W.M.

THE ROYAL ENGINEERS JOURNAL.

Vol. XIV. No. 4. OCTOBER, 1911.

CONTENTS.

CONTENTS.

Authors alone are responsible for the statements made and the opinions expressed in their papers.

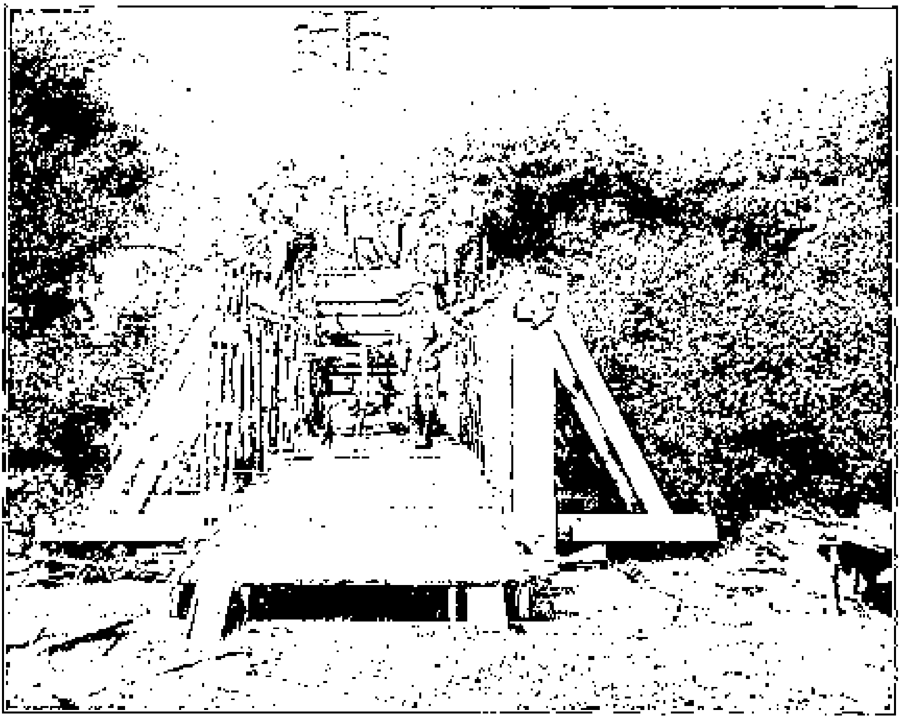


Photo 3. 49' "Warren and Plate" Bridge, Herne, Hampshire, 1904

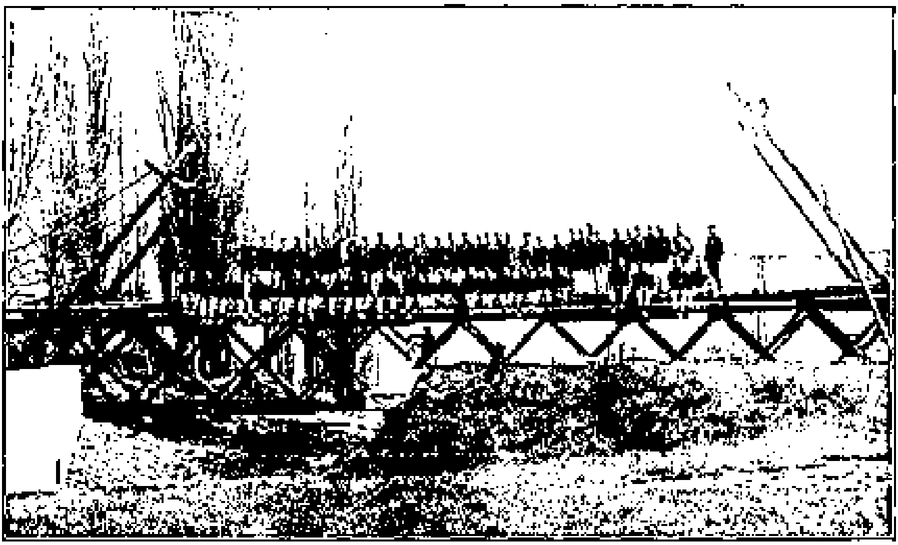


Photo 4.—88' Bridge, Kingston, Ontario, 1908.

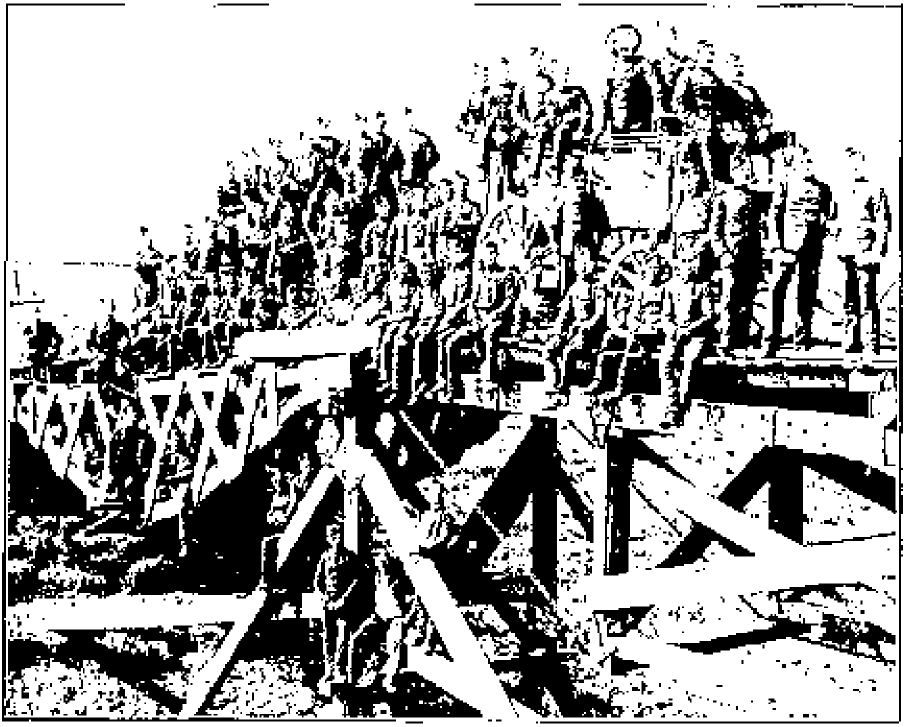


Photo 1.—90' Bridge of 2-girder spans (36' and 42') with central trestle, Chatham, 1902.

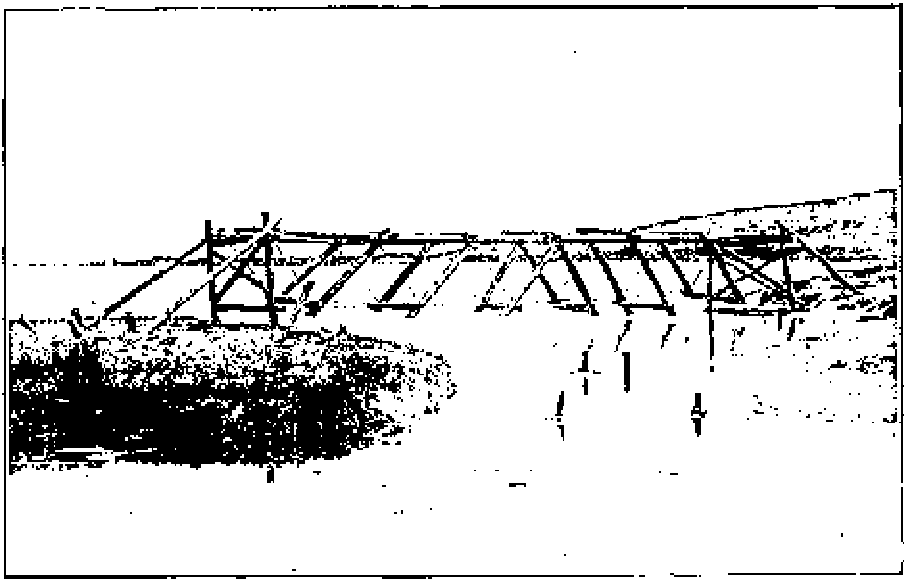


Photo 2.—57' Bridge (telegraph materials), Christchurch, Hampshire, 1904.

GIRDER BRIDGES FOR MILITARY ENGINEERS.

(Continued).

By CAPT. E. N. MOZLEY, R.E.

PART II.

DETAILED DESCRIPTIONS OF BRIDGES.

1. 51′ BRIDGE FOR CAVALRY IN SINGLE FILE.

Built at Christchurch Camp in 1899 by Cavalry Pioneers and R.E. N.C.O.'s. Width of roadway 6′, carried on the top of two girders 6′ centre to centre.

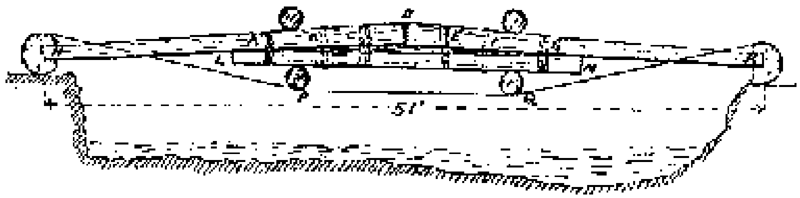


FIG. 5.

Type of Girder.—Each girder was a "fished beam" as in *Fig.* 5.

(*a*). *Description and Method of Construction of Girder.*—Two poles, HD and DK, 5″ at tip, 11″ at butt, were laid butt to butt on cross-pieces, which provided clearance above the ground and eventually acted as rollers in launching. A third pole LM of equal dimensions to the other two was laid alongside them as shown.

LM was lashed to HD and DK with 2″ lashings at A and G and with wire at C and E. (Cordage is preferable to wire as it is easier and quicker to use; it should be well wedged up).

2″ auger holes were then bored through both spars at B and F and a hardwood trenail, 18″ long slightly larger than the hole, was driven through each. The idea of the trenails was to oppose the horizontal shearing stress between the spars and so to convert them into a single beam of depth equal to the combined depth of the spars composing the girder.

The space at D between the butts caused by the taper of the spars, was closed by a hardwood wedge to resist the thrust.

(*b*). *Method of Launching.* Each girder was launched separately, being rolled out half-way and then pulled across by a fall from a 15′ sheer legs erected on the far side. It was found that a single girder would not remain vertical but leaned over sideways. There would be no tendency to do this if the girders were lifted up into vertical planes as soon as they were built and cross braced to prevent them distorting again. They could then be hauled across together.

(*c*). *Trussing the Girders.*—To strengthen the bridge the girders were subsequently trussed as follows:—Cross-pieces were lashed across at P and Q and other cross-pieces were placed at the ends of the girders at H and K, so that the ends of both girders butted against square seatings on the cross-pieces and were secured by spikes driven through the outside of the cross-pieces. Wire ties of the requisite strength were then passed from H to K under P and Q and made fast. This trussing should take place before launching, in which case men should bear down on the ends of the girder so that on their release the ties may be quite taut.

If however the trussing takes place before launching, it will make the use of rollers difficult unless some expedient such as the following is used:—After constructing, connecting and trussing the girders and before launching, lift them on to two light spars running from P to Q and make fast P and Q to them. These auxiliary spars can then move on the rollers.

(*d*). *Working Party and Time.*—Two R.E. N.C.O.'s and 14 Cavalry Pioneers built and launched the bridge in 13 hours. It would only have taken 10 hours if cordage had been used instead of the wire lashings.

(*e*). *Remarks.*—The deflection at the ends, between H and L and between M and K was considerable. It would probably be best to allow the lower spar LM to continue the whole length, from H to K, breaking joint with the upper spars. The trenails would then be placed near the abutments, where the shearing stress is greatest. Double the number of trenails might be used.

Of course this method of construction does not make a perfect truss, but the type is possible for small gaps where nails are not to be had.

2. 80′ Bridge for Infantry in Fours, with One Central Trestle.

Width of roadway 9′.

This bridge will be treated as two separate single spans, one of 36 and the other of 42′.

(i.). *36′ Span.*

(*a*). *Description.*—*Type of Girder.*—Bowstring (bow downwards) (*Fig.* 6).

The girders were placed with the bow downwards for the following reasons:—

(*a*). The straight flange, which is less liable to buckle than the curved one, is thus in compression.

(β). The girders, when placed, are in a state of stable equilibrium. If the bow were upwards they would need external bracing to keep them upright.

Each top flange consisted of 7 ($\frac{3}{4}''$) boards.

Each bottom flange consisted of 8 ($\frac{3}{4}''$) boards.

For 3′ at each end the flanges were bolted together through a wedge placed between them. Five $\frac{1}{2}''$ bolts were used. The ends were then boxed in by means of vertical boards on each side.

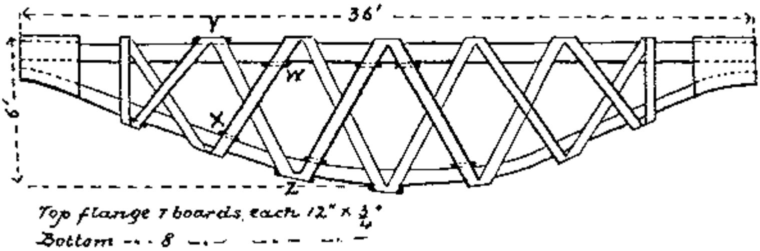


FIG. 6.

The web consisted of a double series of bracing, as shown in the figure. There were 14 braces on each side of each girder. These were not nailed to the boards of the flanges, which were too thin to take the nails, but to pieces, 2″ × 12″, as at W, X, Y, Z, which were themselves nailed to the flanges. These pieces should be placed inside the flanges for compression braces, as at W and X, and outside the flanges for tension braces, as at Y and Z.

