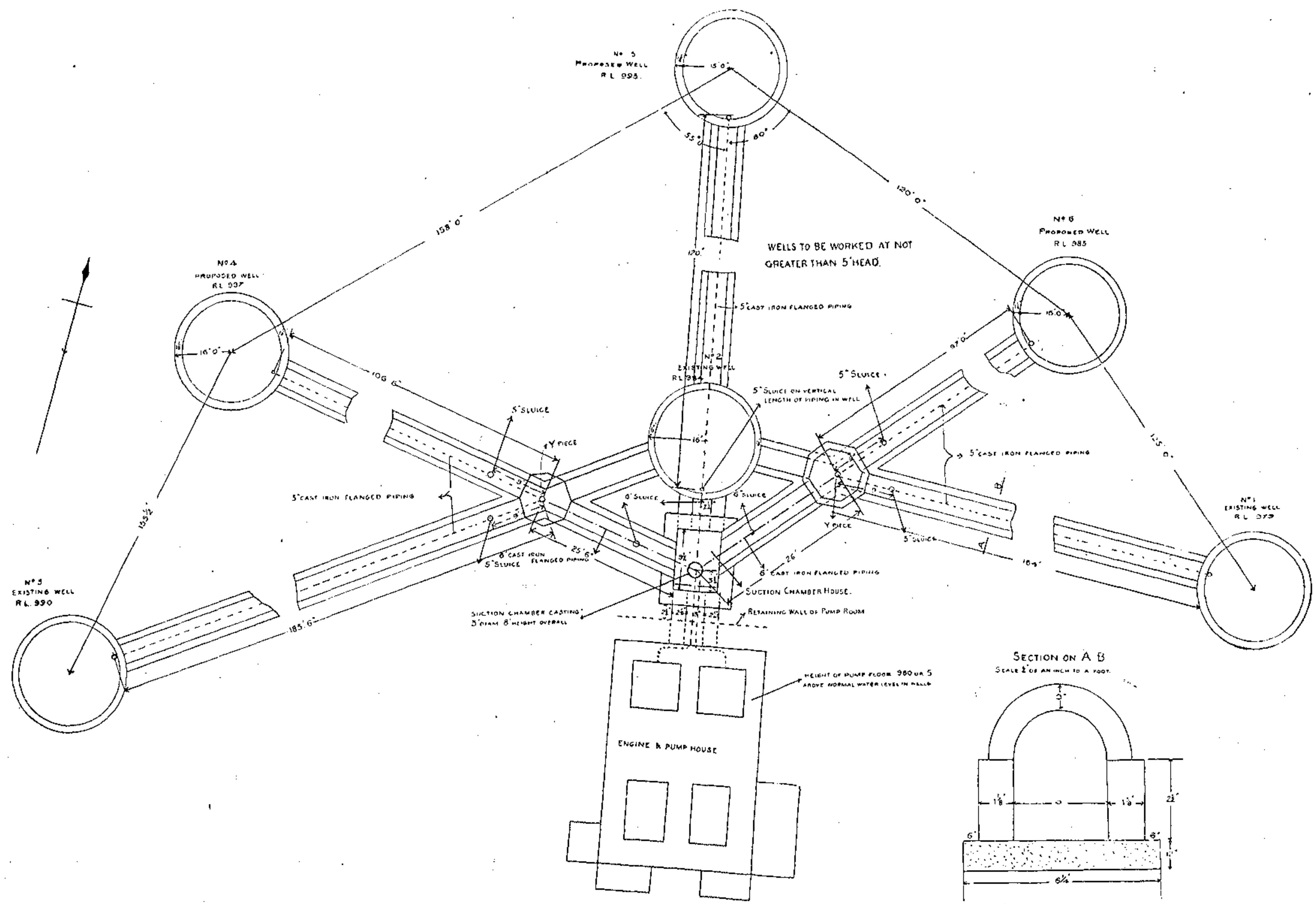
THE WATER SUPPLY OF RISALPUR, N.W.F.P.

PLATE III.



THE WATER SUPPLY OF RISALPUR, N.W.F.P.

PLATE II.



NOTES ON SERVICE DETECTORS.

By LIEUT. A. H. SCOTT, R.E.

THE object of these notes is to gather into one manuscript divers facts which have been recently published in various technical papers, notably *The Electrician*, on the types of detectors which are actually in use in the Army Signal Service.

These detectors are :—(1), The "Perikon" detector; (2), the "Carborundum" detector; and (3), the "Vacuum Valve" detector. Of these the first is the simplest in action and is the most universally employed.

The "Perikon" Detector (Fig. 1).—*Fig.* 1 shows a side elevation of a service pattern "Perikon." The detector is made by arranging a corner of a fragment of zincite to press against a piece of chalcopyrite (iron copper sulphide) or euribisite, and is one of the most sensitive known. It belongs to the class of detectors known as "rectifiers," and can be used with or without the aid of a local voltage.

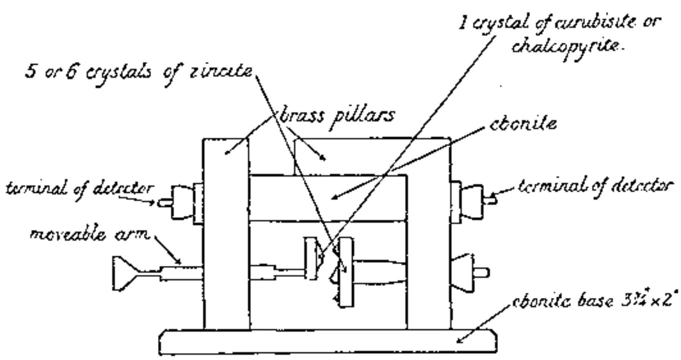


FIG. 1.—*Service Pattern of Perikon Detector.* (*Side Elevation*).

In the latter case its action is believed to be due to a combination of the Joule and Peltier effects, and can be explained as follows :—When an alternating voltage, such as is received at the aerial of a radio-telegraphic station, is applied to the detector, the temperature of the junction of crystals rises, owing to (1) the Joulean effect, (2) the Peltier effect. The resistance consequently diminishes and a large current results, which under the influence of the applied voltage passes through the junction. When however the voltage is reversed, the resistance of the junction is much increased, since the Peltier effect for a current in the reverse direction is to cool the junction and the greater the current the greater the cooling effect. Thus the amount of current that passes during the second cycle of alternation is very small; *i.e.* the detector acts as a rectifier, permitting only the passage of pulses of uni-directional current. These pulses, if strong enough, are heard in a telephone. In certain cases it is found that a slight difference in potential between the terminals of a detector increases its sensitiveness.

In 1910, Dr. W. H. Eccles carried out some very interesting experiments on the energy relations of certain detectors. His results with regards to the "Perikon" are shown in *Figs.* 2, 3 and 4. *Fig.* 2

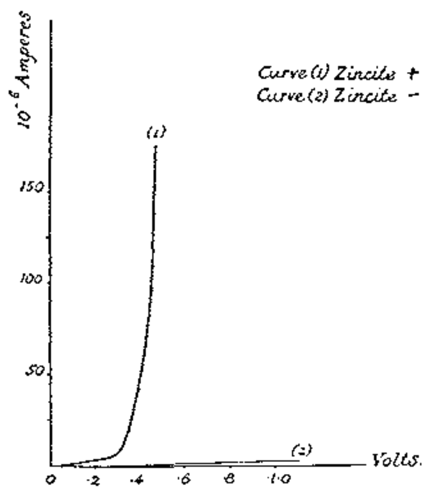
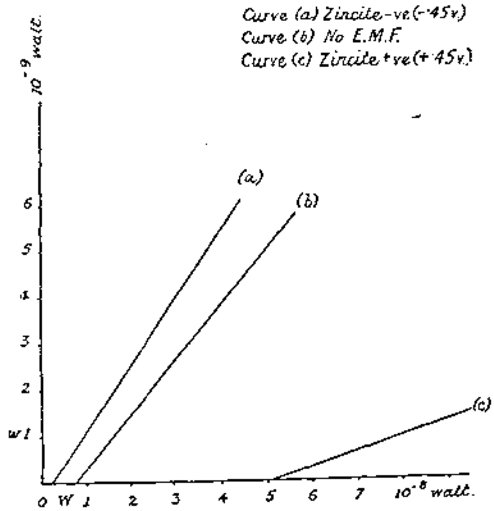


FIG. 2.—*Dr. Eccles' "Steady Current Curves" for the "Zincite Chalcopyrite," i.e. Perikon Detector.*

shows the effect of applying to a Perikon detector a gradually increasing E.M.F., and measuring the corresponding current. The most sensitive condition was discovered to be when the Zincite crystal was maintained at a potential of about ·45 volts below that of the pyrite. *Fig.* 3 shows the relation between the intensity in sound received in the telephone and the energy of trains of oscillations sent through the instrument, the E.M.F. at the terminals of the detector being kept constant. The curves show that even when the detector is used without a local voltage it is very sensitive. To get the maximum effect, however, it is best to have a P.D. of ·45 volts between the terminals, the zincite being the negative terminal. *Fig.* 4 shows the effect of sending trains of constant energy value through the instrument, and measuring the change of intensity in the sound in the telephone, when the steady E.M.F. at the terminals is varied in steps.



w=power delivered by detector to telephone.
W=power given in form of electrical oscillations to detector.

FIG. 3.—*Dr. Eccles' Power Curve for Perikon Detector.*

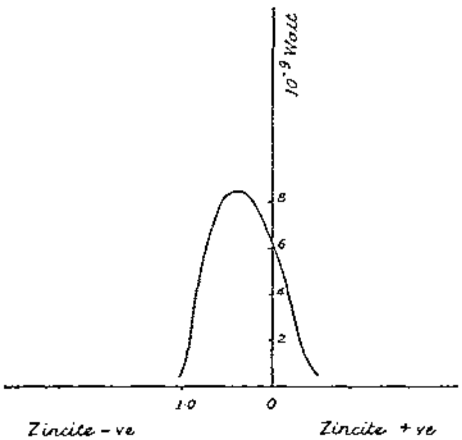
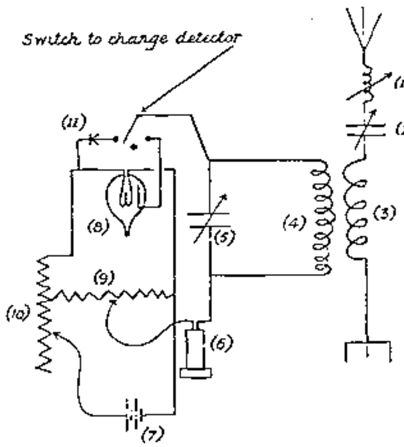


FIG. 4.—*Dr. Eccles' Sensitiveness Curve for Perikon Detector.*

(2). *The "Carborundum" Detector.*—This detector consists of a crystal of carborundum clamped between brass plates so that a smooth crystalline edge, or corner, is in contact with one plate, and a blunt and more amorphous part of the crystal in contact with the other plate.