The bracing was of the lattice type, the planks being in pairs on both sides of each girder.

It is necessary to see that compression braces are not forced into a curve between the flanges or they will have a tendency to buckle.

(*b*). *Method of Constructing the Girders.*—The longitudinal section of the girder was laid out on the ground with pickets, which enclosed the flanges. The planks of the flanges were then laid down in lengths, breaking joint, and nailed together with 5″ wire nails. The flanges were then bolted together at the ends with $\frac{1}{2}''$ bolts and boxed in and then the bracing was nailed upon one side. Then the girder was turned over and the bracing put on the other side.

(*c*). *Method of Launching.*—The girders were hoisted into position by two pairs of sheers, one on each bank, which lifted them up into the air, and, by paying out and taking in the tackle, carried them across and lowered them into position. One pair of sheers had to be a long way off owing to the second span in the bridge ; this made the operation more difficult. A 7″ bearing was given on the cap of the central trestle.

(*d*). *Cross Bracing between the Girders.*—It was found that the girders were liable to rock in their seatings owing to wind or traffic. They were therefore braced together with a spar connecting the centres of their lower flanges, and two transverse diagonals from the centre of the lower flange of one girder to the centre of the upper flange of the other. This gave complete rigidity.

(*e*). *Time and Men.*—Making girders 6 men 29 hours.

Launching and completing roadway 40 men 6 hours.

(N.B.—The double span caused abnormal difficulties in launching).

(*f*). *Remarks.*—The dimensions of the web planks should decrease from the abutments to the centre; at the former points the compression planks should be 3″ thick to prevent buckling.

(ii.). 42′ *Span.*

(*a*). *Description.—Type of Girder.*—Inverted Queen-post roof.

The two girders were built together on land into one frame and so launched.

Fig. 7 is a longitudinal elevation.

Fig. 8 is the plan of one upper flange.

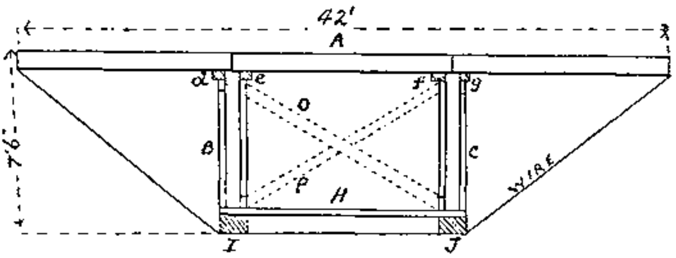


FIG. 7.

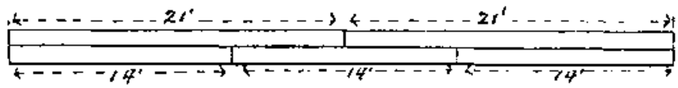


FIG. 8.

Each upper flange A was built up of scantlings 12″ × 6″ as in *Fig.* 8. The spikes were placed all along the beam but most thickly at the joints.

The struts B and C were dogged to A and also secured by transverse pieces *d*, *e*, *f*, *g*, spiked across from the under surface of one upper flange to that of the other.

Distance pieces H were dogged to the feet of the struts B and C.

Distance pieces I and J connected the feet of the struts B and C on one girder to the corresponding points on the other girder.

The usual diagonal bracing, shown in the photograph, completed the structure.

Sizes of Timbers.—Upper flanges, 21′ and 14′ pieces, 12″ × 6″ in cross section.

Struts B and C 6″ × 6″.

d, *e*, *f*, *g*, 6″ × 2″.

Distance pieces H, I, J, 6" × 3".

Cross bracing, 9" × 2".

Size of chain, 1½".

(*b*). *Method of Construction.*—The composite beams forming the upper flanges were put together and then the girders were built upside down. The chain was spiked through the links where it passed under the feet of the struts and was secured to the ends of the beams by a screwed hook of 2" iron, passing through a hole in the beam and bolted up against an iron plate fitted over the shaped ends of the beams, as in *Fig.* 9.

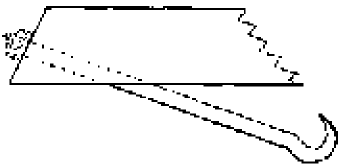


FIG. 9.

Iron plates should not be put under the feet of the struts, as the links of the chain should be allowed to bite into the wood there to avoid the possibility of the links getting bent.

(*c*). *Method of Launching.*—The girder was picked up by the two sheers on either side of the 80' gap, turned over in the air and dropped into place. This method was a very difficult one and the process of turning the girder over in the air should always be avoided. This girder could probably have been built the right way up.

(*d*). *Time and Men.*—Making girder 16 men 15 hours.

Launching and completing roadway 40 men 4 hours.

(N.B.—The double span caused abnormal difficulties in launching).

This type is not sound, as it cannot, if the bow be downwards, be rolled and slid across, but has to be lifted into place by means of sheers on both sides of the gap, which is difficult for any but small spans. If the bow be upwards, the usual method of launching is possible, but then the roadway has to be carried on the lower flanges, which means a distinctly bigger structure. Nor in such cases is the launching so easy, since the lower flanges have to be raised to reach the abutments on the far side of the gap.

3. 49' BRIDGE FOR CAVALRY IN SINGLE FILE.

Built at Herne Camp near Christchurch in 1904 by R.E. Launched by R.E. and Cavalry Pioneers.

Width of roadway 6'. Carried on the lower flanges of two girders 9' 6" apart, centre to centre.

Types of girder used :—

(i.). Warren. Depth 6'.

(ii.). Plate. Depth 6'.

(i.). *Warren Girder.*

(*a*). *Description.*—*Fig.* 10 is a skeleton diagram of the girder, which is divided into seven panels, the slope of the braces being 60°. Each panel of the flanges and each web brace consisted of 6" × 1" deal planks, the number of planks being written against the member in *Fig.* 10, as is also the nature of the stress to which it is subjected. Where reversal of stress could take place both + and − is shown, the upper sign being the normal one when the bridge is fully loaded or unloaded.

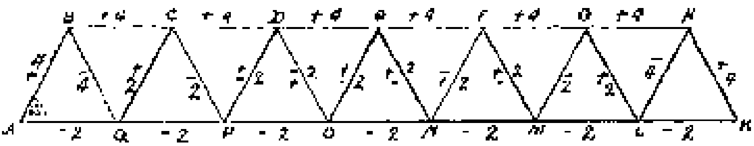


FIG. 10.

Camber.—Each central interval from joint to joint is theoretically 7', but in order to give a camber each tension member was bored with the auger holes $\frac{1}{8}$" less than the 7' centre to centre, and each compression member with the holes $\frac{1}{8}$" more than 7' centre to centre.

Joints.—The joints consisted of :—

1$\frac{3}{8}$" oak trenails at A, B, C, D, O, P, Q.

1" trenail at E.

1" iron bolts and nuts at F, G, H, K, L, M, N.

The planks were threaded on the bolts or trenails alternately, *e.g.* :—

At B they were in this order :—A plank of AB, then a plank of BC, then a plank of BQ, then a plank of AB, and so on.

At A they were in this order :—A plank of AB, a plank of AQ, two planks of AB, a plank of AQ.

And it is important that the planks which are most highly stressed should not be on the outside at panel points, in order to allow the bolt or dowel to offer a double-shear resistance to them.

All compression members had their planks braced together at 2' 4" intervals with blocks. The planks of tension members were braced together with a block at their centre.

In order to prevent the top flange buckling it was given a width of 18" at the centre and proportionally at other points.

In order to prevent the trenails or bolts from tearing through the ends of tension members all such members were cut long enough to allow 12" of overlap beyond the auger hole. (See *photos*).

Cover Plates.—The flanges BH and AK are built up of planks 14' long (*i.e.* twice the length of each panel). All joints occurred halfway between the panel points, and every alternate plank in each member (*i.e.* 2 out of 4 in the top flange and 1 out of 2 in the bottom) was broken in the middle of each panel and connected to the plank which butted it, by means of cover plates. (This involved the insertion of some 3′ 6″ and 10′ 6″ pieces at the ends of the flanges to adjust the joints). Cover plates were 6″×1″ planks bolted or trenailed to the main flange planks on each side of the joint, thus making a fish-plate connection. They were 4′ or 5′ long and were fixed to the main planks with 1 or 2 bolts or trenails on each side of the joint.

The bearing stress per square inch is greater in the case of 1″ bolts than of $1\frac{3}{8}$″ dowels, but the latter are the weaker against shear.

The maximum bearing stress on the planks was 1,900 lbs. per square inch.

The maximum shearing stress on the trenails was 900 lbs. per square inch.

In order to obtain uniformity and simplicity, the number of planks in each member and the sizes of the dowels, trenails and bolts connecting them were arranged as in *Fig.* 10 and as detailed in the description. This brought some variation of unit stresses on the various members, which could to some extent be compensated on service by the use of the better material where it was subjected to the greater stress.

(*b*). *Calculations.*—The Warren girder was calculated in the usual way. The maxima stresses on the members, after allowing for the various possible loadings of the bridge, were as follows :—

Web Braces.

AB=KH=+5,544 lbs.	PD=MF=+2,466 or − 277 lbs.
BQ=HL=−5,474 „	DO=FN=−2,326 or + 277 „
QC=LG=+3,954 „	OE=NE=+1,150 or −1,460 „
CP=GM=−3,814 „	

Flange Members.

$$\left.\begin{array}{l} AQ=KL=\ \ 2{,}773 \text{ lbs.} \\ QP=LM=\ \ 7{,}406 \text{ ,,} \\ PO=MN=10{,}206 \text{ ,,} \\ ON=\qquad\ 11{,}172 \text{ ,,} \end{array}\right\} -$$

$$\left.\begin{array}{l} BC=HG=\ \ 5{,}509 \text{ ,,} \\ CD=GF=\ \ 9{,}226 \text{ ,,} \\ DE=FE=11{,}109 \text{ ,,} \end{array}\right\} +$$

The stresses per square inch on planks, after using Gordon's formula for long struts in the case of compression members and allowing for trenail holes in the case of tension members, did not exceed 1,313 lbs. and 1,271 lbs. respectively.

(ii.). *Plate Girder.*

(*a*). *Description.—Figs.* 11 and 12 give the two cross sections of the girder, *Fig.* 11 being that for the central 29′ and *Fig.* 12 that for the 10′ at each end.

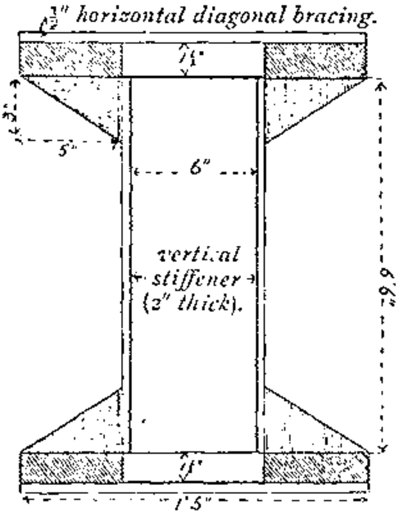


FIG. 11.

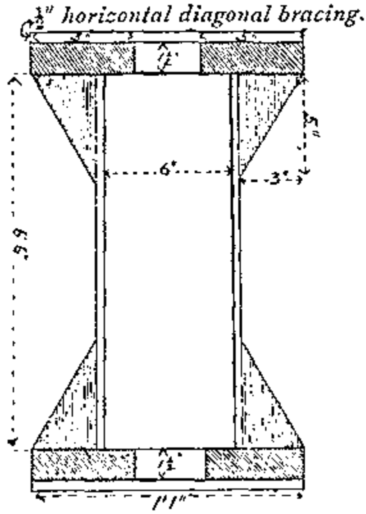


FIG. 12.

Each flange consisted of two triangular pieces, 3″ × 5″. These pieces were placed with the 5″ horizontal for the central 29′ of the girder in order to give greater nail area for the cover plates and to increase the width of the compression flange, and with the 5″ vertical for the remainder of the girder in order to give greater area for nailing the web plates. This is in accordance with the variations of the flange and web stresses respectively. The 5″ × 1½″ planks shown above and below the two triangular pieces in each flange are cover plates transferring the stress at the joints of the triangular pieces.

The two triangular pieces in each flange were in 10′ lengths, each breaking joint with the other and with the piece immediately below.

The web consisted of a double series of 6″ × ½″ planks placed at a 45° slope in a vertical plane and nailed to each upper and lower triangular piece. *Figs.* 13 and 14 show a side elevation of a girder, respectively at the end and at the centre. It will be seen that, while the web planking is continuous at the ends, it opens out towards the middle until the boards are spaced at 2′ central intervals at the middle of the girder. This is in accordance with the decrease of shearing stress towards the centre.

The other series of web planks (not shown in *Figs.* 13 and 14) ran in the opposite diagonal direction.

Vertical stiffeners, 6′ 6″ × 6″ × 2″ placed every 7′ along the girder connected the two series of web planks, which were nailed to them.

Vertical end stiffeners, 6′ 6″ × 13″ × 2″ at each end of the girder were nailed up against the ends of the flanges and web planks (see *photo*).

A light system of horizontal diagonal bracing, composed of pieces 6″ × ½″ connected the two sides of each flange, above the top cover plates and below the bottom ones.

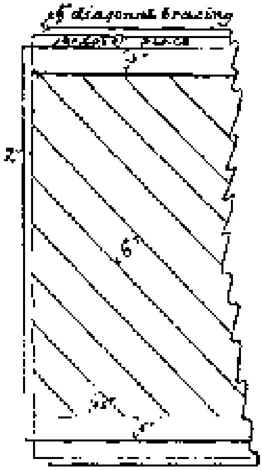


Fig. 13.

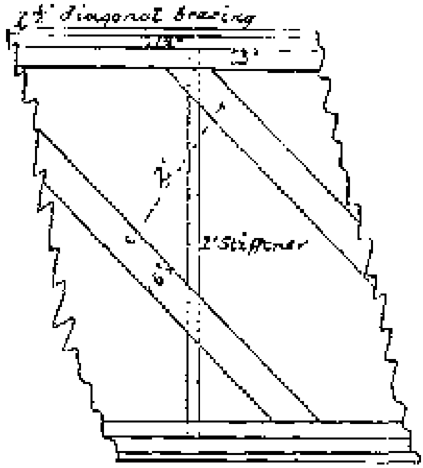


Fig. 14.

The web planks of the two series were braced together where they passed with blocks 6″ × 4″ × 4″, to which each plank was nailed; these blocks were not placed closer together along a plank than 12″.

(*b*). *Calculations.*—The plate girder was calculated in the usual way. The flange stress at the centre was 11,250 lbs. The stress per square inch of the flanges at the centre was 750 lbs., which allowed sufficient margin for the possibility of buckling in the compression flange or of weakness through nail holes in the tension flange. No attempt was made to reduce the area of the triangular flanges towards the abutments as there would not then have been sufficient nail area for the cover and web planks.

The maximum shearing stress was calculated with a 2-ton wagon at one end of the bridge and the rest of the bridge crowded with cavalry. The web itself is amply safe to carry this. The shearing stress on each nail connecting web planks to flanges at the abutments due to the horizontal shear was 148 lbs., allowing four nails to the horizontal foot-run on each side of the girder. 2½″ cut nails were used here.

The maximum interval at which web planks could be placed (centre to centre) at the middle of the bridge to give sufficient resistance to shearing when half the bridge only was loaded was found to be 2′.

The length of cover plates to allow sufficient nail area, at 12 nails per square foot, to transmit the stress along the flanges was calculated.

It was found that these flange cover plates had to be nearly continuous in the tension flange and were therefore made entirely so there. In the compression flange the duty of the cover plates is to preserve the alignment of the butting flange pieces and they were made to extend from 18 to 30" each side of each joint to ensure this.

(*c*). *Method of Construction of Girders.*—(*i.*). *Warren.*—This girder was made on a level grass meadow close to the site. It is easy to put together if careful attention is paid to the correct order of planks at each panel point.

It was found that bolts and nuts were much easier and more satisfactory to use than trenails. The former were easy to drive into the holes bored for them and their nuts gave them a good grip on the planks. The latter were hard to drive into position (a red hot poker was found useful for making the holes, but the soundness of this method is perhaps doubtful). When the trenails were driven they got no grip on the planks, which tended to spread apart whenever they received a shock. Nailing the distance pieces between the planks partially remedied this defect.

(*ii.*). *Plate.*—This girder was also put together close to the site. It took less time and was easier to make than the Warren. It was also stiffer than the latter. It was difficult to get a seating for the road transoms on the bottom flanges of this girder; the web had to be cut through for this purpose, which weakened it.

(*d*). *Method of Launching.*—As soon as the girders were built they were lifted up into vertical planes and placed on stout rollers the right distance apart. They were then braced together with temporary planks nailed diagonally across the top and bottom flanges.

A 6" × 3" plank was then nailed to the bottom flanges at the end nearer the gap, and to it was attached a sling into which was hooked the lower block of a "double and treble" 2" fall. The upper block of the fall was made fast to the cross-piece of a 20' frame on the far bank.

This tackle lifted the outer end of the bridge as it was pushed across and assisted to pull it across. The sling, into which the lower block hooked, passed round both girders to steady them.

To assist in preventing the tipping of the bridge as it moved across the gap, another 6" × 3" plank was secured to the *top* flanges at the inshore end and was held down to holdfasts on each side of the bridge by ropes which were slowly paid out.

Two horizontal guys were also passed round the girders (one round each girder) as lateral preventers.

Fig. 15 (which is not to scale) is a general elevation showing the process of launching. The position of the girder shown by the dotted lines is that when the frame first exerted an *effective lifting* action.

The main party (on the near bank) push the bridge forward on the rollers. It was found necessary to stop very often because the ends of the sloping braces in the Warren girder got jammed up against the rollers. This is a distinct disadvantage in the open truss type of girder. As there was only one block pulling the bridge across, the latter had a tendency to twist, a result which the constant necessity for lifting the Warren girder tended to increase.

It would have been better to have had *two* blocks and falls from the frame.

The horizontal diagonal braces connecting the bottom flanges of the two girders while they are being pulled across should be of 1¼" planking, as they are subjected to considerable crushing stresses when passing over the rollers.

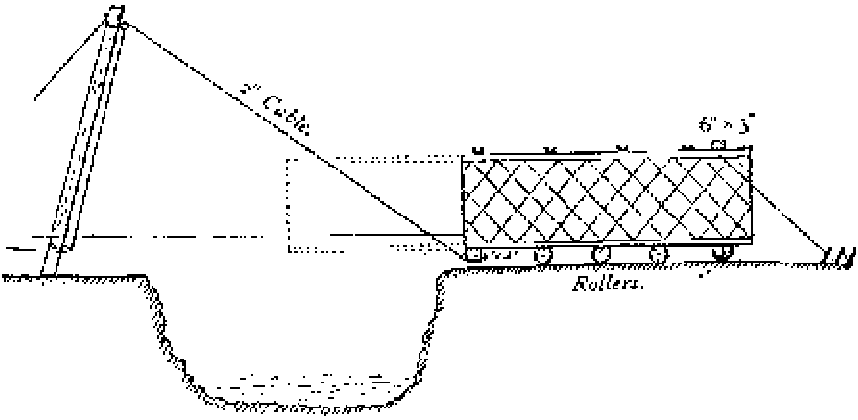


FIG. 15.

(*e*). *Time.*—Six carpenters built and connected the girders in 50 hours. The work being experimental, only a few men worked at it, otherwise it could probably have been built in 20 hours by 16 men. Launching took 50 men one hour.

(*f*). *Remarks.*—The bridge in its final position still retained its camber but might have been stiffened *laterally.*

A few days later, after heavy rain, it was found that in the Warren girder the dowels had swollen and the holes apparently contracted so that the planks had a tendency to tear. This tendency was confined to dowel joints alone. The bolt joints were still good in every way. Lateral oscillation was very small even when a heavy wagon and men moved rapidly across the bridge.

After rain the bridge, which was fixed at one end, expanded in length by ¼".

(*g*). *Deflection.*—Careful measurements were taken of the deflection of the girders under various loads.

The following table gives the results :—

Load at Centre (exclusive of superstructure).	Deflection in Inches at Centre. Plate Girder.	Warren Girder.
30 cwt. (stationary)	$\frac{1}{2}$	$\frac{3}{4}$
" " " *after 5 minutes.*	$\frac{5}{8}$	$\frac{13}{16}$
26 " " *after 1½ hours...*	$\frac{3}{4}$	$\frac{12}{16}$
32 " (moving) when at centre	$\frac{1}{2}$	$\frac{11}{16}$
Permanent deflection at centre after load was removed	$\frac{7}{16}$	$\frac{1}{2}$

N.B.—The maximum deflection permissible may be taken as $\frac{1}{450}$ span (= $1\frac{1}{2}''$).

Joints were examined after the tests; no serious defect was found.

4. 57′ BRIDGE FOR CAVALRY IN SINGLE FILE.

Built at Christchurch Camp in 1904 by R.E.

Launched by R.E. and Cavalry Pioneers.

Width of roadway 6′, carried on the top of two girders 7′ apart centre to centre.

(*a*). *Description.—Type of Girder.*—Warren. Depth centre to centre of flanges 5′ 6″.

The girders were built up entirely of 8″ telegraph poles for compression members and telegraph wire for tension members with the addition of four planks for counterbracing.

Fig. 16 is a skeleton diagram of a girder. Compression members are shown in continuous lines, tension members in dotted lines.

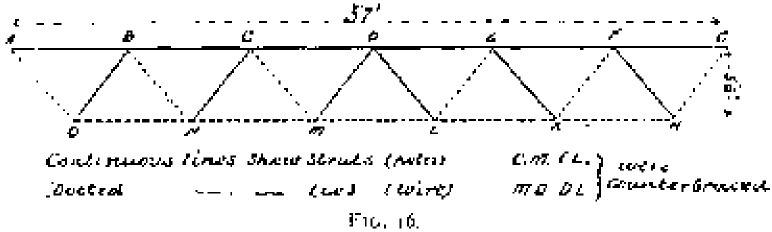


FIG. 16.

The slope of braces was about 40°.

The bridge was intended to be supported on seatings at the bank level on which the ends of the upper flanges should have rested, but owing to the shallowness of the gap a trestle 6′ high had to be erected on each bank upon the transoms of which the ends of the upper flanges of the girders rested.

(*b*). *Method of Construction.*—The chief difficulty lay in the joints, especially those where compression members met.

Description of Joints.—(1). *Top Flange.*—Poles 19′ long, sufficient to cover two panels, were used. The poles of the two top flanges broke joint with each other.

The girder was put together on its side on the ground. It was given a camber of 1′ at the centre and proportionately at other joints to produce a hog-backed shape. Where two poles met end to end they were cut square and the camber produced by inserting a couple of wedges between them, as in *Fig.* 19. A 2″ oak dowel (AB in *Fig.* 17) was inserted into auger holes bored in each butt.

Joints A and G.—At these joints the wires AO and GH passed through auger holes bored horizontally through the pole.

Joints B, C, E, and F.—At these joints the wires of the diagonal tension braces passed through horizontal holes in the pole nearer the abutment, *e.g.* the wires of BN passed through a hole in AB. The diagonal compression brace was shouldered into the pole farther from the abutment. *Fig.* 18 is a view of the joint at B. *s* is the shoulder cut in the panel BC, against which the brace OB butts. *p* is the auger hole in AB through which the wires of the brace BN pass. *q* and *r* are two other auger holes. OB is wired in its place by series of wires between *r* and *p* and between *r* and *q*.

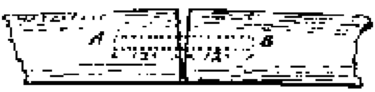


FIG. 17.

B.

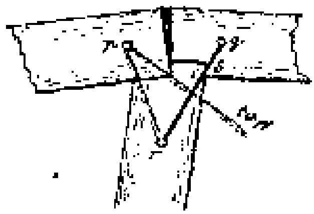


FIG. 18.

Joint D.—This joint has the two braces MD and DL scarfed to butt against each other. They are also slightly recessed into the poles of the top flanges as in *Fig.* 19. The four poles are wired together as shown through auger holes *t*, *v*, *w*, *x*.

Joint D.

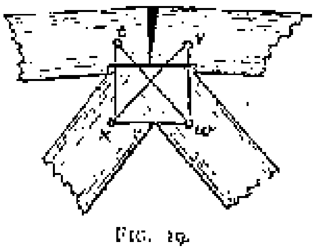


FIG. 19.

Joints O, N, M, L, K, H.—In these joints an auger hole was bored horizontally (at right angles to the plane of the girder) through the pole about 9″ from its end and the wires of the two or three tensional members connected to it were passed through the hole. Wires of each member in the lower flange were independent of those of the next member.

Horizontal Bracing.—The top flanges were connected together by the usual horizontal lattice bracing of 8" poles and 2" boarding. The lower flanges were connected by similar bracing but wire was used for the diagonals, and the poles were 5" in diameter. Diagonal wires were also placed to cross brace the quadrilaterals formed by each corresponding (*i.e.* opposite and parallel) pair of web braces in the two girders (see *photo*), in order to prevent distortion during launching.

(*c*). *Calculations.*—The Warren girders were calculated in the usual way. The weight of each girder was 2,275 lbs.

The maxima stresses on the web members were as follows:—

$$AO = GH = -7{,}568. \quad OB = HF = +7{,}428. \quad BN = FK = -4{,}750.$$

$$NC = KE = +5{,}100. \quad CM = EL = \begin{cases} -2{,}446 \\ +318. \end{cases} \quad MD = DL = \begin{cases} +1{,}376 \\ \text{or} -402. \end{cases}$$

The stresses on compression braces of the web are well within the limits of safety for 8" spars, provided the joints are well constructed.

Where compression members are liable to reversal of stress (which is only the case in the members MD and DL and then only to a small extent) it is important:—

(*a*). To have no play in the joint.

(*b*). To have the brace wired to the flange at the joint with a sufficient number of returns of wire to take the reverse stress.

The tension members CM and LE were counterbraced by nailing a couple of planks on either side of the tie and bracing them together. These planks are not seen in the photograph as they were not put on until the girder had taken up its final position and the wires were fully stretched.

The maxima stresses in the lower members were as follows:—

$ON = KH = -9{,}616$ lbs.

$NM = LK = -15{,}504$ lbs.

$ML = -17{,}377$ lbs.

The upper flange members, being in compression, are obviously sufficiently strong.

The number of wires in tension members was proportional to the stresses in them.

(*d*). *Testing a Girder.*—One girder was tested in the following way (*Fig.* 20): Two pairs of sheers, *a* and *d*, 10' to the crutch were placed about 57' apart and well stayed. The girder was erected in a vertical plane and then lifted on to the two sheers so that it was clear of the ground and supported by the ends of the top flange only. In this position it was found to have lost its camber, which was restored to it by the following method.