It is similar in action to the Perikon, and *Fig.* 5 shows how it is connected up in certain service sets.



(1) Aerial Tuning Inductance.
(2) ,, ,, Condenser.
(3) Primary of Oscillation Transformer.
(4) Secondary of ,, ,,
(5) Billi Condenser.
(6) Telephone Receiver.
(7) Storage Battery (12 Volts).
(8) Vacuum Valve Detector.
(9) Potentiometer.
(10) Series Resistance.
(11) Carborundum Detector.

Fig. 5.—*Connections with Alternative Carborundum, or Vacuum Valve Detector.*

(3). *The "Valve" Detector.*—The "Vacuum Valve" detector consists of an incandescent lamp of carbon or tungsten, fed by storage batteries, with a small sheet or plate of metal held in the bulb near the filament. The action of this valve is similar to that of the Perikon detector, the alternating voltage received causing a flow of uni-directional impulses from the filament to the plate. These impulses affect a telephone placed in the detector circuit. A potentiometer is provided to obtain the maximum sensitiveness of the valve, and is placed across the battery supplying current to the lamp.

The connections of this detector, which is largely used by Messrs. Marconi in their field sets, are given in *Fig.* 5.

AUTOMATIC WATER GATES.

By LIEUT. J. S. YULE, R.E.

THE extraordinary progress that has been made of recent years in the regulation of rivers for purposes of water power and irrigation does not attract, for the most part, wide attention. It is only when the imagination is touched by the completion of a great engineering work, such as the Assouan Dam, and its inauguration by notabilities, or when the lament of a landscape artist at the desecration of Niagara in the interests of electric lighting finds its way into the correspondence columns of the daily press, that the subject is brought before the public eye. Yet the amount of work that is being done in this branch of engineering is tremendous. In Sweden, where water power is available in all the timber-growing districts, the industrial applications have been developed to the full; in other countries of Europe, in America, in New Zealand, progress is equally rapid, and a beginning is now being made in India, Egypt, and Mesopotamia. In all these undertakings it is the organization that is being developed; the general engineering problems are, on the whole, of a type and have perhaps received less attention. A recent attempt to solve one of these problems—the automatic regulation of weirs and flood gates—should be of interest, especially as the solution is on new lines and of singularly attractive ingenuity.

Up to the present no reliable forms of automatic flood gates and sluices have been in use, and it was the obvious necessity for a satisfactory and simple type that led Mr. Henry Davey to pay attention to the problem of their design. It is by his courtesy that I am enabled to describe the result of his work and reproduce his drawings.

The regulation of water for irrigation, or for power, or of rivers against flood must be sure and speedy. In the first case there is ample power available to operate the gates, but in the two other cases, men would probably have to be employed. In all, it is essential to deal with a flood as soon as it begins, and it is only by eliminating as far as possible the human element that this can be done. An automatic flood gate is a power gate and is independent of human control for its action. The general principles of regulation are the same in all cases; but in practice, details and difficulties rise which make for differences. The means of regulation may be divided into three classes, namely:—Weirs, flood gates and sluices.

Weirs.

A weir may be used as a dam to raise the level of water in a reservoir, or as a by-pass to prevent the water behind a dam from rising too high. The only automatic one in use is a syphon weir. This is a very simple device, a syphon pipe with the short end cut off and the mouth of the syphon the crest of the weir; but its application is very limited. Any other form of automatic weir must be moving and a moving weir is a flood gate. One form of gate has been devised which is automatic under certain conditions—a rectangular flat gate is pivoted with its axis at the centre of pressure. It is balanced when the head water covers the face, but not against tail water. On the water rising, additional pressure is put over the whole face but as the upper part is twice the area of the lower, the gate tends to open. This gate discharges above and below but it does not hold up the head water. With bottom discharge, the discharge for a given opening of the gate is greater than with a top discharge, and the head water is kept from rising or falling to any great extent.

The two most important conditions that automatic gates should fulfil are :—

(1). That they should be sufficiently sensitive to open at the beginning of a flood when the water has risen only 2 or 3 in.

(2). That, as all gates are subject to variations in conditions of work due to the collection of weeds and grit, the power available for working them must be greatly in excess of that necessary under normal conditions. The power is obtained from the difference in level between the head and tail water and is usually sufficient.

The first of Mr. Davey's gates does not entirely fulfil the first condition. It consists of the shutter described above pivoted at the centre of pressure. The lower portion is covered with a semi-circular shell, to the inside of which the tail water has access (*Fig.* 1). The gate is then balanced for both head and tail water. If this gate in the closed position is at 45 degrees to the horizontal and the top of the hemi-cylinder the normal head water level, when the flood water rises to the top, the tail water will tend to open the gate which is kept down by the water flowing over it. This gate will open and close slowly (as it should do) because the water can only flow slowly in and out of the hemi-cylinder through the hole X. It will be noticed that a considerable rise and fall of flood water is necessary to actuate this weir and it does not therefore fulfil the condition as to sensitiveness. It must be balanced in itself when empty and a weight added to close it again when the flood has ceased.

The next weir is constructed on a somewhat similar principle. It is a hemi-cylinder turning on a hollow trunnion (*Fig.* 2). In a vertical position when the inside of the gate is filled with water the pressure of the head water is on the curved surface and at all points

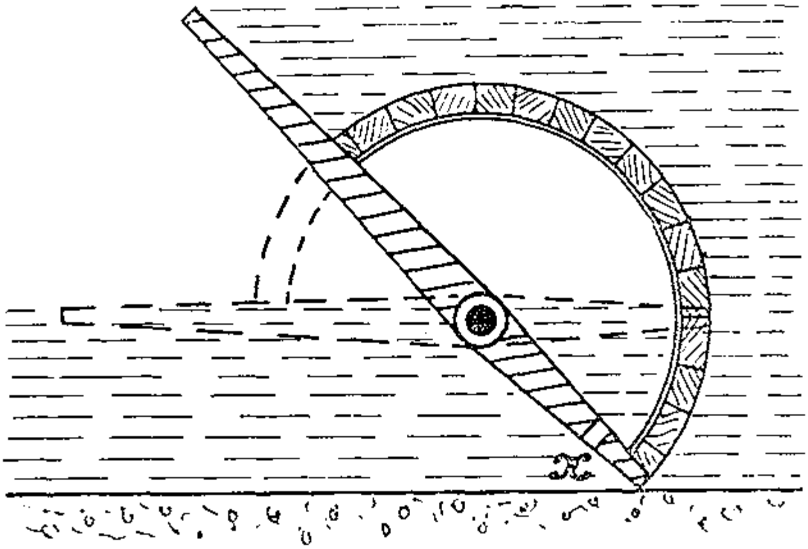


Fig. 1.

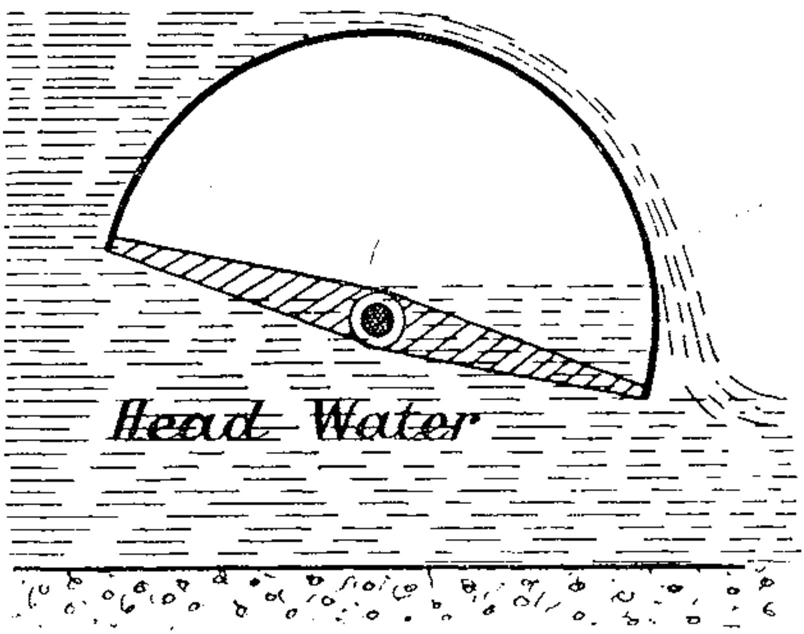


Fig. 2.

normal to it. The resultant pressure passes through the axis of the gate and there is no tendency for the gate to move. It is kept shut by the weight of the shell. When the shell is empty the pressure of the head water is on the vertical surface, and the resultant pressure acting at the centre of pressure two-thirds of the way down, tends to open the weir. If an arrangement can be made by which the gate is full of water under normal conditions, and empty in time of flood, the gate will be automatic. This is easily arranged. In a chamber at the end of the gate is placed a float which rises and falls with the rise and fall of the head water. To this float is attached a valve which, when the float falls, admits water through the hollow trunnion to the interior of the shell and closes the gate. When the float falls, the valve closes, the admission of water ceases and at the same time a discharge passage to the tail water opens. This allows the shell to empty and the gate opens. The float and valve are of the simplest nature and can be taken out without disturbing anything else. It is not necessary for the valve (nor the shell, if the valve is sufficiently large) to be water-tight. In fact leakage holes are provided in the lower part of the drum to prevent the accumulation of silt.

It will be seen that as the gate opens, the effective pressure on the gate tending to open it becomes less, because some of it is converted into kinetic energy in giving velocity to the water, and, as the gate tilts, the turning moment decreases. Both causes are compensated for by decrease in the moment of the weight of the gate tending to keep it closed. This gate is very simple. It is very sensitive as it will work with only a rise or fall of 3 in. It is of very strong construction, being in fact a box girder. Lastly, the power available for working it is very greatly in excess of what is necessary under normal conditions. A large hole in the shell would prevent its action, but this contingency could be met by the provision of handgear which would usually be provided for other reasons. The float chamber would be protected by a grating against choking by weeds and other floating obstructions. For short gates this form of weir is expensive but its strength admits of its being made very long; for example, an 8-ft. gate might be 30 ft. long.

The next figure (*Fig.* 3) shows a similar gate operated in such a way that admission and discharge from the interior of the gate is unnecessary. In this case the semi-circular shell is towards the water. At the end of the gate is a square chamber in which fits

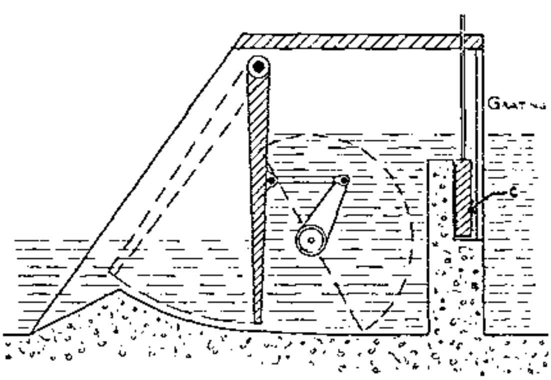


FIG. 3.