Two more pairs of sheers, *b* and *c*, 11' to the crutch were made. The girder was then lifted off the crutches of the sheers *a* and *d* by about 25 men and the new sheers were placed a little way each side of the centre as at *b* and *c*. The sheers *a* and *d* then took none of the weight and the ends of the upper flange sagged, the joints opened a little more, thicker wedges were driven in, and the wires of all tension members were tightly windlassed. The sheers *b* and *c* were then gradually lowered and the girder once more rested on *a* and *d*; and this time it retained its camber owing to the increased thickness of the wedges and the shortening of the ties.

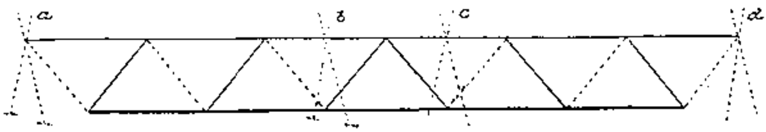


FIG. 20.

The testing was then carried out by erecting a derrick F about 15′ high (10′ would suffice) opposite to and 13′ 6″ away from the centre of the girder (see *Figs.* 21 and 22). A single block G was lashed to its tip. Two stout pickets DD were then driven into the ground 1′ 6″ from the centre of the girder and a cross-piece C lashed to them about 3′ above the ground. A strong lever E was placed under C and one end, which was vertically under the centre of the top flange of the girder A, was connected to it by 36 wires, while the other end, which was vertically under the block G, was secured to a fall which passed through G and held a tray at H which could be

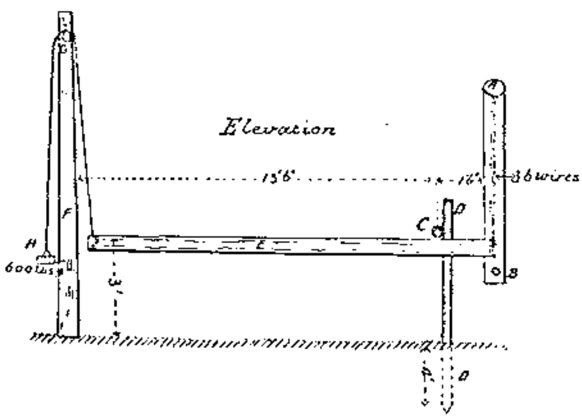


FIG. 21.

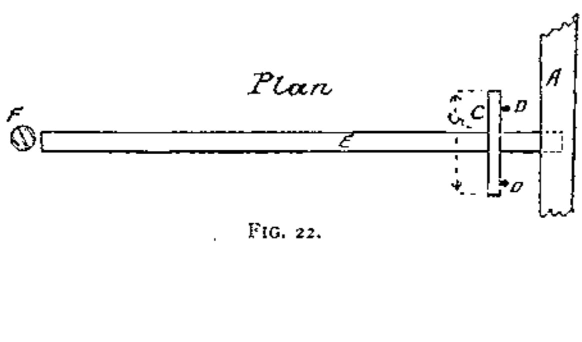
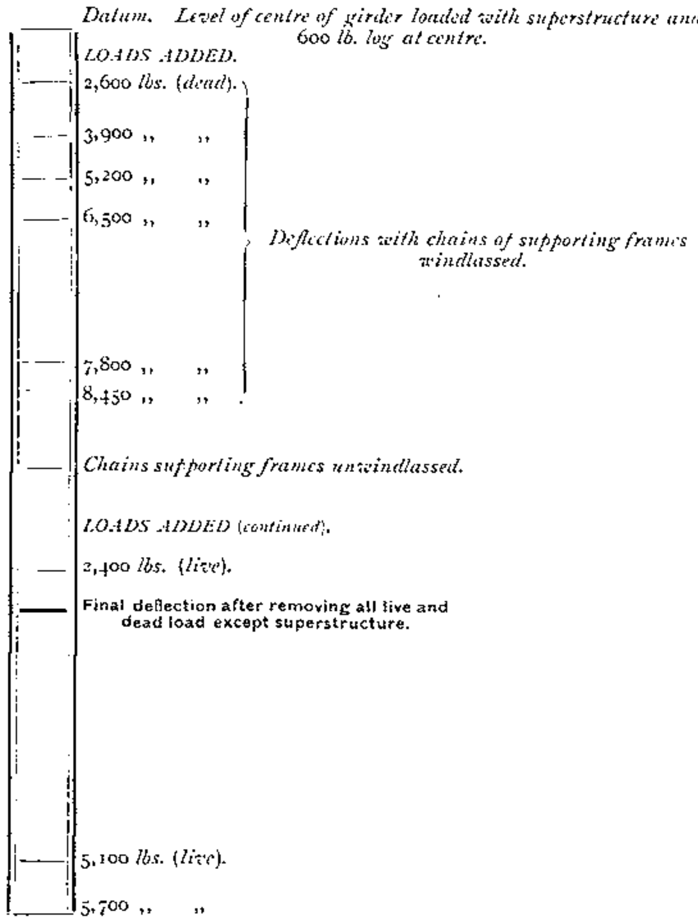


FIG. 22.

loaded with sandbags of known weight. The arms of the lever E pivoting at C were as 9 to 1.

Weight was added to H till, when 600 lbs. was on the tray and the deflection at the centre was 4", one of the tension members in the bottom flange, B, tore through its auger hole. The equivalent load on the centre of the girder when this occurred was of course 5,400 lbs. The top joints had stood the test well, with no signs of failure.

The actual failure could easily be remedied by binding round the poles with wire at the auger holes. This was subsequently done everywhere. No further test was made as the girder had otherwise stood the required test. (A central load of 5,400 lbs. on one girder equals a distributed load of 21,600 lbs. or 380 lbs. per foot-run on the bridge).



Full Scale Diagram of Deflections of 88' Bridge (FIG. 30).

FIG. 23.

(*e*). *Launching the Girders.*—The girders were carried one by one by a party of about 40 men to the edge of the gap and were then erected vertically, parallel to each other and the proper distance apart. They were propped up in this position while the horizontal diagonal bracing between the top flanges and the wire bracing between the bottom flanges and web was fixed. Two 20' two-legged frames were meanwhile erected either side of the gap with the legs far enough apart for the whole bridge to pass between them. A block and tackle was suspended from each frame transom and hooked on to bridles fastened to the top flanges. By means of these tackle the whole bridge was lifted by the near side frame and pulled by the far side frame across the gap. The bridles had to be occasionally shifted and while this was being done the weight of the girders was taken by extra ropes passing through single blocks lashed to the tops of the frames.

Lateral preventer ropes were very necessary (fixed to the top flanges) while the bridge was moving across, as there was some tendency for the camber to translate itself into a lateral deviation of the top flange.

The process of launching was not very satisfactory owing to the fact that the gap was a shallow muddy one instead of a deep one (for which girder bridges are best suited). When the forward end sagged as it moved across it rested on the mud. Had the gap been deep enough it would have been practicable to allow the forward end to droop very considerably, as it could be pulled up again by a nearly vertical hoist when it got across.

When the bridge was across, trestles were erected to carry the ends of the top flanges.

(*f*). *Time Table of making One Girder* :—

	Men-Hours Labour.
Cutting poles to length	9
Making dowels	2
„ joints on top flange	21
Boring auger holes (and wiring round ends of poles)	10
Wiring tension members	66
Total labour for one girder ...	108
„ „ „ two girders ...	216
Carrying to gap and raising (30 men 1 hour)	30
	246
Cross bracing between girders (12 men 8 hours)	96
Launching bridge (50 men 3 hours) ...	150
Total labour	492

A suitable distribution would be as follows :—

Building two girders	36 men 6 hours.
Carrying to gap and raising	36 men 1 hour.
Erecting frames and cross-bracing between girder	36 men 3 hours.
Launching	36 men 3 hours.
Total labour	36 men 13 hours.

(*g*). *Remarks on the Completed Bridge.*—After a short time the girders lost their camber. It would have been advisable to give 1′ 6″ to 2′ camber at the centre in constructing them.

The bridge was very stiff and had little lateral oscillation. It would be a good thing to give it a greater depth, but this is difficult as girders deeper than 6′ or 7′ are very difficult to erect and launch. Wooden gusset plates or fish plates at all the top flange joints would relieve the strain on the dowels which may fail without giving warning, though no instance of this occurred.

As the top flange joints stood the test load admirably they would probably be found satisfactory under service conditions. This kind of bridge might be of use when time was not of the highest importance, or when no other material to span a deep gap or a torrent was at hand. No material other than poles and wire is needed, no tools besides augers, saws and pliers, and very little skilled labour.

5. 78′ Bridge for Cavalry in Single File.

Built at R.M.C., Kingston, Canada, in 1906 by cadets.

(*a*). *Description.*—Width of roadway 6′. Carried on top of one girder of triangular cross section. Depth of girder centre to centre 6′.

Type of Girder.—It was thought that a girder bridge of cross section as in *Fig.* 24, *i.e.* having two top flanges and one bottom flange, would provide greater freedom from internal distortion and would save material and weight. It was in fact two girders inclined to the vertical and having a common lower flange. Results proved that the type though strong enough when finally in position was not satisfactory, as it had to be launched upside down and then turned over, a process which took much time just when time should especially be economized. It was found as well that a loss in the lateral stiffness of the lower flange resulted, which allowed overmuch oscillation.

Considering the bridge as composed of two girders, having a common lower flange, the top flanges consisted of 8″ round spruce spars, in 10′ and 20′ lengths and the bottom flange of 10″ spars in two 27′ lengths and one 14′ length, butting where they met. The butt joints of all flanges were strengthened by $1\frac{7}{8}$″ oak trenails 16″ long placed in axial holes in the end of each pole $8\frac{1}{4}$″ deep and 2″ diameter: in the case of the top flanges the joints were further secured by three planks, 4″ × 2″, 4′ long, fishing the joint on the top and the two sides. Each butt joint of the bottom flange was connected up by a wire sling of the necessary strength to take the tensional stress, passing through transverse 2″ auger holes 2′ from the ends of the spars. It will be seen in *Fig.* 29 (where the girder is upside down) that the lower flange was only 68′ long, which was sufficient.

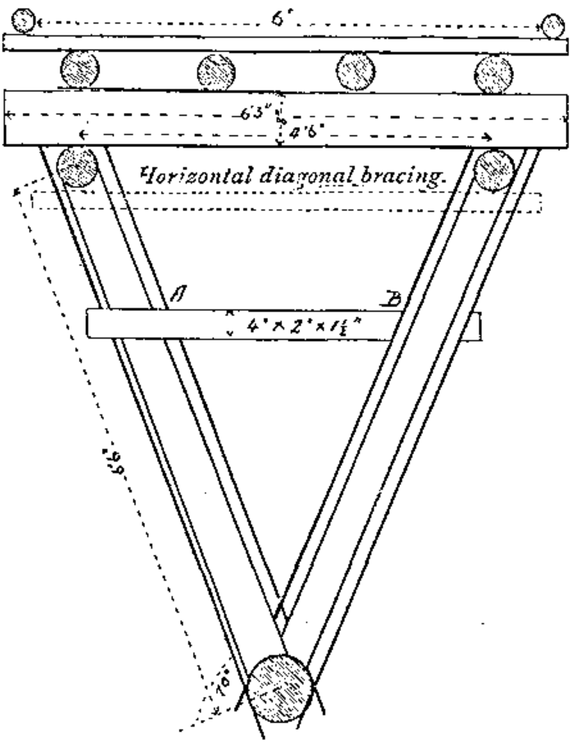


FIG. 24.

The web consisted of 8″ by 1½″ boarding nailed diagonally on the outside to top and bottom flanges; the boards touched each other at the abutments and were spaced at 2′ central interval at the centre: and on the inside of each girder there was another series of diagonal boarding, 8″ × 2″, running the contrary way and spaced at equal central intervals of about 5′ throughout.

Distance Pieces between Top and Bottom Flanges.—Every 5′ along each girder a distance piece or stiffener 6′ 6″ × 8′ × 2″, was placed perpendicular to the flanges and shaped at the ends to fit them as in *Fig.* 25.

FIG. 25.

The four distance pieces at the ends were 3″ thick.

The distance pieces on each girder were placed not quite opposite to each other (or they would have interfered with each other on the common lower flange), but close enough to allow a horizontal brace (AB in *Fig.* 24) to be nailed across them.

The upper sides of the joints of the top flanges were wedged with pieces of $\frac{1}{8}''$ sheet iron to give a camber to the bridge.

Wind Bracing.—8″ road transoms were spiked across the two top flanges at 8′ 6″ central interval and between them a system of horizontal lattice bracing of $8'' \times 1\frac{1}{2}''$ planks was spiked to the under-side of the flanges. The top flanges were also wired together at intervals to prevent them spreading.

Duplication of Web at Abutments.—The diagonal web boarding near the abutments was strengthened by cross boarding of the same size. This cross boarding covered the whole face of the girder for 15′ from each abutment. The cross boarding was not completed till after launching.

(*b*). *Method of Construction.*—The three flanges were first of all built up upon a platform of small piles of chesses at intervals, the tops of which were levelled. A pile was placed under each joint in a flange.

The ends of spars in the flanges were cut square and bored for the dowels, which were inserted. The sheet-iron wedges on the upper side of the top flanges were inserted and the fish plates nailed on. The joints of lower flange were wired together.

The two top flanges were placed parallel and at the correct distance apart and framed together by means of the transoms and wind bracing which were spiked on.

This frame ($78' \times 4'\ 6''$) was then raised to the required angle and propped (as XY in *Fig.* 26). The bottom flange Z was placed in the correct position with reference to XY. The stiffeners XZ and YZ were then fixed and connected by the transverse pieces AB (*Fig.* 24) and then the exterior and interior web boards were nailed on.