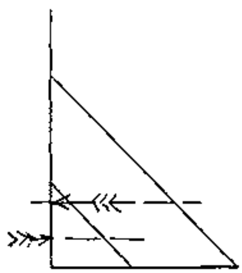


FIG. 3*a*.

loosely a radial piston of wood. It is attached to the axle of the gate as shown. The total pressure diagram is *Fig. 3a* in which the small triangle represents the pressures of the tail water and the large one that of the head water with the centre of pressure shown by the arrows. A board *c* protected by a grating may be raised or lowered to fix the head water to any desired level. We can arrange weirs of this kind in sets, two gates 6 ft. by 20 ft. to each actuating piston. What difference of pressure will actuate the gates is a matter for experiment, but if the motion of the piston at the centre of pressure is equal to the circumferential motion of the gate—as it is in the drawings—the moving force, with the piston 6 ft. high and 5 ft. wide, is 3,200 lbs. This is where the tail water is half-way up the gate. If we take a valve as high as ·2 for the co-efficient of friction for the bearings, we only lose 600 lbs., a small fraction of the total available force. With no tail water it is about 4,000 lbs. at the circumference. Leakage can be prevented by the use of semi-circular stanching rods at the ends of the cylinders.

These moving weirs have a distinct advantage over fixed for storage reservoirs, because they hold up the water to the level of the highest flood instead of to the bottom of the spill way, and add this height to the capacity of the reservoir.

Flood Gates.

On rivers, flood gates are very often required to have a far greater discharging capacity than weirs, and have to deal with large obstructions such as trees which are brought down by the floods. The device described above in connection with weirs is employed to actuate falling shutters which cannot be injured by large floating bodies passing over them.

The shutter itself (*Fig. 4*) is hinged at $\frac{2}{3}$rds its depth from the top

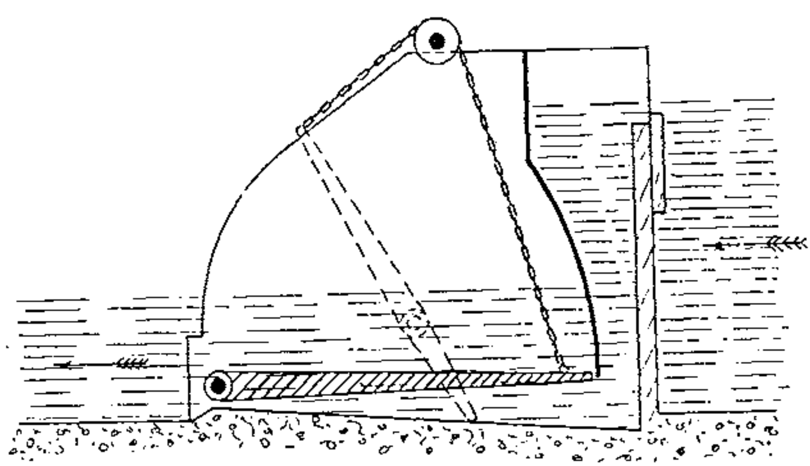


Fig. 4.

and is actuated by the radial piston device already described. It is balanced on the head water side, but a rise in the tail water tends to open it and this tendency reaches a maximum when the tail water is ⅔rds the way up the back of the shutter. A ratchet and pawl can be provided to keep the gate down till it is released by hand, which is sometimes desirable.

Collapsible shutters are extensively used in India, but the operation of raising them is always tedious and, in the case of the Ganges canal, the canal head must be closed and the water emptied all but 3 ft. to form a cushion to the falling shutters. A clumsy form of automatic gate is in use on Lake Fifa. The gates are operated by floats working in wells; these are expensive and complicated to construct and their action is uncertain. They take up a great deal of the water way, but gates of the hemi-cylinder type, which can be made longer would not do so to anything like the same extent, and would be better also from the point of view of simplicity and cost.

SLUICES.

The simplest form of automatic sluice is that shown in *Fig.* 5. It is limited in its application but would be useful as a relief sluice on mill dams, etc. The sluice is of triangular section, rising on inclined rails, and is of sufficient weight to resist the pressure of the head water. In an automatic sluice the rise must be less than the rise of flood water, but by ballasting it with water it may be made to rise much higher on letting out the water by hand. The principle involved is made use of in the following designs.

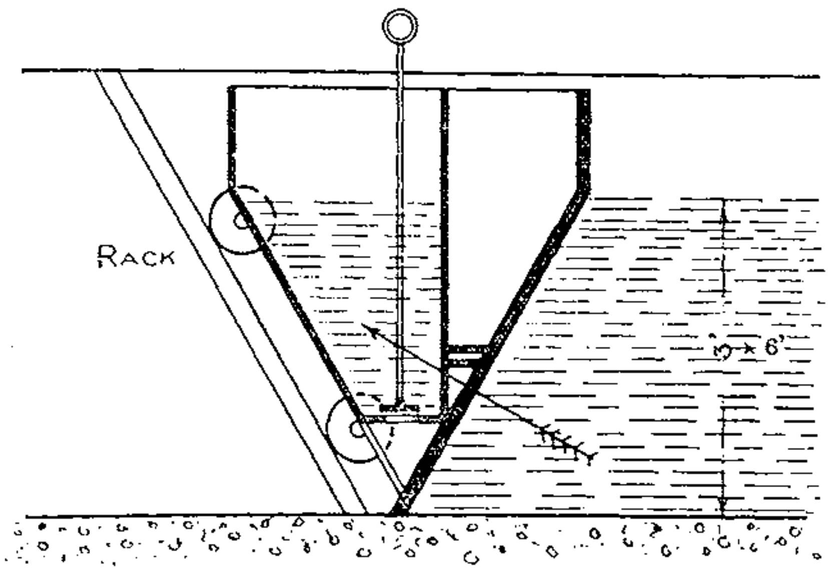


FIG. 5.

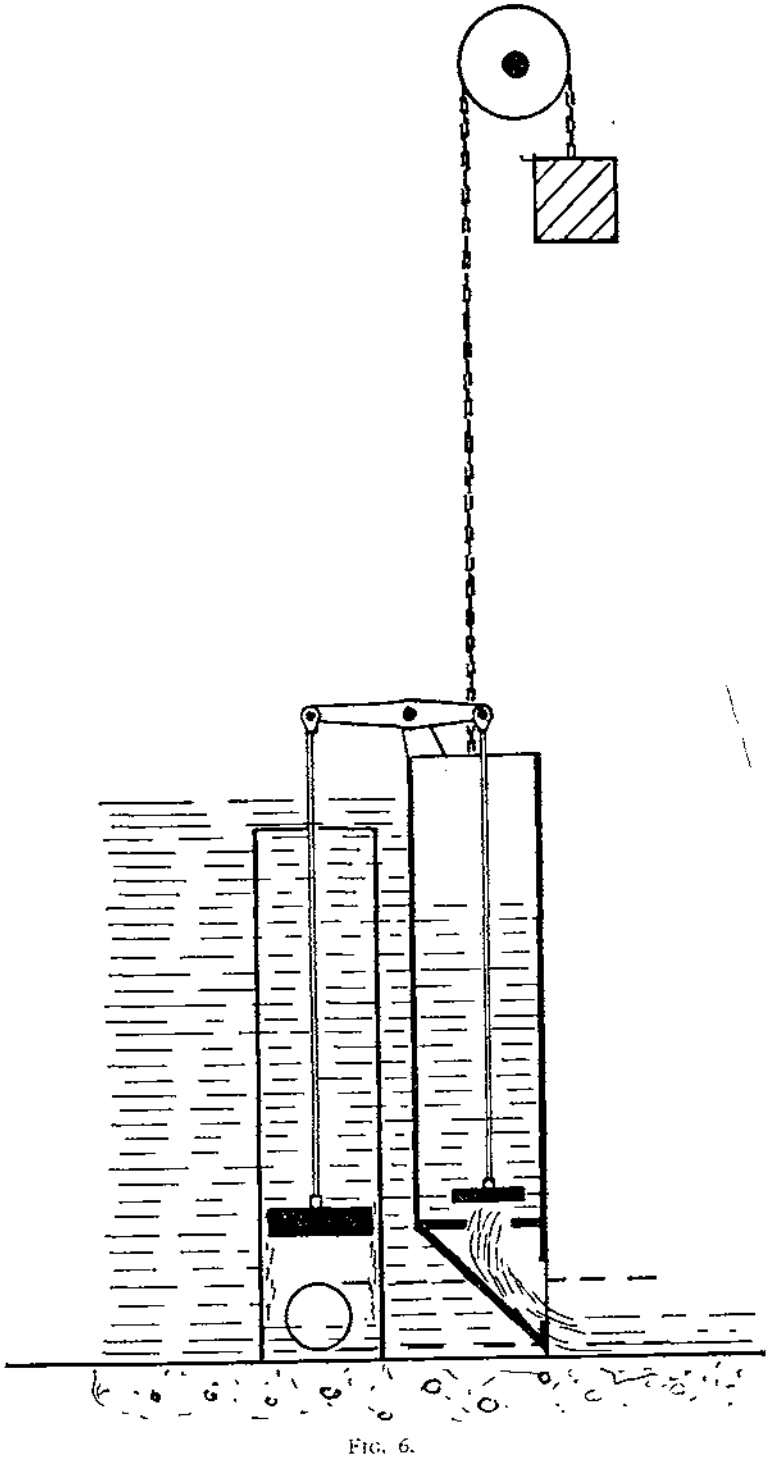


Fig. 6.

The gate is built hollow and is partly balanced (*Fig.* 6). The unbalanced weight of the gate is sufficient to resist the tendency of the normal head water to lift it. By letting water out of it, it will open, and by filling it again it will close. This is done by means of a valve which is actuated by a rise or fall in the head water. At the end of the gate is a pipe with a loosely fitting piston which is connected to the valve. The bottom of the pipe is open to the tail race. When the head water rises over the top of the pipe the piston is forced down and opens the valve. This lets the water out of the gate which opens. When the head water falls below the level of the top of the pipe and closes the valve, the head water fills the gate through a hole in the face and the gate closes. This gate is supported by the difference in level of the head and tail water.

The gate itself need not be perfectly water-tight; a considerable leak would be of no consequence provided that a large discharge valve were used. So much of the weight of the gate is balanced that its operation by auxiliary hand power can be easily arranged. The gate runs on wheels fixed in the gate post which only project sufficiently to prevent the sluice touching. If the gate is required water-tight standing rods must be placed in the angle of the gate and post.

All the above designs depend for their action on simple hydraulic principles, and fulfil the requirements for automatic gates which were considered above. They are all simple in construction, and need not be water-tight. In consequence, no elaborate machined parts are necessary. They are sensitive in action and have a big reserve of power for contingencies. The actual movements of the gate themselves are not sudden either in opening or closing so that no harm can be done by unexpected strains coming on the supports due to jerky working. No single design of water gate is universal in application, and it is not claimed that the above short descriptions exhaust the possibilities of the subject. They may, however, be of use to those who have practical experience in these matters, and of interest to others, even though that interest may only be of an academic kind in the neat solution of a problem in hydraulics.