The girder had to be revolved about the lower flange in to the position $X_1Y_1Z_1$ (*Fig.* 27) to complete the boarding.

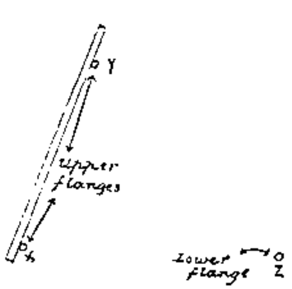


FIG. 26.

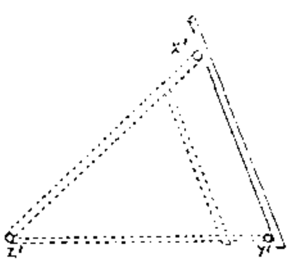


FIG. 27.

Only every other board in the web was nailed on before launching in order to lighten the weight. The remainder were nailed on when the girder was in site.

The exterior and interior boarding in one girder ran the reverse way to each other diagonally. The two systems of exterior boarding also ran the reverse way to each other.

All web boards were nailed to the stiffeners where they passed them.

On the completion of the girder it was turned over on to XY (*i.e.* upside down) ready for launching.

(*c*). *Calculations.*—The bridge was calculated as though it consisted of two ordinary plate girders, each with a lower flange equal to half the 10″ spar forming the single lower flange of the bridge. The weight of the total bridge (exclusive of road-bearers and chesses) was about 8,000 lbs., of which the flanges weighed 3,377 lbs.

It was found that the horizontal shearing stress at the abutments was 3,333 lbs. per foot-run (both girders together).

It was necessary to ascertain the ultimate resistance of the nails employed (6″ wire) connecting the timbers employed ($1\frac{1}{2}$″ fir planks to spruce logs).

This was found by experiment to be about 800 lbs. per nail.*

Four 6″ wire nails can easily be driven side by side as at *aaaa* without hurting the fibres of the board, and if necessary three more nails might be driven as at *bbb* (*Fig.* 28).

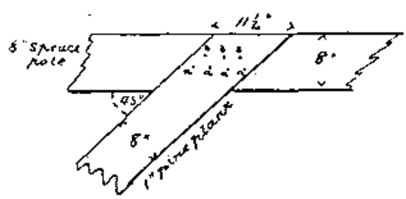


Fig. 28.

Now each web plank was 8″ wide and being placed at 45° to the flange took up a length of 11″ along the flange. There were two sets of

* *Experiments.*

Thickness of Plank.	Kind of Nail.	Breaking Stress (per nail).	Nature of Break.	Remarks.
2″	6″ wire.	809	Nails pulled out of log.	Nails driven home.
1″	6″ wire.	785	Nails pulled through boards.	Ditto.
1″	6″ wire.	693	Ditto	Heads not driven into board.
1″	6″ cut.	537	1 nail broke .... 1 „ pulled through board................	Heads not driven into board.
1″	6″ cut.	720	Ditto	Nails driven home.

web planks. Allowing a factor of safety of three, the required number of nails connecting each plank to each flange was $\frac{3333 \times 11 \times 3}{12 \times 2 \times 800} = 6$, which could be driven without splitting the planks.

It must also be remembered that the web was also strengthened by double boarding at the abutments.

The spars of which the flanges were composed, were strong enough against compressive and tensional stresses and the number of wires connecting the spars in the lower flange was calculated in the usual way.

(*d*). *Method of Launching Girder* (*Fig.* 29).—The girder was launched by means of (*a*) a 58′ derrick, F, in the centre line of the bridge on the far side of the gap.

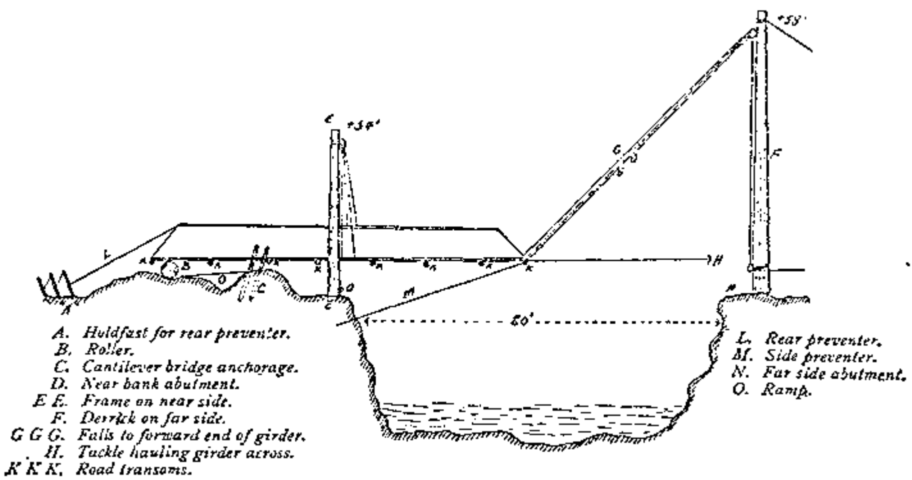


FIG. 29.

(*b*). A 35′ 2-legged frame, E, astride the centre line of the bridge on the near side of the gap, between the legs of which the bridge passed as it was launched.

The derrick had, lashed to its tip, three single blocks, through which falls passed to the girder. These falls were connected to "runner" tackles.

The frame had, lashed to its transom, four single blocks. Through these blocks falls passed, two of which were connected to runner tackles and two to holdfasts (the latter assisted to take the weight and were paid out as the girder went forward).

The bridge was launched upside down as it was of triangular section and would have been difficult to keep upright, had it been launched on its lower flange. Four elm rollers, B, each 3′ long and 20″ diameter, stripped of their bark, were used to roll it forward.

The mistake had been made of lashing on the road transoms KK across the top flanges during construction. When the girder was turned upside down these transoms impeded the rolling action, as every time the girder advanced 10′ (*i.e.* one bay of roadway) the roller got foul of the transom and the girder had to be lifted to get out each roller in turn to roll it forward; cross planks should have been nailed *above* the two flanges and the transoms not put on till later.

Another serious impediment to launching was an old cantilever bridge anchorage, C, which it was not thought desirable to remove, and which was in the direct line just behind the near abutment. The road transoms, as they came in turn to this anchorage, had each to be lifted over it, causing great waste of time and moreover, as the ground just in rear of the anchorage was rather low, the weight of the girder was frequently taken by the anchorage logs instead of by the roller, causing a great increase of friction.

A plank platform, O, was placed behind the abutment and was used to roll the rollers up.

The rolling forward proceeded easily except for the above impediments. The tackles were not needed until the girder got more than 40′ (half its length) beyond the cantilever bridge anchorage, which formed the practical abutment, as the real abutment at D (*Fig.* 29) was too far below the natural forward line of movement of the girder to take its weight till the end.

As soon as the girder got more than half-way out the tackles were brought into use. The three from the derrick (G,G,G) on the far side were made fast to the forward transom, which was of course below (this transom was connected also to the two transoms in rear of it to distribute the stress and avoid pulling the forward transom off).

The four tackles from the frame on the near side were made fast, two to the lower flange (*i.e.* that on top), and one to each upper flange (*i.e.* those at the bottom). They were at first made fast vertically, but as the girder went forward they of course became inclined, and exercised a retarding influence on the girder. It was therefore necessary frequently to cast them off in turn and take them back to a point further back on the girder. A horizontal treble and double tackle was made fast to a holdfast on the opposite shore and to the forward transom of the girder to give a direct pull across. The falls from the top of the derrick gave too vertical a pull owing to the great height of the derrick, and the stress on them would have been too great had they been used as the only forward-pulling agency.

There is always a chance of the girder during launching rushing forward or "taking charge." To avoid this the following preventer ropes are necessary:—Two from the rear to the rear of the girder (L), and one from each side to the front of the girder (M). The former (which prevent the girder rushing forward) may be made fast to the upper side of the girder when the bridge is more than half-way out at which time also the latter may be transferred to holdfasts on the opposite bank.

It would probably have been better to have had runner tackle to all four falls on the near side. Grease should be applied liberally, both to all sheaves and to all parts where the girder or rollers move.

Handspikes (not only 6′ ones but two or three 12′ ones of hard wood) are essential for actual lifting and to encourage the girder forward over bad places. Plenty of packing is also necessary to take the weight at times.

It is important, when the girder is close to the far side, to keep the flanges which are to rest on the abutment X well up above it. Otherwise there is a very considerable lift necessary with the tackle, which may cause difficulty.

Turning the Girder.—As the girder was launched upside down it was necessary to reverse it after it had reached the far side. For this purpose the tackles were arranged as follows:—Five were fixed at equidistant points along that top flange which it was proposed to lift (that flange being of course at the bottom and sustaining half the weight); and two to the bottom flange (*i.e.* that flange at the time on top) to lower away gently and prevent the revolution being too sudden. It was found to be easy to turn the girder, but when it was *half* round it had to support its own weight over the span, although on its side and with its flanges and web quite wrongly placed to resist such a stress. The result was that it bent a great deal when in that position, and some of the joints got somewhat racked. The conclusion arrived at was that this method of launching the girder upside down and then turning it is not sound, owing to the unfair stresses to which the joints are liable during the process.

It is always advisable to allow plenty of length in the girder to give a good seating on the abutments and so to avoid the possibility of it being dragged off either abutment. This actually happened and greatly retarded the work.

It would have been wise to have built the near side frame without diagonals and with side struts and guys instead. This would have allowed the tackle from that frame to swing freely backward and forward without interfering with the diagonals.

(*e*). *Time.*—Men-hours labour employed:—

	M.H.
A. Construction of girder	296
B. Launching. (Excessive, for reasons given above)...	313
C. Turning. („ „ „ „ „)...	120
D. Fixing remaining bracing	43
E. Roadway	51
Total	823

N.B.—In addition to above the derrick took 147 M.H. and the frame 50 M.H. Making a total of 1,020 M.H.

(*f*). *Test.*—A class of 28 cadets started half from each end of the bridge and marched towards each other, meeting crowded at the centre and marking time. The deflection increased temporarily to $3\frac{1}{2}''$ and permanently to $2''$.

Load=4,200 lbs. live central=8,400 live distributed=108 lbs. live load per foot-run, to which must be added the weight of the girder (8,000 lbs.) and of the roadway (6,000 lbs.)=A total *dead* distributed load of 26,600 lbs., *i.e.* 340 lbs. per foot-run.

This triangular cross section of the plate girder bridge however is not recommended. It was purely experimental, and the necessity of launching it upside down and then turning it over forbids its use where time in launching is to be reduced to a minimum.

6. 88′ Bridge for Cavalry in Single File.

Built at R.M.C., Kingston, Canada, in 1908 by cadets. Width of roadway 6′, carried on top of two girders 7′ 4″ centre to centre.

(*a*). *Description.*—*Type of Girder.*—Each girder was of the "double Warren" or lattice type (*Fig.* 30), the braces of the web making an angle of 45° with the flanges. Depth (centre to centre of flanges) 7′ 4″.

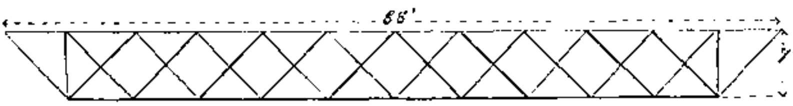


Fig. 30.

The flanges consisted of $5'' \times 5''$ scantlings, 10′ and 20′ long. The pieces butted and were connected at the joints by two fish-plate pieces (above and below the joint) $5'' \times 2\frac{1}{2}''$ or $2''$. In the compression flanges the butting surfaces were considered to be partly capable of taking up the compressive stress and the "fish plates" extended 4 or 5′ each side of the joint and were nailed to the flange. In the tension flanges the stress was transferred across each joint by bolting the pair of "fish plates" together through the flange on both sides of the joint in the usual way, a sufficient number of $\frac{1}{2}''$ bolts and nuts (from 5 to 8) being used each side of the joint and the "fish-plates" were made long enough to take them all, at 6″ central intervals.

No reduction of the size of the flanges was made towards the abutments, as they would in that case not have been large enough to take the bolts.

Each web brace consisted of a pair of planks of the necessary scantling (varying from $5'' \times 3''$ at the abutments to $3'' \times 1''$ at the centre). The web planks were bolted through the flanges at each end with a bolt of sufficient diameter (varying from 1″ to $\frac{3}{8}''$) and were nailed to the planks of the opposite braces where they crossed each other at the middle.

Each pair of compression braces, or tension braces liable to counter stress, was connected with small lattice bracing nailed on at 45° to the direction of the brace. Each pair of tension braces was connected above and below its centre with a pair of small lattice braces.

Wind Bracing.—(*a*). *Lower Flanges.*—Horizontal diagonal planks were nailed across the tops of the flanges.

(*b*). *Upper Flanges.*—The road transoms 6″ × 6″ were notched 1″ deep on the underside and placed across the flanges (which fitted into the notches) and were then spiked to the flanges. A lattice system of horizontal diagonal planking was fixed in pairs between the transoms, both planks being on the top of the upper flanges. Planks were 6″ × 1″.

Abutment Pieces.—The ends of the top flanges rested on the abutments and since they carried the whole weight they were reinforced by pieces 4′ × 8″ × 5″ wired underneath them. These pieces should have been bolted to the ends of the flanges.

Transverse Diagonal Bracing.—It was thought advisable to cross brace the bridge at intervals, *i.e.* by fixing bracing from the top flange of one girder to the bottom flange of the other girder and *vice versâ*, to prevent distortion during launching.