ECONOMICS OF ENGINEERING.

(*Lecture by* MAJOR W. A. J. O'MEARA, C.M.G., LATE R.E., BARRISTER-AT-LAW, *to Students, Faraday House, 26th February*, 1913).

INTRODUCTION.

THE Science of Economics deals, as you are well aware, broadly speaking with questions which concern the creation, production, distribution, circulation, and conservation of wealth. The expression wealth is naturally not employed here in a restricted sense, as meaning money alone, but is used in a far wider sense, so as to include all those public utilities which are considered practically indispensable by all civilized communities in the age in which we are living. When it is remembered how very large is the part that engineering enterprises, for example, such as canals, harbour works, railways, tramways, etc.,—which are properly said to constitute the wealth of a nation,—have played in recent times and continue to play to-day in contributing to the prosperity of a people, it needs no words of mine to point out the great importance which should be attached to the study of economics in general, and the economics of engineering in particular by all who are now, or may in the future be engaged in the development of our engineering undertakings.

The fundamental principles on which the practice of modern engineering are founded to-day are after all only those upon which the science of economics itself is based. The scientific economist advocates nothing more alarming than the striving after efficiency, in the amplest meaning of this term. And is this not the same lesson which is being inculcated almost daily throughout the year not only by the professors in our engineering schools, but also by the engineers responsible for the welfare of our important engineering undertakings.

It appears to be extremely simple to formulate the conditions necessary to secure the highest degree of efficiency; as a mere statement, nothing more is required to attain this end than to eliminate waste in every shape and form. But when an enquiry is set on foot to ascertain what the application of this simple rule may involve in any particular case, it then soon becomes evident how considerable must be the amount of forethought, preparation, and investigation which must be devoted to the formulation of the exact measures to be adopted in order to realize the results aimed at. In order to obtain the highest degree of efficiency, it is absolutely necessary that all the aids to speculation and enquiry which the wit of man can devise should be brought into use. The scientific economist, whatever may be the subject to which his enquiries and investigations may be directed, must resort to experiment, observation, hypothesis, verification, deduction and induction. These are processes which are familiar to you all, and may help you to realize that I am dealing with a subject which is really familiar to you under, perhaps, a different name.

The Science of Engineering Economics, it has been said, is divided into two broad classes, viz.:—The economics of policy and the economics of practice. Unfortunately, in this country it is often assumed that the former concerns the financier exclusively, and is outside the domain of an engineer, although it is freely admitted that the matters *comprised in the economics* of practice belong more properly to the sphere of the engineer. The views held on this subject in this country by no means coincide with those prevailing in the United States of America, and in many parts of the Continent of Europe. Formerly, when the problems dealt with by the engineer were confined very largely to those relating to the design and construction of structures, and of works of a stationary character such as bridges, roads, aqueducts, etc., it may be, that no very serious disadvantages may have arisen from the separate consideration of these two aspects of the problems connected with the economics of engineering. But to-day the whole character of engineering enterprises is very different from that which prevailed a century, or even less, ago. The engineer is no longer concerned alone, with the design and construction of stationary structures, but also with the development of enterprises which have vastly different characteristics. Many of the problems which the engineer is called on to solve to-day require not only the provision of plant, of which motion is the very essence, but he is also required to prepare projects, which involve from their birth the consideration of the equally, if not more, important questions connected with the methods and means to be adopted to take care of their growth, that is to say, in a double sense *engineering enterprises have ceased to be stationary in character.* I venture to suggest that even this very cursory glance at the problems associated with modern engineering undertakings is sufficient to indicate that under the altered circumstances of to-day, the solution of the problems connected with the economics of engineering is likely best to be effected by the consideration of the two aspects, those of policy and of practice in combination, and that the education and training of an engineer is as necessary for dealing with the problems connected with the former aspect, as much as these qualifications are essential for dealing with the problems connected with the latter aspect of engineering economics. I recognize that if the only argument which could be advanced in support of the view I have expressed were to consist in a recommendation to follow the example of other countries, there would indeed be little to commend in my proposition, and I could not hope to convince. However, as I proceed with my subject, I will endeavour to analyze the situation a little more in detail, and to put before you certain elements involved in the consideration of the problems connected with the economics of engineering as a whole, so that by the time I have reached the concluding part of my paper you may have in your possession sufficient material on which to argue out the situation, and to come to your own conclusions.

I have touched upon this matter here, because after I had accumulated the material for this paper, I experienced some difficulty in separating it, in order that I might deal with it under the two main heads of policy and practice. Finally, I came to the conclusion that it was practically impossible to treat these two aspects of the question as entirely separable and independent.

Engineering covers so wide a field nowadays that, in the time at my disposal, it is quite impossible for me to deal comprehensively with all the matters which affect the economics of engineering. It is, therefore, necessary for me to limit the scope of my subject to such matters as are likely to be of particular interest to my audience. I fancy that the majority of those whom I have the pleasure of addressing here, intend to adopt the career of an electrical engineer, and under these circumstances I feel that I cannot do better than to examine some of the problems connected with the economics of engineering as it affects electrical undertakings. From another point of view this may also prove advantageous, for is it not the enterprises in the field of electrical engineering which are so largely responsible for the difference in the characteristics of the problems dealt with by engineers a century ago, and of those which engage the attention of the majority of engineers to-day to which attention has already been drawn?

I fully realize that even this limitation may not prove entirely sufficient, for the reason that electrical engineering may be said to represent what at first sight appear to be two opposing interests, namely, that of the manufacturer and that of the consumer. However, so far as the consideration of the subject of economics of engineering is concerned, the problems which require attention have many points of similarity, whether it is the interests of the manufacturer or those of the consumer which have to be investigated. And, indeed, it is possible to go even further than this, for it may be stated as a general proposition, that the interests of the manufacturer of electrical plant are really not opposed to, but coincide with the interests of the consumer, and *vice versâ*. The only real difference in these interests lies in the conception which may be formed of the share of profit which should be derived by the one party or the other in return for the part which he has played in the production of the wealth represented by the success of an undertaking.

I propose now to deal somewhat more in detail with some of the elements in the situation which affect the economics of engineering. In order to obtain a thoroughly comprehensive grasp of this subject, a fairly wide field of investigation must necessarily be covered as so many collateral matters affect the situation. It is very easy to stray into the fields lying on the borderland of engineering economics, and particularly into that of social economics. It may not be possible for me to avoid a reference to these collateral matters from time to time, but an attempt will be made to confine the paper to those points which more immediately concern the engineer.

An exhaustive investigation into the economics of engineering would require a detailed examination of the subject under several distinct main heads, each requiring further subdivision. I cannot hope, however, to do more than to touch on the fringe of the subject to-day, and will confine my examination to the four main heads, which I hope may prove of most interest and of some value to my audience.

These four main heads are :—

I. Markets ;
II. Methods of management of engineering enterprises and the technical details relating thereto ;
III. Diversity of interests of employers and employed ;
IV. Effects of legislation on engineering enterprises.

I. Markets.

The mention of the first of these main heads in a paper dealing with an engineering subject probably brings home to you more clearly than any other statement which I may have made, how great indeed is the difference between the engineering problems of a century ago and those of to-day. Whatever may be the commodity one may have to dispose of, a market containing consumers in sufficient numbers is essential if any progress is to be made. " Seek the consumer," can no longer remain the maxim exclusively of the producer of food supplies, and the purveyor of ordinary household utensils, nor even that of the manufacturing engineers, but it must be, to-day, equally the maxim of all those who undertake to supply consumers with electrical energy on their premises, or who convert it for the purpose of furnishing a public service in one form or another ; thus for example, in the case of both a tramway or a telephone service, consumers must be sought and catered for. But how different are the problems which have to be handled when the products of an electrical engineering undertaking have to be disposed of, as compared with those connected with the search for markets for ordinary wares and the products of the soil ?

In the electrical field, as you are aware, owing to the existence of continuous and alternating current systems of supply, and the various voltages which are in use, many technical details have to be considered in the design of electrical plant and accessories, so that it is quite possible that plant, etc., manufactured for one market may be wholly unsuitable for another. These factors naturally affect the question of manufacturing for stock, a matter which is of supreme importance in connection with the economic welfare of a manufacturing concern.

Again, in connection with the supply of electrical energy, technical considerations loom large in the arrangement and character of the distribution system to meet the varying nature of the load which may have to be taken up at different periods during the twenty-four hours. When it is remembered that a very large part of the capital cost of an undertaking for the supply of electrical energy is usually sunk in the distribution network, it can readily be imagined that a faulty disposition of the mains and feeder system may easily affect the economics of such an undertaking from the point of view of earning profits. And if by any chance an unsuitable market has been chosen for the disposal of electrical energy, the situation is by no means so easily dealt with, as is the case where many other kinds of commodities are concerned. It is usually possible to transfer ordinary goods from an unsuitable to a suitable market; true, this involves a loss of payments made for freight, but even so, it may still be possible that under such circumstances no dead loss is incurred; but it is rarely possible to pick up main and distribution conduits and cables in a locality which provides an unprofitable market, in order to relay them in another locality which may provide a remunerative market, without incurring some dead loss.

The question which next requires consideration is whether in electrical engineering matters connected with the choice of, and catering for markets should properly be considered as problems connected with economics of policy, or those connected with the economics of practice. It seems clear from the brief references which have been made on the subject that considerable technical knowledge is really necessary to deal with such questions, and that, indeed, aspects of policy cannot well be efficiently dealt with without at the same time taking into consideration those aspects which affect practice.

II. Methods of Management and Technical Details.

It is proposed now to examine the second of the main heads, which deals with the methods of management of engineering enterprises, and the technical details relating thereto. The matters comprised under this head can be conveniently treated in three main subdivisions :—

(*a*) Organization,
(*b*) Management of the enterprise, and
(*c*) Technical aspects of the enterprise.

(a). *Organization.*

There are certain general principles of organization which are of very general application and require to be strictly observed if efficiency is to be attained, whatever may be the nature of the undertaking or enterprise under consideration. The larger that an organization is, the greater is the benefit to be derived from the application of these principles, which are as follows :—

(i.). The work should be definitely and clearly subdivided, and the control of the different subdivisions should be expressly assigned to specific officers in such a manner that there can be no conflict of authority.

(ii.). A direct chain of command should be constituted, that is to say, every individual in the organization should clearly know to whom and for what work he is responsible.

(iii.). Real authority and responsibility should be created, so that each officer should really supervise the operations for which he is nominally responsible ; and the controlling officers should also have direct and individual control of the subordinates employed under them.

(iv.). The choice of officers for the control of the various groups should be determined by the specific nature of their experience and their peculiar aptitude for the duties assigned to them, that is to say, an officer should only supervise work which he is competent to judge and concerning which he can make helpful constructive suggestions to his subordinates.