This diagonal bracing between the girders was fixed as follows (*Fig.* 31) :—

Two 6″ × 1½″ planks were nailed, the first from A on a web brace of one girder to B on the web brace of the other and the second from C on a web brace of the latter girder to D on a web brace of the former. So that a web brace of one girder is cross braced to the web brace opposite to it on the other girder. Every alternate pair of web braces sloping one way and every alternate pair sloping the other way were thus cross braced together.

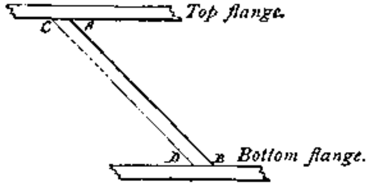


FIG. 31.

(*b*). *Calculations.*—The girders were calculated in the usual way to arrive at the necessary dimensions of planks and sizes of bolts for bearing and shearing. The cross section of the flanges was for convenience kept the same throughout.

(*c*). *Method of Construction and Erection of Girders.*—The flanges were put together on a low staging of piles of chesses and bolted or nailed up with the cover plates.

The top and bottom flanges of a girder were then laid on their sides at the correct interval, a camber was given them by picketing the ends and intermediate points and the web braces on one side laid on. The holes in the flanges and in the web braces for the bolts were then marked and bored and the bolts driven through.

The girder was then turned over and the web braces on the other side bored and threaded on the bolts which were then nutted up. It is necessary to thread the web braces at important joints, *i.e.* those towards the abutment, so that a minimum shearing stress comes on the bolts (see page 198).

The two girders having been thus bolted up were raised into vertical planes, opposite each other and the correct distance apart. This operation was easily done by 30 men.

Each girder was strutted up with planks and then temporarily secured as in *Fig.* 32, where AB and CD are the two girders, AC is light planking nailed between the top flanges, AE and CF are guys.

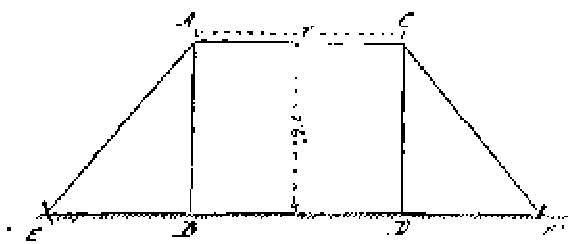


Fig. 32.

It is important to get the lower flanges parallel and correctly placed, the right distance apart and opposite each other. The top flanges can be placed in the right vertical planes subsequently.

As soon as the bottom flanges are correctly placed the lower flange wind bracing should be fixed to keep them correct. The top flanges must then be pulled to the right distance apart throughout and the planks AC renailed to keep them there. The transoms having been prepared with notches 1" deep to fit over the flanges are placed and nailed down. The upper ends of *compression* braces (beyond the bolt) may be sawn off, but not closer to a bolt hole than 4".

Next, the top flange wind bracing may be fixed. In the meantime the lower flanges must be blocked up level and plumb bobs hung from the top flanges to see that they are vertically over the bottom flanges throughout.

Then the transverse diagonal bracing between the girders is fixed and the bridge is ready to carry forward and launch.

Notes on Construction Details.—All holes for bolts were bored with an auger $\frac{1}{8}$ less than diameter of bolt.

Where braces passed each other, a 5" distance piece was placed between them to which they were nailed.

The heads of bolts through lower flange cover plates were downwards so that the nutted end would not interfere with rolling out.

(*d*). *Test of 88' Bridge.*—*Fig.* 23 is a graphical representation of carefully measured deflections taken at the centre under *central* loads of amounts shown. The deflections given are those of the better built of the two girders; the other girder had a weak spot and consequently gave deflections 20 to 30 per cent. greater than those shown.

It will be seen that the deflection under a load equal in value to cavalry in single file was $\frac{1}{400}$ the span; further, that the chains of the strengthening frames gave some assistance, as their release increased the deflection by the amount shown; and lastly that the bridge had by no means reached its elastic limit, even when loaded with a weight equal to 25 per cent. more than cavalry in single file, as is seen by the reduced deflection when the excessive load was removed.

(*To be continued*).

THE COMPLETION OF THE BARO-KANO RAILWAY.

By CAPT. F. D. HAMMOND, R.E.

IN his lecture on the construction of the Baro-Kano Railway given at the S.M.E. in October last and subsequently printed in the April number of the *R.E. Journal*, Capt. Mance was only able to deal with that portion of the work which had been done prior to June, 1910. A brief account therefore of the last year's work up to the time when railhead reached Kano, together with a few notes on organisation, locomotive work, etc., may be of interest.

It will save reference to the article in question to give a *résumé* of the main features and direction of the railway. Baro is situated 400 miles up the left bank of the Niger; ocean-going steamers drawing about 11' of water with a carrying capacity of roughly 1,000 tons, known locally as branch-boats, can reach Baro during high river which lasts from the beginning of August till the middle of October; during the remainder of the year the freight is carried by stern wheeler tugs and barges. The railway follows roughly a north easterly direction on the first section from Baro to Minna, with gradients of 1 in 143 in the upward, and 1 in 166 in the downward direction. Minna (mile 111) is the first engine-changing station, and the point chosen for the junction with the Lagos Government Railway. On the next section from Minna to Kaduna (mile 215½), where the line crosses the river of that name, the gradient is changed to 1 in 60 in both directions owing to the more broken nature of the country. From Kaduna to Zaria (mile 266), the junction of the new line to the Bauchi tin fields, the gradient remains the same, but from that point to Kano (mile 355½) is decreased to 1 in 80.

The rail used is of British standard section weighing 45 lbs. to the yard and 30' long, with steel sleepers, 72 lbs. in weight, with 12 sleepers to the rail length.

By June, 1910, track had been laid as far as mile 212 by means of deviations, but as the permanent bridges had only been completed as far as Kugu (mile 176), it was decided to run through traffic only up to that point during the rainy season which lasts from the middle of May to the middle of October.

TRANSPORT OF MATERIAL.

As a general rule in any new railway, such as the one under notice, which taps an entirely new and hitherto unexploited country, the carriage of materials for construction, provided the latter is carried on at anything like a reasonable speed, will be greatly in excess of any public traffic which may be expected for the first few years after construction is completed. There are of course a few notable exceptions where areas are opened up which are very rich in natural products and which require practically no development to return a large and paying traffic, but these may be regarded as special cases. In the ordinary circumstances it is therefore essential to economy, that such an expensive item as the rolling stock should be cut down to the absolute minimum necessary for constructing the line according to the programme and rate of speed laid down.

In this particular case the rolling stock decided upon as the necessary minimum, consisted of eight 8-coupled and five 6-coupled main line, and five shunting engines, 190 low-sided and 25 high-sided bogie trucks, of which one 8-coupled and one 6-coupled engine and all the high-sided trucks arrived at Baro in October, 1910, and were available for the final year's programme only.

This quantity of rolling stock would have been inadequate to transport the large supplies of material required at railhead whilst platelaying was in actual progress, in addition to complying with the various demands of mail, ballast, pick-up trains, etc., and therefore the opportunity was taken during the rainy season to forward all material as far up the line as possible. Two depôts were formed to receive it, one at Kugo and one at Minna, to which all permanent way and bridge material either on hand at Baro or arriving there during the shipping season was despatched; in the latter case rails and sleepers were loaded direct from the steamers into trucks.

Much extra handling would have been saved if everything could have been sent direct to the depôt at Kugo and off-loaded there, but this was impossible both because the change of gradient from 1 in 143 to 1 in 60 north of Minna cut down by about 50 per cent. the loads which any particular class of engine could pull, and also because the banks on this northern section were new and it was not considered safe to work the heavier 8-coupled engines over them during the first rainy season after they had been made, so that, whereas the trains on the Baro-Minna section consisted of 20 loaded bogies, north of Minna 7 bogies were the maximum load during these months. To get the greatest work possible out of the trucks, all those arriving at Minna which could not be forwarded to Kugo within 24 hours were off-loaded and the empty trucks returned to Baro. By this means all heavy material was cleared out of Baro by the end of October.

The completion of the permanent bridges north of Kugo was meanwhile pushed on, but work was considerably delayed by late and exceptionally heavy rains. The bridges were finished and the four miles of track which still remained to be laid to reach Kaduna were completed by the first week in November. A depôt was at once started there, to which the material stacked at Minna and Kugo was forwarded. By this time the rains had stopped and the track and banks on this section were in sufficiently good condition to permit the working of the heavier engines. This facilitated the work by increasing the train loads which could be taken. The depôt at Minna was cleared by the middle of December and that at Kugo by the end of January. The latter portion of this was done after platelaying had commenced but the lead was not great so that but few engines were required up to that time on the railhead section.

The next item which required attention was the picking up of material on the lower section, which was very important as it was required for subsequent use in laying the main line; several miles of rails alone had to be picked up, the majority being from old deviations and a very large number were bent and required straightening before they could be used again. All was forwarded to Kaduna where it was sorted out and the bent rails straightened by three rail-straightening machines worked by hand power. The maximum output of these machines was 40 rails a day per machine, working with double shifts of labourers.

The one disadvantage in this scheme of transporting material by successive stages was the expense involved in loading and unloading, but this was insignificant when compared with what would have been the cost of the extra locomotives and trucks necessary to take it direct from the base to railhead whilst platelaying was in actual progress, and with the lead increasing by over a mile a day. To this undoubtedly the subsequent success of the platelaying programme was due in a large measure, as on no occasion was railhead ever held up for want of material.

Platelaying.

It is unnecessary to describe in detail the methods employed in platelaying as these were dealt with fully in the previous article. As before, Lieut. Maxwell, R.E., was in charge of this section of the work.

In the programme for the season as originally laid down, it had been arranged to start tracklaying early in November, but, as mentioned above, the late rains had delayed the erection of the permanent bridges and consequently the construction of the deviation across the Kaduna River. The latter was finished on the 11th December and platelaying commenced on the following day. This delay was not in a way disadvantageous as it not only allowed of more material being brought up to Kaduna but also permitted the party in front, engaged in putting in deviations and minor culverts, to get a substantial lead of about 15 miles, and so avoid the trouble of previous years when railhead was frequently held up owing to culverts, etc., not being ready. This lead they were able to keep until Kano was reached.

Owing to the late start, and to obviate any chance of interruption by an early rainy season, tracklaying had to be pushed on at the fastest rate which circumstances would allow. The ruling factor in this was the rate of supply of material, as the platelaying party were quite competent to lay down as much as could be sent up from the depôts.

The average amount laid each working day varied from 1½ to 2 miles a day; this, allowing for Sundays, public holidays, changing camp, etc., averaged out about 38 miles a month. This average was maintained for the first 115 miles which were laid in 90 days, including all non-working days. By this date, the 11th of March, such good progress had been made that only 24 miles remained to be laid in order to reach Kano, and any fear of interruption by early rain was needless and the rate of progress was consequently eased off slightly. Kano (mile 355½) was reached on April 1st, the whole distance of 139½ miles having been laid in 111 days, an average of 1·26 miles per day.

The number of labourers employed in the platelaying, keying and first lift parties varied from 990 in December up to 1,270 in March.

The table below shows the actual progress made each month; the 3⅕ miles shown as being laid south of Kaduna in October and November were not laid by the proper platelaying party but by a small gang, and did not form part of the season's platelaying programme. They are therefore not included in the statistics given above.

1910–1911. Month.	Main Line. Mileage.	Additional Track laid.	Cutting out Deviations.
October	$1\frac{7}{10}$	—	—
November	1½	2	—
December	22	1	—
January	$36\frac{3}{5}$	2	—
February	37	1¼	—
March	42½	1	1
April	1¾	½	1
	$143\frac{1}{20}$	7¾	2

WORLD'S RECORD IN TELESCOPIC TRACKLAYING.

It had been arranged that an attempt should be made to beat the world's record of 5 miles for a single day's telescopic platelaying made by Messrs. Pauling in Rhodesia. This was successfully accomplished on March 8th when 6⅓ miles were laid. Work was commenced at 5.50 a.m. and finished at 6.40 p.m. A further ¼ mile had been laid out, but it was not possible to link it up owing to the darkness coming on and all the gangs being tired out. 1,622 natives were employed and 17 Europeans, of the latter all but four were either Sappers or ex-Sappers. Three large and one small engine were employed, the last being used solely on taking tank trucks back to be filled and returning with them to the large engines. About ½ mile of sidings was laid on the previous day for the accommodation of material trucks. It is interesting to note that the weight of rails and sleepers handled, alone amounted to over 900 tons. Usually when an attempt of this kind is made the average of work done suffers owing to the time taken in preparations, but this did not occur in this case as the track laid during that particular week was 10½ miles, which was well up to the average.

Water Supply.

One of the worst difficulties with which the officer in charge of the platelaying party had to contend was the supply of watering facilities to the engines on the upper section. Throughout the more northerly portion of the Protectorate water is comparatively scarce and is usually obtained from wells. In a few places temporary earth dams had been made, towards the end of the rainy season, across the beds of streams, but in most cases water had to be found by digging in the dried up beds, and as these holes soon became exhausted new ones had continually to be made to replace them. Improvised tank trucks were found to be of great use under these conditions; they consisted of four 400-gallon tanks connected together and erected on a low-sided bogie with a hand pump for pumping into the tender. Three such trucks were used, one on the construction train, one with the engine feeding the construction train with material, and the third wherever required most.

Organization.