(v.). The sections into which the work is subdivided for the purposes of supervision should be so arranged as to afford an easy means of ascertaining the costs of each class of work, on a unit basis, at the various stages, so that comparisons of the unit costs at different periods, and, therefore, the efficiency, may be readily determined, and

(vi.). The organization should admit of all routine work being carried out expeditiously and without duplication of process.

The above statements, it is thought, make it quite clear that the staff organization must be adapted to the business or works organization, and not *vice versâ*. This is a matter of considerable importance, and in some countries has received much consideration. It is naturally more difficult to apply the foregoing rules to a particular case, than it is to state them here. The whole object of an efficient organization is to provide co-operation in the highest degree, and to eliminate friction as far as possible, since friction is perhaps the most wasteful of all influences in our human institutions. The importance of an efficient organization both with regard to the subdivision of the work and the classification of the Staff cannot be exaggerated, such an organization is, without doubt, the most potent influence in promoting economy. The great point to be borne in mind is, first, to have as few main divisions as possible in your organization, and secondly, to reduce the number of subdivisions in each main division to the lowest limits. A certain number of main divisions are absolutely necessary in every large undertaking in order to provide an efficient control of each specialized branch of work. The character of an undertaking, as a rule, automatically settles the minimum number of such divisions which may be necessary in a particular enterprise. In a large engineering concern, manufacturing plant, which I recently visited, there were but three main divisions, each under the control of an engineer, namely :—

(i.) Engineer's department,
(ii.) The workshops, and
(iii.) Sales department.

This organization may be said to be functional, for the engineer's department is responsible for the design of the plant being manufactured, and the output—including examination and testing on the completion of an order. The manager of the workshop is responsible for producing the articles designed in the engineer's department at the most economical price, and the sales' manager for obtaining orders. The manager of the workshop has his own engineer of methods, whose special duty it is to plan out the various steps necessary to turn out the finished articles required by the engineering department, and at the same time the engineer of methods is at liberty to put up suggestions to his chief for the modification of the details of any design sent into the workshop if thereby economy, without loss of efficiency, is likely to be secured. Suggestions relating to alterations of design must, however, be submitted to the engineer's department for consideration, and approved by it, before adoption in the workshop.

I gathered that this organization works very satisfactorily in practice, and that it is rarely that differences of opinion between the engineer and the manager of the workshop are sufficiently serious to warrant an appeal to the engineer-in-chief and general manager of the undertaking.

Sufficient has been said, it is thought, to demonstrate that in an engineering enterprise matters of organization cannot satisfactorily be considered apart from the technical aspects of the business, and that the details of organization affect problems associated as well with the economics of practice, as those connected with the economics of policy.

(*b*). *Management.*

It is now necessary to turn to the subject of the Management of Engineering Enterprises. In its general sense, management includes the determination of the policy of a Company or Corporation, as for example such matters as the designing of the organization, the selection of the staff, the acquisition of patents, the supervision of the work done, and the expenditure incurred, the form of the accounts, provision for depreciation, etc. It is on the skill of management that the profits of an undertaking depend.

It is somewhat remarkable that, although commercial institutions have been in existence for some centuries now, and, in consequence, many opportunities have existed to study management as a science, yet as a matter of fact exceedingly small progress has been made in studying the important problems connected with this subject. Indeed, it is admitted that modern industries have developed far more rapidly from the technical point of view than they have either in respect of the organization of the services, or in the management of modern businesses. So thoroughly is this realized in some countries, that a movement is on foot to obtain official recognition for a diploma course in commercial engineering in order to train men to deal with problems of management. Many of the questions which affect the management of an engineering enterprise require for their solution minute calculations that can only be made by trained experts, and these can only be made on the basis of exact and carefully sifted statistical data: to take but one example, that of the value of a patent, who but a technical expert can really determine the financial value of a patent process or device to a given undertaking?

Policy questions in engineering, it is clear, resolve themselves into the consideration of the costs of alternative schemes, of which the various elements have been carefully considered and brought to account; and generally speaking it is dangerous from the point of view of the economics of engineering, to ignore the answer which is provided by the figures of annual cost in such cases. Competition is essential, and in the case of engineering enterprises the taking of risks must depend also on the study of the technical aspects of the question. Therefore, so far as our subject is concerned it would again appear that the economics of policy and the economics of practice cannot without some disadvantage be considered separately.

(*c*). *Technical Aspects.*

The next subdivision deals with the technical aspects of the enterprise, and involves mainly questions of practice which are extremely familiar to you, and I therefore propose to review them very briefly indeed, although even in the field of electrical engineering alone they cover a wide ground.

Now that engineering problems are becoming more and more complex, the mastery which an engineer must necessarily acquire in his every-day work of the matters comprised under this head, must tend, it seems to me, gradually to enhance his value in the industrial world.

The matters comprised in this branch of the subject may be conveniently considered under six heads :—

(i.). Materials.
(ii.). Design.
(iii.). Lay out.
(iv.). Methods of execution.
(v.). Operating of plant.
(vi.). Accounting.

(i.). *Economy of Materials.*—The importance of exact knowledge concerning the properties of the materials used by engineers has fortunately been long recognized, and, in consequence, much valuable data has been accumulated concerning their physical properties, and the efficacy of the various preservatives employed to prolong their life. You are all fully aware that the engineer who possesses knowledge of the physical properties of materials, the forms in which they can be purchased on the market, the useful life of various kinds of materials, the price at which the materials required can be purchased at the date of demand, and the different conditions under which they may be employed in structures and machines, is readily able to determine whether the employment of one material or another will prove most economical in any particular case, and I need not therefore enter into any further details on this head here.

(ii.). *Economy of Design.*—Matters connected with design give free play to the imagination, or in other words, the inventive genius of the engineer; and he who has best mastered the leading principles in the sciences which are included under the subject of Physics, and is able to apply these principles in some one or more original combinations, is on the high road to success. It is well to remember that an idea is often the source of great wealth, and it is new ideas which promote the economics of engineering, and bring about that progress which is continually going forward. The more complete your knowledge of the sciences associated with the art of the engineer, the more will it lay in your power to do your share in promoting the economics of engineering. This knowledge combined with that concerning the properties of materials will prove invaluable to you, particularly at times when there may be an enhancement in the price of certain materials either owing to their scarcity, or to the effects of legislation ; for it will be possible for you readily to think of substitutes which will under the circumstances serve your purpose in the place of materials which are either unprocurable, or too costly for the purpose you have in view.

(iii.). *Economics of Lay-Out.*—Under this head fall questions relating to the location of generating stations, sub-stations, the routes of main and distributing conductors, the routes of tramways and sizes of the cars, the planning of a factory, the types of machines to be installed, provision to be made for the storage, etc., of new material, arrangements to be made for the disposal of the finished articles, etc. In many of these cases, questions have to be considered relating to future extensions, and also those relating to the steps to be taken to restore the services in case of a temporary breakdown. The character of modern engineering undertakings is so various that the problems connected with the lay-out in different kinds of undertakings naturally vary considerably, and are innumerable. It would not be profitable for me to do more than mention the subject as one having a considerable influence on the economics of engineering. So much has been written on this head in relation to practically every branch of electrical engineering that no difficulty need be experienced in obtaining very exact data for dealing with each class of problem which may present itself to the practising engineer, not only from text-books, but often better still from the pages of the *Journal of the Institution of Electrical Engineers*.

The problems connected with this branch of the economics of engineering involve the study of the methods to be adopted in order that the investment of capital necessary for the attainment of definite results may be reduced to a minimum. The investigation of this aspect of the question is closely associated with that of design, and you are all familiar with the many devices resorted to by engineers to maintain the enterprises in their care at the smallest annual expenditure, such for instance, as apparatus for improving the power factor of alternating current systems, the employment of accumulators in connection with central station supply, boosters, etc. I can only add that, in order to be quite up to date in these matters, it is essential that the engineer should consult the most recent issues of the *Journal of the Institution of Electrical Engineers*.

(iv.). *Economy in Methods of Execution.*—Works may be either executed by the workmen employed directly by an undertaker, or by contract. So far as the undertaker is concerned, the results obtained may prove different, but from the point of view of the economics of engineering, the principles involved are identical.

The most sure method of ensuring economy in execution consists in the careful preparation of the programme dealing with the order and the method in which the details of a work are to be carried out, and in the adoption of an organization, in the case of the gangs of workmen, suitable for this purpose. A matter which often requires considerable attention in the execution of new works is that connected with the delivery of machinery and materials on the site of the work at the due date. Failure in this respect throws the gangs out of work and often involves a considerable waste of money, and has been at times the only reason which has caused a contract to prove unprofitable. Such failures can generally be obviated by careful supervision, and the preparation and submission of requisitions for materials in good time. It need hardly be pointed out here that it is the efficiency of supervision which more than anything else promotes economy during the execution of a work. Another question which also has considerable influence on the economics of engineering is that connected with the distribution of work in such a manner that the skilled hands shall be kept employed at their trades all the year round. Dismissal of such men may, at times, result in their drifting into other occupations, and, therefore, getting out of the reach of an employer when most wanted. It may not always be possible to prevent the dismissal of skilled hands, but forethought and skilful management can often reduce the necessity for the adoption of such a course to a minimum.

(v.). *Economics of Operating of Plant.*—The character of the plants to be operated, and the nature of the enterprises in which the same kinds of plant are to be found differ so widely that here again it is only possible in the limited time which is available to attempt a very general survey of this aspect of the question. The problems which fall into this group are those which relate to the steps to be taken in order to avoid waste of fuel and stores, to utilize to the best advantage the services of individual members of the staff and individual machines, to reduce to a minimum the idle time of the men and of machines, etc.

Considerable progress has already been made in coping with the questions which fall under this head, particularly by the introduction of automatic appliances which, fortunately, have reduced the waste of fuel and other materials, as well as having contributed largely to a reduction in labour charges. However, in many engineering enterprises the control of labour expenses is still a matter of considerable difficulty, and this is particularly so in those undertakings in which the plant consists of a network spread out over a comparatively large extent of territory, as for example, in the case of electric power supply and of telegraph and telephone undertakings. In such cases the outdoor staff is continually on the move, making supervision and control difficult, if not impossible. The most effective means of ensuring economy in such cases consists in the systematisation of the various kinds of operations, and the assignment of factorial values (in hours) to the different items of work. The check then becomes a statistical one. It is sometimes possible to utilize these factorial values for delimiting the area within which each individual workman should be employed, and in such cases they act to some extent as an anticipatory check before expense is actually incurred. In cases where direct supervision is practically impossible, I have found this method invaluable.

Another method which is largely employed to control the work of even individual workmen is that involving the issue of a "Works Order" for every separate job. The "Works Orders" naturally provide the means of calculating the unit cost of the various classes of work, and thus information can always be obtained for comparing the relative values of the men employed on similar classes of work.

There are some situations where the volume of work varies in an extremely regular manner from hour to hour throughout the day: this is the case in the manipulation branches of the telegraph and telephone services. In such cases, it is usual to plot the load, hour by hour, as a curve, and to plot a second curve showing the numbers of operators required to deal with the loads shown in the first curve during each of the hours of the day. The duty rosters can then be easily compiled from the information derived from the second curve. There may be other situations also in which this method of control may prove valuable. This is also a check of the anticipatory type, which after all is the best in those cases in which you have the necessary data to apply it. The value of a proper system of statistics as an aid in controlling the operations of a large undertaking cannot be exaggerated. It is really astonishing how readily statistics prepared on a sound basis indicate sources of waste, and, in consequence, serve the purpose of those who are interested in the economics of an undertaking.

(vi.). *Accounting.*—The antiquity of accounting, in some measure, indicates its importance. The earliest system in Great Britain dates back to the beginning of the twelfth century. The oldest statement of account in this country now in existence is the English Pipe Roll for the year 1130—1131; and the oldest private account in existence is the Household Roll of Eleanor, Countess of Leicester, for 1265. Questions relating to accounting affect both the economics of policy and the economics of practice. The cost at which a commodity can be supplied, whether in the form of electrical energy or of a machine, must vary according to:—

(*a*). The value of all the plant employed in producing the commodity in question, which is composed of three elements, namely:—

(i.). Interest on capital.

(ii.). Annual depreciation charges.

(iii.). Annual expenditure for minor repairs.

(*b*). The period during which the plant is in use in producing the commodity, in which is included the time during which the plant is idle.

(*c*). The cost of labour required to operate the plant, which includes the value of the time lost, and also supervision and management charges.

It is essential for the successful operation of an undertaking that capital charges shall be kept down; it is therefore permissible to charge the cost of new works to the revenue account, but the charging of maintenance costs against the capital account will always invite the criticism of an auditor. And you will readily recognize that this should be so. There are various methods in which the charge for depreciation may be brought to account; a comparative examination of these methods form a subject for special enquiry, which is outside the scope of this paper. The questions relating to the capital account and depreciation are matters which to a great extent belong to the province of policy; whilst questions affecting running costs, that is to say expenditure on minor repairs, cost of labour, of supervision, and of management are matters which belong more properly to the province of practice.

Matters relating to the capital account and depreciation need not, it is thought, be further pursued here; but those relating to running costs are of such immediate importance to the engineer that a few words will not perhaps be out of place here.

Much study has been given in recent years to scientific cost finding, and, as enterprises become more complex, the methods of accounting for ascertaining running costs become increasingly important. However much care may be devoted to the elimination of waste in the several operations which have already been referred to, yet no advantage will be derived therefrom, unless at the same time the system of accounting adopted can show at what cost definite savings in actual expenditure have been obtained. No single model of accounting is likely to combine all those features which will render it universally suitable, without modification, to meet the requirements of every kind of enterprise. In any particular case the best results are likely to be obtained by the joint study of the special features of the undertaking in question by expert accountants and engineers. The preparation of an accounting system which is based on such a study will be of most value to the latter in effecting his control, whilst at the same time providing a means for ascertaining the components in the cost of the various important items required by the management for fixing sale prices of the commodities produced by the undertaking. How very important the subject of scientific cost finding really is, may be gathered from the announcements in *The Times* of the 19th and 20th February last, which state that recently the printing trade has been affected by the changing conditions of the times. The reduced working hours in London, charges under the Insurance Act, the increase in the cost of materials have been factors which have raised the cost of production. In consequence, the Master Printers appointed a committee to investigate the question and to put forward proposals. This committee has completed its task and by taking the best features of the systems investigated by it, it has produced a system adapted to printing businesses from 2 to 30 departments, and consisting of from 10 to 1,000 employés. In these days of keen competition exact knowledge as to the cost of production of the commodities which an undertaking desires to place on the market is absolutely essential; it is for this reason that a scientific system of cost accounts is necessary in every engineering undertaking in which regard is paid to the economics of the enterprise.

III. Diversity of Interests of Employers and Employed.

The interests of employers and employed are identical so far as the production of wealth is considered, but when it comes to a question of distribution there is a real divergence. It is this divergence which has led in modern times to the serious and almost continuous conflicts between capital and labour. It is difficult to estimate the enormous loss of wealth which has been involved in this struggle. Naturally economists have endeavoured to devise measures to remove, as far as may be possible, the causes tending to produce these disastrous conflicts. Profit sharing and co-operative production have been tried as remedies: the former appears to secure the greater advantages with lesser disadvantages. Profit sharing elicits the interests of the workman in the enterprise, while at the same time permitting the control and management to remain vested in the hands of the employers, whose skill and experience are essential to the success of important industrial undertakings, and it is in this latter respect that profit sharing differs from co-operative production.

Another remedy which has been tried is that of Conciliation Boards. Such institutions have existed in our Colonies and in some European States for some years past, and as you are probably aware such Conciliation Boards were brought into existence in this country very recently in connection with the Great Railway Strike about two years ago. Perhaps the best known example of Conciliation Boards are the *Conseils de prud hommes* in France and Belgium, whose functions are not concerned with the determination of the general rate of wages for the future, but with the interpretation of particular contracts. These *Conseils* are also occupied with the redress of minor grievances and the adjustment of individual quarrels.

Since every measure which tends to bring about harmony between the conflicting interests of capital and labour, directly and indirectly, is a means of reducing waste of wealth, the study of the weak and strong points of the various remedies suggested, and adopted, is of value in connection with the consideration of problems connected with the economics of engineering. The subject is a wide one and perhaps strictly speaking forms part of the subject of social economics. It is thought that this passing reference is sufficient to bring the matter to your attention.

IV. Effects of Legislation on Engineering Enterprise.

Legislation has in recent years materially affected the problems connected with the economics of engineering, as indeed the economics relating to all industries. The enactments of the legislature which have found their way on to the Statute Rolls have not only altered the conditions existing in our factories, but also the relations existing between employers and employed. The tendency of such legislation has been to put an increasing burden and responsibility on the shoulders of those associated with the control and management of engineering enterprises. The field covered by this legislation is so wide that I must content myself with merely drawing your attention to the fact that in dealing with problems of economics of engineering it is necessary to bear in mind that existing statutes, and, in some cases, even those which may be under the consideration of the legislature, introduce factors into the situation which cannot with prudence be overlooked by you.

Conclusion.

I fear that I have only been able to put before you a bare outline of the nature of the problems connected with the economics of engineering, however, I hope I have put sufficient material before you to enable you to realize to what extent the policy aspect is associated with that of practice in that branch of engineering with which you propose to concern yourselves. I can only hope that the day is not far distant when the engineer will occupy a recognized status and controlling influence in the engineering industries of this country. The progress made in this direction will largely depend on your own efforts; the future of a great profession lies in your hands. It is by a study of all the matters I have outlined that you will put yourself in the most advantageous position to discharge your duties so as to bring added prestige to your profession. You cannot have failed to realize fully that, under the conditions of to-day, in the higher lines of engineering work the difference between mediocre qualifications and high grade knowledge will often mean the saving of thousands of pounds to a community whose interests are entrusted to an engineer.

That you all desire to be ranked in due course with the high grade men of your time goes without saying, and there is no doubt in my mind whatever, that there is no surer way to your attaining the height of your ambition than that of assuming the *rôle* of an economist, whose mission, as has been shown, it is to discern and to assist others to recognize the unseen waste which is continuously going on. I can only trust that the remarks which I have made to-day, may have indicated with sufficient precision the means by which you may obtain personal success, and, by which, at the same time, you may be able do your share in raising the calling of an engineer to the foremost rank among the learned professions.

NOTICES OF MAGAZINES.

Militär Wochenblatt.

German Airships at the Commencement of 1913.

The following is a *résumé* of an article by Capt. Romberg, with the above title:—

The past year has proved in a high degree the reliability of the German airships. It now remains to make a practical use of the experiences that have been gained and to maintain Germany's superiority in airships. Although they have lately shown their independence of wind, which was quite unhoped for, their use is still restricted by weather influences. The power of these influences can in some measure be diminished by the construction of suitable hangars; for most of the airship accidents have occurred in getting the craft in and out of their sheds. "Double hangars" have been built so that the airship can be got out obliquely, and screens to which they can be made fast running on rails have been tried to provide shelter from the wind. But there are not enough and the writer advocates "triple hangars" and looks forward to "revolving hangars" coming into universal use. One of these has been built by Siemens Schuckert, and is now in possession of the army. The revolving hangar is kept with its axis in the direction of the wind, the entrance to leeward. This orientation of the hangar assists landing, as it indicates to the pilot the direction of the wind at ground level. Efforts must be made to reduce the cost of production of hydrogen and to get a motor spirit that can be made from native German products. Capt. Romberg considers that air craft could usefully be employed on postal service and for survey work.

The day of small airships is over, their place is taken by aeroplanes. The size must depend on the speed, radius of action and carrying capacity required, and they cannot be too great. A ship must have at least two motors; some of the big ships have three and four. Most of the Zeppelin and Parseval ships use the Maybach motor.

As regards radius of action, field hangars are out of the question, and airships must start from and return to their own permanent ones.

In construction, the liability to damage on landing must be borne in mind. The non-rigid types have advantages in this respect, but by use of wood in the body of the airship the necessary elasticity and strength can be obtained, as has been shown in the Schütte-Lanz airship. The Siemens-Schuckert airship has achieved a speed of 20 metres per second (about 45 miles an hour). This can no doubt be improved on. The Zeppelin airships, with the one exception of the "Schwaber," which travelled 17,076 miles before it was burnt on 28th July, 1912, have shown themselves wonderfully reliable. The "Victoria Luisa" travelled roughly 18,000 miles between February and November, 1912, and the "Hansa," 7,300 miles between July and November. Eighteen Parsevals are under construction; by use of three motors the speed has been increased to 45 miles an hour. Seven foreign nations have ordered Parsevals.

The writer concludes that German airship construction is in a strong position at the beginning of 1913.

"E."

Revue d'Artillerie.

September, 1912.

Study of the Efficiency of Fire.

Efficiency of Shrapnel.—The author first defines what he means by efficiency, and then proceeds to investigate mathematically the efficiency of the 75-m.m. gun. He traces the trajectory of the balls, and the best height for bursts, the trace of the cone on the ground, and the dispersion of the balls. He then gives the efficiency against men standing, kneeling, and lying, and the numbers of double hits on ranks behind each other. He obtains one thousandth of the range as the best height for bursts when ranging, and three thousandths for efficient fire; it should be somewhat less up to 3,000 metres range, and rather more at longer ranges. The following principles are deduced (of which the 2nd and 3rd appear contrary to generally accepted ideas):—

(1). Fire against close formations acquires its maximum efficiency at about 2,500 metres range.

(2). The mean percentage falls rapidly as the number of ranks increases.

(3). Efficiency against close formations is very notably inferior to that obtained against troops in open order.

The article is to be continued.

Light Machine Guns and Repeating Rifles.