The ordinary procedure in railway construction is to divide up the line into various sections each in charge of an engineer who is responsible for the whole work of construction in that section, and who either indents for such rolling stock and engines as he may require or has a certain number allotted to him. A different organization was adopted on the Baro-Kano Railway, each distinct branch of the construction being placed under a separate engineer who was directly responsible to the Director of Railways. Thus the platelaying and traffic were placed under Capt. Mance, with Lieut. Maxwell in charge of the platelaying, and a civilian assistant traffic manager; the locomotive department under the writer of this article with two civilian assistants, and the bridging and earthworks respectively under two civilian engineers. This system has the undoubted advantage, where only a limited quantity of engines and rolling stock are available, that the greatest and most economical use can be made of them, which it is very difficult to do where the control is split up amongst various engineers. It also results in better care being taken of the engines. The men of the R.E. detachment were split up amongst the various departments according to their trades, the majority being in the platelaying party, but several were in the locomotive department and others employed on earthworks and maintenance.

Notes on Locomotive Work.

The locomotives in use consisted of:—

Six 4–8–0 tender engines built by The North British Loco. Co.
Two 4–8–0 tender engines built by Hawthorne, Leslie & Co.
Two 2–6–2 tender engines built by Nasmyth, Wilson & Co.
Three 2–6–0 tender engines built by Hawthorne, Leslie & Co.
Three 0–6–0 tank shunting engines built by The Hunslet Engine Co.
Two 0–6–0 tank shunting engines built by Hudswell, Clarke & Co.

Thus it will be seen that no less than six different types of engines were employed. This was more or less unavoidable owing in great measure to the engineering strike on the North East Coast in 1908, but such reduplication of types should if possible be avoided. Spare parts for each separate type have to be kept not only at headquarters but at each running shed, some of which may never be used but must be ready to hand in case of breakdown as nothing can be obtained from England in less than two months. Three different classes probably would have been sufficient, one heavy and one light tender class for use on the main line, and one fairly heavy shunting class.

Only engines built by firms of the highest standing should be bought, owing to the rough usage to which they are subjected and which makes it imperative that only the best materials and workmanship should be used. Two instances occurred of newly-made banks subsiding under the weight of heavy engines, the engine in the one case turning over on its side and in the other turning over and sliding to the bottom of an 18′ bank. In the first case the engine was at work again within five days of being righted, and in the second the engine was taken into the shops and overhauled but had sustained no material damage beyond the breakage of a few minor details such as lamps, glasses, etc. In both cases had the materials or workmanship, especially of the boilers and frames, been in any way faulty, serious damage would have resulted.

The question of spare parts is a most important one, and to purchase a very complete supply of these, especially for the first year's work, is undoubtedly an economy. They can usually be turned out cheaper and better in England than in the local workshops, and in the case of such parts as cannot be made locally an engine may be laid up for a long time awaiting the arrival from England of some necessary part. This does not apply so fully in the case of brasses, bushes, etc., as, unless a large proportion of these are made locally, it is difficult to find a use for the scrap brass obtained from the old ones. Even in this case a complete supply should be stocked for the first year. The running sheds along the line must be kept supplied with a sufficient number of such spares for normal running requirements, and replenished as required. It is very useful if time permits to compile a "Normal Stock List" showing the normal stock it is proposed to keep on hand; this also simplifies the work of making up yearly or half-yearly indents. In these remarks, as in the previous ones, it is assumed that there is no large parent line or workshops close at hand from which stores can be obtained.

Ample storage accommodation also repays the extra expenditure as stores can then be properly sorted and looked after, whereas, where little space is provided for the purpose, there is a great liability to confusion and consequent waste.

The sections into which the line was split up were roughly about 120 miles long, a running shed being provided at the end of each section; this also constituted the normal run for an engine and its driver. These sheds were all provided with wheel pits in addition to the ordinary examination pit. The type used consisted of a concrete pit of sufficient depth to admit of a pair of driving wheels being dropped out clear of an engine standing over the pit. In the top edge of each transverse wall of the pit, a cross-girder was bedded into the concrete and to it were bolted the rail-bearing girders which took the weight of any engine passing over. The short lengths of rail across the pit were fishplated in the ordinary way and so both the rails and girders were easily removed after an engine had been placed in position over the pit. The wheels were then lowered by a long-screwed jack on to a trolley at the bottom of the pit, which was made sufficiently broad on one side to allow of the wheels being raised, if necessary, and taken away clear of the engine above. It is interesting to note how little use is made in England of wheel pits, the work of removing wheels being very often done by the clumsy method of jacking up the engine, which, unless care is taken, is also more dangerous.

Where Walschaert or other forms of external valve gear are used, a useful type of inspection pit is one which has a narrow pit running along each side of the main pit, the rails being carried on walls running between; the subsidiary pits are about the same depth as the main one. The men detailed to do any work on the gear can then stand to do it instead of having to kneel or even lie down as is ordinarily necessary.

Great difficulty was experienced in the last year's platelaying in keeping the engines on the northernmost section in decent running order, as the running shed and water supply at Kaduna were not completed until after railhead had reached Kano, by which time the main stress of the work was over. This meant that no proper running repairs could be carried out north of Minna which was 244 miles away from Kano. To get over this difficulty a temporary wheel pit was made at Kaduna; a site containing good firm soil was chosen and a pit of the ordinary dimensions excavated. This was lined with sleepers for its whole depth, the sleepers being held in position by rails driven as deep as possible into the ground, and anchored back. Girders and rails as for the ordinary wheel pit were used. This worked admirably as a temporary expedient for over three months, and enabled work to be carried out at Kaduna which would otherwise have had to be sent down to Minna.

The absence of any facilities for washing out engines at Kaduna presented more difficulties, as the water on the whole of the Kaduna-Kano section was extremely bad. This necessitated frequent changing of engines and sending them right back at first to Minna whenever washing out became necessary. Latterly this was remedied by an ingenious apparatus devised by one of the Assistant Locomotive Superintendents. On the North British Loco. Co.'s engines the clack box of the injector had a cock to shut off connection with the boiler, and also a screwed cap on top which could be removed for purposes of inspection. A coupling was made which screwed into the seating of the latter and coupled at the other end to a long length of armoured hose fitted with a wash-out nozzle. This coupling was attached to an engine under steam, the stop-cock to the engine having first been closed; then, when the injector was worked, it delivered a jet of water through the wash-out nozzle at very high pressure. The engine which was to be washed out was then pulled alongside the one under steam and could be washed out very quickly and efficiently. Another advantage was that the water used for washing out was very hot, and it was not necessary therefore to let the engine cool down before washing out which should always be done when cold water is used owing to the risk of damage to the boiler from the sudden change of temperature. The gear could be fitted to all the North British Loco. Co.'s engines, so that any engine of this class which happened to be available could be used to wash out any engine requiring it. The idea is a neat one, but can only be adapted for use with injectors having the clack box separate from the main injector.

The running sheds were fitted with the ordinary bench and forge together with a fairly large store and office for the foreman or driver in charge; the one at Minna had also a small foot-lathe and hand-shearing machine.

The main running arrangements were similar to the ordinary practice; an attempt was at one time made to let each driver have his own engine as it tends to make him look after it better, but it was found to be impossible during construction owing to scarcity of engines and cases of sickness amongst the drivers.

Each engine was at first fitted out with a complete set of tools which was handed over from driver to driver. But tools, such as spanners, were, as always, in great demand and had a mysterious knack of disappearing off the engine when it was near men belonging to other departments. A new system was then instituted; no tools were issued to engines, but each driver was given a locked-up tool-box fitted up complete with tools, gauge glasses, etc., which he took on to whichever engine he was detailed for, and for this box the driver was responsible. The results were excellent, the drivers liked it as they could rely on having a full kit of tools and very few tools disappeared after it was started.

Fuel.

When the line was projected it had been intended to burn coal, but the greater portion of the first year's supply went astray. It was therefore necessary to burn wood only at first, and the consignments of coal which did finally arrive were so small that mixed wood and coal had to be used. The results were surprisingly good, especially with some of the better woods, considering that the fire boxes had not been specially designed for the purpose. Even up to the end of construction, partly from motives of economy (coal at Baro costing 51s. a ton) but more largely owing to fear of shortage, mixed coal and wood were used except during the rainy season. On the shunting engines, where heavy steaming was not required, wood alone was used practically the whole time. For main line work the steaming qualities of the mixed fuel, although of course not to be compared with those of first-rate coal, gave sufficiently good results when it was used judiciously and the wood well seasoned. The main disadvantages were the sparks, the quantity of ash and the halts for re-wooding as a tender load of wood is consumed very quickly. Wood fuel was stacked at every watering station which were from 20 to 25 miles apart, and the gangs of woodcutters and water boys stationed at these places assisted in loading up. The usual quantity of coal allowed in these cases was about 20 to 25 lbs. per mile.

The cost of freight on the coal formed such a preponderating amount of the total cost that it paid to obtain the very best Welsh coal. This was done in the earlier consignments, but the wastage caused by the frequent rehandling from steamer to steamer was so great that quite an appreciable proportion was lost before it ever reached Baro, more especially in the case of Welsh coal which is very liable to crumble. Subsequently Patent fuel was obtained, the wastage in which was very small and which bears transport and exposure to weather very well.

Personnel.

The engine drivers met with on construction, especially in Africa are usually, I understand, rolling stones who go on from one construction job to another as they can earn better pay than on open-line work; they are a pretty rough class, unsteady and somewhat addicted to drink. The drivers on the Baro-Kano Railway, with the exception of eight N.C.O.'s and sappers, were drawn entirely from English railways; they were mostly firemen who had passed as drivers but had to wait some time before there would be vacancies for them as drivers, owing to the slow promotion.

They were chosen very carefully both by examination of their previous records and by personal interview. They proved to be a remarkably steady and hard-working set, two essential qualities where men have to work very often "on their own"; in fact no single case of drink occurred during the whole time. The work was very trying and the hours long.

The firemen were natives, the majority of whom at the start had never seen a locomotive before, and, although they improved and will improve further as time goes on, they were never efficient. This of course threw a lot more work and responsibility on the drivers. The same drivers and firemen always worked together so that the driver reaped the advantage of any instruction he imparted.

Natives from the coast colonies were used for the shunting engines; in French West Africa native drivers are employed throughout, but, although the French native artizans appear to be more intelligent than the English coast natives, I think the white driver, although much more expensive, is more economical in the long run when repairs and upkeep of stock are taken into consideration.

WORKSHOPS.

The workshops at Baro were simple and inexpensive and call for little comment. The only item of special interest was the gear used for engine erection; this consisted of a tall gantry built up out of 12" x 12" baulks, the lifting tackle being a 15-ton differential tackle. This served its purpose but is now being replaced by a proper traversing overhead crane.

After the first year all wooden sleepers, joists, etc., were cut from local timber. The timber used most was a species of bastard mahogany; the forest was situated on the line about 20 miles north of Baro, where the sawmill was installed, the timber being brought down in the log. It was impossible to erect the sawmill on the actual site as it was too unhealthy. The mill consisted of a horizontal log band saw for splitting up the logs, a large circular saw with self-moving table, two smaller circular saws, a planing and surfacing machine, and the usual accessories such as saw-sharpening machines. The chief trouble experienced was in the warping of the timber due to having insufficient time which could be allowed for seasoning in order to keep up with the heavy demands for sleepers and scantlings.

An ice machine, a soda-water machine and a large condensed water apparatus were attached to the workshops and undoubtedly contributed largely to the comparatively clean bill of health.

Coast natives were employed in the workshops supervised by European foremen, but they were very inefficient and all special work had to be done by the white foremen. It is hoped in time however to institute a proper apprenticeship scheme for training the natives of the country but careful white supervision will always be a necessity.

ECHOES FROM THE ENGINE ROOM.

By "INSPECTOR."

INTRODUCTION.

"INSPECTOR" has, for some time past, been concerned with pumping machinery ranging up to 80-H.P. and with various direct current electrical installations of small size.

These "Echoes" deal more particularly with the plants above referred to, but in order to harmonize them as a whole some use has been made of those valuable aids to the author of a technical pamphlet—"Scissors and paste."

THE PUMP FAMILY.

ECHO NO. 1.

PUMPS GENERALLY.

The pump family is a numerous one and it would be beyond the scope of these notes, as outlined in the "Introduction," to deal with all its many branches; attention is therefore confined to the more common varieties.

In order to avoid ambiguity it will be necessary to define briefly a few terms which, in pumping literature, have not always got a universally accepted meaning.

The terms "pump" and "pumping engine" are treated as being interchangeable although this may not be altogether accurate. The point is not of supreme importance. A triplex power pump certainly is a "pump" and not a pumping engine; the same may be said of a centrifugal pump, but what about the ordinary steam operated boiler feed pump? Strictly speaking the steam end of a pumping engine is a steam engine, and the water end is a pump.

It will be convenient to call those reciprocating pumps which have no rotary motion whatever in their main parts "straight line pumps." The smaller parts of such pumps may however have a semi-rotary movement *e.g.*, when fitted with valves of the Corliss type (see *Plate*).

Straight line pumps may be either simplex or duplex. The ordinary "Worthington" pump may be quoted as illustrating the latter class; of the former class there are several typical examples, made by such firms as Mumford, Weir, Evans and others.

There is some ambiguity in the meaning assigned to the term "direct acting" when applied to pumps. One of the merits that has been claimed for the "Worthington" type of pump is that it is direct acting. It is perfectly true that pumps of that type are direct acting, but the term is equally applicable to every pumping engine in which the pump rod forms a direct continuation of the steam piston rod, and it is suggested that the term is no less applicable to any pump in which the reciprocating movement of the piston rod is directly reproduced in the pump rod, without the intervention of cranks or levers between the two, whether the pump happens to be fitted with a flywheel or not, *e.g.* the ordinary wall Donkey Pump, and pumps of the "Cameron" type are examples of direct acting flywheel pumps.