Tactical necessities exact extreme mobility in machine guns, hence the conception of a new arm, the repeating rifle. The automatic rifle is the simplest expression of this arm. Dirigibles and aeroplanes demand an arm of this kind. The rapidity of fire approaches 250 shots a minute. The weapon is supported on a fork to steady the aim and fired from the shoulder. Denmark and Russia have already adopted the automatic rifle, and its advantages and inconveniences are discussed, and a photograph is given of a Danish Hussar armed with one.

The Light Vickers Machine Gun.

A new weapon based on the Maxim, but weighing only 12¾ k.g. against 27 k.g. for the latter. A general description is given, and the action, methods of feeding, firing and ejection of the fired cases are explained. The water jacket holds 7½ pints. The newest carriage is the adjustable tripod, of which there are two types, Mark E being provided with an axle and wheels for man haulage, and Mark F being merely a tripod stand intended to be carried by man or horse. Five good photographs are published, also three plates with 25 figures.

ARTILLERY ENGINEERS.

A further contribution towards the discussion of this subject.

October, 1912.

PIEDMONTESE ARTILLERY INVENTIONS OF THE 18TH CENTURY.

The adoption by Italy of a new field gun recalls the fact that in the 18th century the Piedmontese already had breech-loading guns, cartridge and projectile in one, and guns resting in cradles. This article is borrowed from the *Rivista di Artiglieria e Genio*, and describes the guns invented by Chieppo, Genner, Bertola and Salmour. Of historical interest only.

LIGHT MACHINE GUNS, AND REPEATING RIFLES.

The Danish Schouboe repeating rifle is described, with two plates and several figures. 500 rounds can be fired per minute, but normally only 200 are fired. The most serious defect of this weapon is the insufficiency of the cooling arrangements. Only 1,000 consecutive shots can be fired, it is better to fire only 500 and then change the barrel, which only takes 30 seconds. To each squadron of Danish cavalry is attached a section of three repeating rifles, carried by three troopers, with a fourth trooper leading a pack horse for the ammunition. The equipment, with weights, is given, and further photographs are reproduced. The Russians used a number of these weapons in Manchuria with satisfactory results. An extract is copied from the Russian Regulations, relative to the ballistic properties of the weapon.

VARIOUS INFORMATION.

Particulars are given of the field and mountain artillery and howitzers now being made use of by the five Powers at war in the Balkans.

November, 1912.

CONTRIBUTION TOWARDS THE HISTORY OF THE ARTILLERY.

The Responsibilities of the French Artillery in 1870.—The French artillery in 1870 showed itself far inferior, both in weapons and tactics, to that of the Germans. This inferiority is attributed on one hand to the necessity in the latter years of the reign of Napoleon III. for strict economy, and on the other hand to the discredit into which the Prussian artillery had fallen after the war of 1866. These two factors are discussed at some length with a view to extracting from them salutary lessons for the future. The history of the introduction of breech-loading, and of steel in place of bronze is also given.

THE METHODS OF TESTING METALS AT THE CONGRESS OF NEW YORK IN 1912.

An International Association exists for the purpose of testing materials, and meets about every third year. It is divided into sections dealing with (1) metals, (2) natural and artificial stones and cements, (3) other materials. The previous meeting had been at Copenhagen in 1909. Resolutions passed at the latter gave a direction to the proceedings of the New York meeting. The account is divided as follows:—

Chapter I. Objects for research established by the Congress of Copenhagen in 1909.

Chapter II. Summary of the principal results presented at the Congress of New York in 1912.

Chapter III. General resolutions passed on the subject of various questions submitted to the Congress.

Chapter IV. Conclusions affecting the tests to be applied in artillery laboratories.

The account is somewhat technical, and deals only with the metal section, but would be of considerable interest to anyone dealing with the properties of metals.

VARIOUS INFORMATION.

A short account is given of the German field howitzer, called the field howitzer 98/09. The sight has seven graduations for distance corresponding to seven different charges. The battery consists of six howitzers, and 154 rounds per gun are carried. The Swiss artillery is to be increased by 12 batteries of howitzers of four guns each, 12-c.m. Krupps, also by three mountain batteries of 7·5-c.m. Krupps. The former carry 600 rounds—shrapnel and shell—and the latter 900 rounds per gun. The fortress artillery in the fortifications of the St. Gothard and St. Maurice are to be supplied with mobile fortress guns, consisting of 12-c.m. howitzers and 7·5-c.m. field guns. The first issue will be 26 howitzers and 30 guns.

December, 1912.

STUDIES OF FIRE EFFICIENCY.

The last of a series of articles by General V. Tariel. The results of experiments are compared with the results calculated from his formulæ, and are found to agree very closely for infantry standing in dispersed order. Owing to the difficulty of arranging figures to represent them sufficiently accurate, experiments against troops lying down and in close formations, and also against artillery, could not be properly carried out.

Influence of Slope of Ground.—The influence of the slope on the efficiency of fire varies according as the slope falls to the front or rear.

Slope Falling to the Front.—For the same height of burst, up to 3/1000 of the range the total mean efficiency of single shots is practically the same as on the flat. For heights of burst greater than that the efficiency increases as the slope increases. With searching fire it is different, for the successive salvoes tend to burst on impact, this tendency increasing with the slope. The general rule for efficiency on slopes greater than 1/20 is to increase the corrector by 2/1000 after each salvo up to 3,000 metres range, and by 1/1000 only for greater ranges.

Slope Falling to the Rear.—Searching fire is efficacious on slopes less than 1 in 20. The third salvo produces little effect on a slope of 1 in 10, and is useless on a slope of 1 in 7. On a slope of 1 in 5 searching fire is useless. Happily this is not actually true, it is the regulations that are wrong. Instead of arranging for searching fire by increasing the angle of sight it should be done by diminishing the corrector by 2/1000 after each salvo.

Two questions still present themselves. How can the steepness of the slope be judged, and what range should be taken. The first question can be answered by enclosing the crest in a 100-m. bracket and then increasing the longer range by 100 m. If percussion shrapnel raises dust the slope is not over 1 in 20. If the smoke only is visible, and after some delay, the slope is greater than 1/20, but generally less than 1/10. If the shot cannot be seen at all the slope is steep. The answer to the second question is stated to be for all ranges and all slopes, 100 metres beyond the crest.

For efficient searching fire the following should be the method employed :—

Obtain a 100-metre bracket enclosing the crest.

First salvo the short range of the bracket, corrector $\frac{3}{1000}$.

Second salvo the long range of the bracket, corrector $\frac{5}{1000}$.

Third salvo the long range of the bracket increased by 50 metres, corrector set at $\frac{5}{1000}$.

Fourth salvo, the same range, corrector diminished by 2.

Fifth salvo, the same range, corrector diminished by 2.

If after the fourth salvo it is seen that the shots tend to burst on impact give 50 metres more elevation.

It should be noted that slopes cannot be efficiently searched when their slope exceeds the angle of descent of the projectile.

The French field gun is then compared with the German 77-m.m. gun as far as data are available for calculating the efficiency of the latter. The results are tabulated, and the following conclusions drawn. The German shrapnel has 10 balls more than the French, but each of the 300 German balls of 10 grains each is less effective than the 12-grain balls of the French shell. Firing on a zone and front of 100 metres the two projectiles are practically equal. On a contracted zone and front the superiority of the German shell increases as the front diminishes, especially against men lying down and close formations. This superiority is the result of the greater inclination of the shell at the moment of burst, and of the smaller cone of dispersion. But the surface of ground efficiently beaten by a single round is notably smaller, one-third or less, than that beaten by the French shell. The less flat trajectory, besides, facilitates fire from concealed positions and fire behind crests on sloping ground is more efficient. It follows therefore that in action behind the same crest as the French gun, and firing at the same mark, it can take better cover. For the same mark, and with the same cover, it can search slopes one-third greater. For the same ground, and with the same cover the dead ground is sensibly less. For example, when the French gun can only fire at beyond 2,000 metres, the German gun can begin at 1,600 metres. Therefore coming into action is easier with the German gun. From this comparison it appears that there is not so much advantage as is generally supposed in a very high initial velocity, and that for a field gun a velocity of 475 metres is ample. This would enable weights to be decreased, simpler arrangements for checking the recoil, with possibly less slaughter.

Fifteen tables referred to in the foregoing articles are published at the end.

A Contribution towards the History of the Artillery—The Responsibilities of the French Artillery in 1870—Breechloading and Steel Guns.

An account of the difficulties experienced in finding a good breech mechanism before and after the war of 1870–71, and of the opposition to the substitution of steel for bronze. The article is historically interesting and is to be continued.

Field Artillery at the German Manœuvres of 1911.

A summary of the most interesting portions of the second of three articles published in the *Artilleristische Monatschefte* for November and December, 1911, and January, 1912.

I. Artillery Positions.

(*a*). *Covered Positions.*—A very convenient method has been evolved for bringing batteries into action. The group commander points out to the battery commanders a reference point (*Hauptrichtungspunkt*) by which the batteries generally place themselves in parallelism. (The word *Hilfsziel*, aiming point, seems reserved for the case where the battery commander, though employing direct laying, prefers to point out to the layers a more visible point). The battery commander rides to the front of the centre of the site for the battery, places the *cercle de pointage No. 1*, and points out the reference point to the N.C.O. in charge. The N.C.O. i/c *cercle No. 2* proceeds behind the centre of the site and fixes his instrument, and the flanks of the battery are marked by coloured pennons. The pennons are pointed out by the trumpeter to the officer leading the battery, whose work is thus simplified. The time taken from unlimbering to firing the first shot never exceeded four minutes. Two possible objections to this method are stated and discussed, and decided to be baseless.

All battery officers should be trained to bring the battery into action calmly, keeping under cover and avoiding dust. The writer recommends coming into action in column of sub-sections to avoid collisions between the advancing wagon, and the retiring gun limber. He states that he never saw a sign of one of the enemy's batteries coming into action, and would never have found out their positions at all except by hearing them fire, if it were not for the wretched red flags they hoist to designate that they are firing. Everyone agrees that these flags should be done away with. The projectors tried in 1908 to send a beam of light towards the unit on which they were firing had also the same defect. He recommends a battery firing one shot to show that its target is artillery, two shots for infantry or columns on the march, etc. On one occasion a ladder observatory was seen very indistinctly in some trees. The year before several battery sites had been given away by the staffs, this year there was nothing of that sort.

(*b*). *Open Positions.*—Twice only during the manœuvres were open positions taken up, and then only during a pursuit against columns of infantry in retreat, and they were covered from the enemy's artillery. Direct laying was not employed owing to the difficulty experienced in pointing out the objective to the layers. Even in open positions the observing wagon should be taken to the battery commander, and not placed in battery behind the centre of the front.

(*c*). *Positions in Observation and in Readiness.*—The new French regulations give the preference to positions in observation over positions in readiness. They have doubtless recognized, as we do, that a position in readiness behind the position to be occupied generally only results in waste of time, since at the moment when its intervention is necessary the battery has still to come into action and get ready to fire.

II. Intercommunication.

It is necessary to distinguish between technical and tactical communications. The former shows batteries *how* they should fire, the latter *on what* they should fire according to the general plan. Artillery officers are never now seen sending back information from the infantry firing line, the prismatic telescope supplies the technical communication.

The experience of the manœuvres makes it clear that tactical communication should be from the chiefs of the various arms to their subordinates, and should also be from front to rear, and not *vice versâ*. It is noticed that the artillery are always directed to keep in communication with the infantry, but as the infantry are ahead they can often give useful information to the artillery, and should be trained to do so.

III. Tactics.

In this chapter the author expresses his personal ideas on artillery tactics. One is that the brigade commander should remain near the divisional general to advise him as to the employment both of the batteries in action, and of those in reserve. The beginning of an action by the artillery duel is out of date, grand batteries are no more, and the largest unit that would be employed together is the regiment. Another important modification in the regulations should be to abolish the rule that a numerical superiority in guns should be established from the first. This part of the article is not reproduced, a great deal of it being in direct contradiction to the German regulations.

Matériel.—The author inveighs against the minute instructions given in the confidential pamphlet *Das Feldartilleriegerät* as tending to introduce an unjustifiable mistrust in the *matériel.* Accidents are not common. It is not correct to say that the observatory wagon is too heavy for four horses. The fact is, that in changing position, the battery does not wait for the observatory to be dismantled, and the latter has to come on afterwards. The ladder observatory can be concealed in trees, and has never disclosed the position of a battery in these manœuvres, but in bare country, such as parts of Lorraine, it should be replaced by dismountable masts. The telephone worked well, but a man with a spade should follow up the wire to bury it where it rises above the ground. Horses damage it less than foot passengers. The *cercles de pointage* (*Richtkreise*) and the *lunette à oiseaux* (*Scherenfernrohr*) gave every satisfaction. Of the latter there should be a spare one with each battery, and its place should be on the ladder observatory, or on the wagon body and not on a tripod. The portable shield, behind which it is sometimes placed, protects the battery commander but badly, and gives no protection to his assistants, telephonists, etc. A panoramic telescope, allowing of the easy resolution of the problems for opening fire, should be supplied for the field gun. The present sight does not allow of firing on an aeroplane. The deflection scale allows of insufficient adjustment to follow an object moving at right angles to the line of fire at long ranges.

Equipment.—The author finds the artillery saddle (*Bocksattel*) deplorable, and recommends the issue of the general service saddle (*Armeesattel*). The grey (*feldgrau*) uniform is excellent and very invisible.

Armament.—The issue of a carbine to all N.C.O.'s and men is advocated.

The author concludes with congratulations on the progress made, but bemoans the constant dearth of officers.

A.R.R.

CORRESPONDENCE.

DEMOLITION OF HIGH WIRE ENTANGLEMENT.

DEAR SIR,

The failure of an experiment in cutting a wire entanglement by means of explosives, as related in the February number of the *R.E. Journal*, 1913, may have raised doubts in the minds of some as to whether the operation is feasible.

The experiment appears to have been based on some experiments carried out by a Russian Engineer officer, who adopted the method described in the French "Instruction sur les procédés de franchissement et de destruction des obstacles de la fortification," a transcript of which was given in the *R.E. Journal*, June, 1912. The charge recommended by the latter instructions is one of melinite—99 "pétards" to 5 metres, or 1·8 lbs. per foot-run, the equivalent of which in guncotton is, according to "Mining and Demolitions, 1910," about 2·4 lbs. per foot-run.

The charge used in the Russian experiments was about 2½ lbs. per foot-run, of pyroxiline or guncotton, or almost exactly that adopted in practice by the French.

It seems probable, therefore, that the failure of Capt. Bushell's experiment (using 1⅓ lbs. per foot-run) was due to too small a charge being used.

As far as the writer's experience goes, it is not possible to rely on a perfectly clear gap being made, but the few wires remaining uncut would be easily severed by the wire-cutting party.

Yours faithfully,

E. ROGERS,

Capt., R.E.

Gosport, 21st February, 1912.

The Editor, *R.E. Journal.*

ECONOMY IN CONSTRUCTION.

DEAR SIR,

Re the correspondence appearing in the January issue of the *Journal* under the above heading, I confess to having overlooked all considerations other than those brought to light by the recorded behaviour of bridges subject to live load and impact during the last 50 or 60 years. The case of the Britannia Bridge, cited in my article, which without any allowance for impact was stressed to 7 tons per square inch 50 years after erection, is surely sufficient evidence that its "molecules," in spite of the theoretical canons of molecular etiquette described by your correspondent, made light of the troublesome business of "rearranging themselves." Another example is afforded by the old Arpley Railway Bridge over the Mersey at Warrington, which had been in continuous use for over 55 years before reconstruction. Test pieces cut from members calculated to have been stressed to 7 or 8 tons in ordinary practice, and occasionally more, showed no discoverable deterioration, although the material was wrought iron and not steel. Moreover when the reconstructed bridge was completed, no tests under moving load were carried out, the Board of Trade being quite satisfied with static load tests.

I am speaking without the book, and perhaps your correspondent will correct me if I am wrong, but I believe the Board of Trade has issued no regulations on the subject of Impact. They confine themselves to laying down 6½ tons as the limiting stress, and this rule was enacted in 1877, or *36 years ago*, since when the ultimate strength of steel has no doubt much improved.

I have before me some plans of road-bridge girders, spans 40 ft. to 200 ft., designed by a Canadian firm to the specifications of the Dominion Government. Taking a few members at random I find that they are stressed to 8 tons per square inch, again without any allowance for impact or moving load. Bridges built to these designs may be seen anywhere in Western Canada, Winnipeg, Calgary, British Columbia, or Vancouver Island, so their strength cannot reasonably be questioned.

Sir Bradford Leslie, the eminent bridge designer, writes "In the early days, girders (which are still carrying 90 per cent. of the traffic) were designed without allowance for impact, and if they are unreliable they should all be condemned forthwith: that would indeed be a jubilee for bridge builders!"

If the book mentioned by your correspondent recommends a "mathematical factor" of 2 in. for live loads on permanent bridges, (temporary military bridges built under service conditions, were outside the scope of my article) the necessity for its revision, to bring it into line with modern engineering practice all the world over, at once suggests itself.

Yours truly,

E. ST. G. KIRKE,

Lieut., R.E.

The Editor, *R.E. Journal.*

BOOKS RECEIVED.

Wireless Telegraphy and Telephony. By Wm. J. White, A.M.I.E.E. 100 illustrations. Second edition. Revised and enlarged. 2s. 6d. net. Whittaker & Co., 2, White Hart Street, Paternoster Square, E.C. 1912.

Magneto and Electric Ignition. By W. Hibbert, A.M.I.E.E. 2s. net. 90 illustrations. Whittaker & Co., 2, White Hart Street, Paternoster Square, E.C. 1912.

Estimating for Reinforced Concrete Work. By T. E. Coleman. 4s. net. B. T. Batsford, 94, High Holborn, W.C. 1912.

Spons' Practical Builders' Pocket Book. A Reference Book of Memoranda and Tables for Architects and Builders. Edited by Clyde Young, F.R.I.B.A., and Stanford M. Brooks, Licentiate R.I.B.A. 74 illustrations. 5s. net. E. & F. Spon, Ltd., 57, Haymarket, S.W. 1913.

Spons' Architects' and Builders' Pocket Price Book and Diary, 1913. Edited by Clyde Young, F.R.I.B.A., and Stanford M. Brooks, Licentiate R.I.B.A. Fortieth edition. Price, 2s. 6d. net, postage 2d. extra. E. & F. Spon, Ltd., 57, Haymarket, S.W.

How to Estimate. Being the Analysis of Builders' Prices. By J. T. Rea. Fourth edition. Over 400 illustrations. B. T. Batsford, 94, High Holborn, W.C. 1913.

With the Victorious Bulgarians. By Lieutenant H. Wagner, War Correspondent of the *Reichspost*. 55 illustrations and map. 7s. 6d. Constable & Co., 10, Orange Street, Leicester Square, W.C.

Peine perdue et temps gâché. Notes à propos de l'instruction des cadres. Capitaine G. Cognet. Paris. 1912. Chapelot. Prix, 2 fr. 50.

L'Apprentissage de la guerre. Colonel Gory. Paris. 1912. Chapelot. 134 pages. Prix, 2 fr. 50.

Encore quelques Idées sur l'artillerie. Colonel Potel. Paris. 1912. Chapelot. 91 pages. Prix, 1 fr. 50.

Note posthume sur les grandes manœuvres du 6^e^ corps en 1888, suivie de Considérations sur la Tactique actuelle, par le Général Bonnal. Général Maillard. Paris. 1912. Chapelot. 59 pages avec 2 cartes hors texte. Prix, 1 fr. 50.

Quelques Idées sur la guerre de place. Colonel J. Rouquérol. Paris. 1912. Chapelot. 36 pages. Prix, 0 fr. 60.

La police militaire. Capitaine Favre. Paris. 1912. Chapelot. 16 pages. Prix, 0 fr. 30.

Instruction méthodique des cadres et des élèves caporaux. Lieutenant Biétron. Paris. 1912. Chapelot. 71 pages. Prix, 1 fr. 50

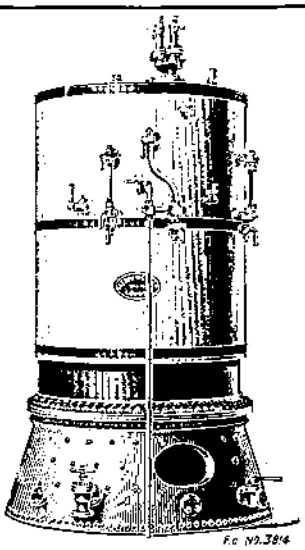
Etude sur la constitution d'une réserve de Tirailleurs algériens. Capitaine Caré. Paris. 1912. Chapelot. 16 pages. Prix, 0 fr. 30.

Remarques sur les facteurs de l'avancement des Chefs militaires. Capitaine F. de l'Harpe. Paris. 1912. Chapelot. 22 pages. Prix, 0 fr. 50.

Notions sommaires sur les Chemins de fer, *à l'usage des officiers et sous-officiers* du service de garde des voies de communication. Par A. Laplaiche, contrôleur général de l'exploitation commerciale des chemins de fer. 1913. Berger-Levrault, 5—7, rue des Beaux-Arts, Paris. Prix, 2 francs.

France et Allemagne. La Guerre éventuelle. Lieut.-Col. Grouard. Paris. 1913. Chapelot. Prix, 3 fr. 50.

La Guerre Turco-Balkanique, 1912. Thrace—Macédoine—Albanie—Epire. (Avec 11 cartes en couleurs hors texte et 10 croquis dans le texte). By Lieut.-Col. breveté Boucabeille. Paris. 1913. Chapelot.



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