The large variety in type suggests the conclusion that no one type is the best under all circumstances. As to which *is* the best for any particular case is often a debatable point. Some compromise is generally unavoidable since "best" may mean, in one case the cheapest, in another, the most economical in steam consumption, and so on. In considering the relative merits of different *types*, it must be presupposed that each type is equally well made. The fact, however, remains that, to some extent, certain makers have specialised in the manufacture of particular types and it is beyond question that some manufacturers can be better relied upon than others to use materials of the highest class. One is therefore, under certain circumstances, unavoidably oppressed with a feeling of uncertainty beforehand as to what type will best suit the requirements to be met. In that case it only remains to specify the duty which the pump has to perform, as well as the general and special factors in the case; select, if possible, the firms invited to tender; and then choose, from the offers received, that pump which is "best" having due regard to first cost, and guaranteed steam consumption, and possibly also to some other points such as simplicity and ease of erection.

One of the best examples in variety known to the writer is in the Hammersmith pumping station of the Metropolitan Water Board. Although the plant is on a large scale the station is well worth visiting by any one interested in pumping machinery.

This echo may be advantageously concluded by a postulate to the effect that, unless it is otherwise stated, all pumps between which comparisons are made are supposed to be in first-class working order. It is necessary to mention this in order to eliminate the uncertain variables due to wear; facilities for repairs and renewals; etc.

Echo No. 2.

MISCELLANEOUS PUMPS.

(*a*). *Air Lift Pumps.*—Air lift pumps are not dealt with herein. The *Water Supply Manual* issued by the War Office in 1909 may be consulted. "Inspector" has come across but few pumps of this type in his wanderings, and the question does not seem to call for any business with the paste pot.

(*b*). *Hydraulic Rams.*—Hydraulic rams must unfortunately be classed with air lift pumps except that as the question is considerably simpler a few general remarks are perhaps permissible. (*Vide* also the *Water Supply Manual*).

Rams may be divided into two classes, "A" and "B." In "A" class the ram pumps part of the water which is supplied to work it. In "B" class the ram is arranged to pump water from one source when supplied with water from another source, but the suction lift of the water pumped should not exceed 5' or 6'. "B" class can therefore be used to pump clean water and to be operated by (a larger volume of) dirty water.

The ratio between driving water and water pumped depends partly upon the design of ram, but chiefly upon the relationship between the head available for working the ram and that to which the water is pumped. If the former variable is neglected then the latter relationship may be expressed generally in the form

$$\frac{Q \times h}{q \times H} = \frac{3}{2}$$

where "Q" is the quantity of driving water, "h" the head under which it works, "q" the quantity of water pumped to a head "H." For example if H = 100', and h = 10', then substituting $\frac{1}{10}$ H for "h" in the above equation we get $q = \frac{1}{15}$ Q. In other words $\frac{1}{15}$th of the driving water is pumped to a height of 100' if the driving head is 10'. This general rule is however approximate only since the greater the difference between "H" and "h" the less efficient will the ram be.

The driving head may be anything over 3' up to one-half of the head pumped against. For a driving head up to 12' the drive-pipe (or "flume") may be vertical but for higher heads it should be laid to an average gradient of 45° in order to avoid severe shocks on the body of the ram.

Rams may be adjusted to work with varying quantities of driving water down to $\frac{1}{2}$ the maximum for which designed. They should have gunmetal valves and seats, and must have large air vessels on the delivery side.

(*c*). *Express Pumps.*—Except to mention them as a modern branch of the family, "express" pumps are but briefly dealt with as they do not figure at present in "the engine room." By "Express Pump" is meant that class of reciprocating pump, in which the suction and delivery valves, or possibly only the suction valves, are mechanically operated, thereby rendering it possible to run the pump at a high speed *i.e.* quick revolution.

The Reidler and Oddie-Barclay may be referred to as types. The latter pump, manufactured by Messrs. A. Barclay and Co., Kilmarnock, has figured in the proceedings of some of the engineering societies, and has been used to some extent for mine work. It would seem that a pump which is capable of standing up to the trying conditions of mine-pumping should have got past the teething stage, and ought to be good enough for general purposes.

Although the "Hatfield" pump, made by Merryweather, is a quick revolution reciprocating pump it would not come under the category of "Express" pumps since its valves are not mechanically operated.

It may be remarked that it is practicable to run a pump at a relatively high periodicity if it has a large valve area, given by a number of valves with small lift, even though the valves are not operated mechanically.

ECHO No. 3.

INJECTORS AND EJECTORS.

Injectors are principally used for feeding boilers either as a standby to the usual arrangements, or, in the case of small stationary boilers, as the normal device for the purpose.

They are made in a great variety of forms and types for different duties as briefly enumerated below.

Exhaust steam type for handling cold water against pressures up to 75 lb. per square inch.

Exhaust steam types with auxiliary live steam connection, capable of working against pressures up to 200 lb. per square inch when supplied with water not exceeding a temperature of 75° Fahrenheit.

Live steam types, lifting and non-lifting, and for "hot" and "cold" water.

Although the type and pattern of injector should be selected with special reference to the duty to be done, any of the standard leading makes are capable of working over a large range of pressures *i.e.* they will take steam from, and supply water to, boilers working at pressures ranging between 20 and 160 lb. per square inch.

Like injectors, ejectors are made for use with exhaust and with live steam. Apart from their use as air exhausters, referred to in Echo No. 17, live steam ejectors are principally of value in "the engine room" for intermittently removing water from sumps, etc.

Injectors and ejectors appreciably raise the temperature of the water passing through them. They are not efficient "pumping engines," but this want of efficiency is, to a great extent, counter-balanced if the arrangements enable the increased temperature of the water delivered to be made use of advantageously.

With steam at 50 lb. and a 20′ head an ejector will raise the temperature of the water about 20° Fah. Therefore theoretically $\frac{1100}{20}=55$ lb. of water will be lifted for every pound of steam. (*Vide* Echo No. 4). The steam consumption per P.H.P. hour may however be taken at between 800 and 1,000 lb.

Although, under many conditions of steam pressure and temperature of water, either device herein referred to will satisfactorily "lift" its water an injector should preferably be fixed so that the water supply thereto is given under a small head. For the live steam ejector it is usual to allow a small lift of 2′ or 3′ if the total head to be worked against exceeds the suction lift practicable having regard to the temperature of the water to be pumped. For both classes of apparatus the supply must moreover be given under a steady pressure; neither apparatus will work satisfactorily if the supply pipe to it is taken off the delivery pipe from, or supply pipe to, a reciprocating pump which is at work.

Makers' catalogues may be consulted as to such details as steam pressures, maximum lifts, heads, gallons per minute, temperature rise of water, etc.

Echo No. 4.

PUMPS OF THE SAVERY TYPE.

The best known type of "Savery pumping engine" is probably the "Pulsometer," but there are several engines of this type made by different firms such as the "Expulsor," "Aqua Thruster," and others.

Although a "pulsometer" is a very much more efficient apparatus for shifting water than is an ejector it is nevertheless not suitable for a permanent water supply. On the other hand a pump of this type is well suited for work of a temporary nature.

Makers' catalogues may be referred to details as to steam pressures, lifts, etc.

Steam Pressure (lb.)		Head, Feet.
30	......	40
50	......	80
60	......	90

For suctions above 5′ a foot valve is desirable but if possible the lift should be kept low. For heads above 20′ a reflux valve should be fitted close to the pump. Air vessels on suction and delivery should be provided if the distances are considerable.

Maximum head recommended is not more than 90′, although some types are made for lifts up to 150′.

For a lift of 20′ and with steam at 50 lb. pressure the temperature of the water passing through the "pulsometer" is raised about 4° Fah. If the number of B.Th.U. in one pound of steam at a pressure of 50 lb. per square inch is taken as 1,100, then this 1 lb. will raise the temperature of $\frac{1100}{4} = 275$ lb. of water 4° Fah. and theoretically 1 lb. of steam will be required for every 275 lb. of water lifted. The steam consumption per P.H.P. hour may however be taken at about 500 lb.

A "pulsometer," and its suction pipe, must be charged with water before steam is turned on.

ECHO No. 5.

PISTON PUMPS.

The "thing" that pushes the water in a piston pump is so very similar to the piston of a steam engine that no special explanation as to the meaning to be assigned to the term "piston pump" seems necessary. In a pump however the piston is sometimes called a "bucket," although strictly speaking the term "bucket" should only be applied to a piston containing a valve, *e.g.* the bucket of a bore-hole pump.

Both in the steam cylinder and in the pump cylinder the piston itself is a comparatively easy fit in the cylinder, and in either case the piston must be packed in some way, in order to make it fit the cylinder closely. In the steam cylinder, as is well known, closeness of fit is attained by means of piston rings which are generally made of cast iron. This procedure would not be suitable for a water pump, as the rings would soon rust up and fail to efficiently perform their proper function. There is, however, a considerable choice as to the material to be used for packing the piston of a water pump *e.g.* leather cups, rope or other fibrous packing, rubber, ebonite, or vulcanized fibre rings or discs, and, for certain duties, metal rings. Leather and rubber are suitable for cold water only; neither is of any use if the pump has to work with hot water, in which case either ebonite, or vulcanized fibre, seems to give as good results as anything else.

If the pump is to be used with hot water, say 120° Fah. and over, the cylinder should be fitted with a renewable brass liner, and the pump rod should be made of bronze. The brass liner is useful in any case for a water pump, but its presence entails an increase in cost.

Piston pumps are used for boiler feeding for all ordinary pressures, and for "general service" for heads up to about 300′. They are not suitable for use with gritty water as the cylinder, or liner, cuts too quickly and the piston packing only lasts a short time. An exception as to their use with gritty water is however referred to under the heading of "Bore-hole Pumps."

Echo No. 6.

PLUNGER PUMPS.

So far as concerns these notes, by Plunger Pump is meant that pattern of pump in which the business part of the pump, corresponding to the piston in a steam engine, consists of a hollow cylinder, the length of which is considerable in proportion to its diameter. The bore of this cylinder is closed in the middle by a stout partition to which is connected the pump rod. The pump chamber is divided into two similar parts by a diaphragm. The cylinder or plunger, slides to and fro in a deep sleeve which is bolted to the diaphragm above referred to. With the aid of a suitable metal packing ring, a watertight joint is made between the sleeve and the diaphragm ; the sleeve fits the plunger closely, the all round clearance between the two, when new, being of the order of 0·00025″ per inch diameter of plunger. No packing whatever is used between plunger and sleeve, and it is rarely necessary to refit the plunger and sleeve until the clearance between the two reaches ten times the figure given above. Ordinarily the plunger is made of cast iron and the sleeve of gunmetal or bronze.

With the arrangement described, no attention whatever is required for years if the water is clean and free from grit or silt. Further it is possible, within limits, to alter the size of the plunger used if the actual pumping conditions render such a course desirable. In one case with which "Inspector" was concerned new plungers, 50 per cent. greater in area than the original plungers, were fitted because it was found that the actual head against the pumps was considerably less than was anticipated.

This type of pump is referred to in the Worthington Pump Co.'s catalogue as the "Regular Pattern," or as the "Plunger and Ring" pattern and is regarded as suitable for heads up to 350′.

The piston-like "thing" above mentioned is legitimately called a Plunger, and therefore it is not unreasonable to call the pump concerned a "Plunger pump," even though the term may be sometimes used to describe pumps which are referred to in these notes as Ram pumps.

The pump rod is generally made of mild steel but the extra cost of bronze rods would often be justifiable, either when the pump is liable to be left standing for long periods, or if the water is at all corrosive. In either case what happens is that the pump rod corrodes, especially where it is not much polished by the packing in the gland, the rod then gets rough, and this roughness soon pulls the packing to pieces. "Inspector" has not, however, come across a "general service" water pumping engine with bronze pump rods, although many boiler feed pumps have rods of that material.

ECHO No. 7.

RAM PUMPS.

It is scarcely necessary to define here what is meant by a "Ram Pump" as the term is not ambiguous.

Whilst ram pumps can be used for all pressures, pumps of this type only, should be used for extra high heads. Ram pumps are also particularly suitable for use with gritty water.

The rams may be either of gunmetal, or they may be cased with that material, or they may be of cast iron; the class of water to be pumped is undoubtedly a factor in the case. The writer is acquainted with differential ram pumps with cast-iron rams which have been working satisfactorily for some years against a head of over 1,500′, and in another case the rams are of gunmetal and the head is over 1,400′. From this, one may conclude that the head has but little bearing upon the material to be used, although the textbooks rather favour gunmetal for the higher heads. As in the case of the rods of plunger pumps more important considerations seem to be (i.) the quality of the water and (ii.) to what extent the pump is likely to be left standing.

ECHO No. 8.

DEEP WELL AND BOREHOLE PUMPS.

Deep Well and Borehole Pumps are dealt with at some length in the *Water Supply Manual*, but it seems permissible to make some supplementary remarks here.

Although water may not actually be within suction distance of ground level, it may sometimes happen that it can be obtained within the accepted limits of suction lift if the pumps are placed some few feet below the general level of the site. Three such instances are known to "Inspector." In one, a steam driven station, the boilers are placed at ground level and the pump room floor is 11′ below this. The plant is condensing, and the condensed steam is discharged at ground level by the air pumps direct without difficulty and without harmfully affecting the vacuum. In the two other cases the pumps are driven by oil engines, and in each case the engine room floor is about 10′ below ground level and the pumps are about 10′ lower; the drive between engines and pumps is by inclined belt. In other cases, if the vertical distance between pump and engine is small, an ordinary vertical type of pump can be driven direct off a vertical engine if the pump rods are suitably extended, up to a limit of about 15′ or 20′ dependent upon the size of the plant. This method of direct driving is applicable to any ordinary project provided the pumps are single acting on the up stroke *i.e.* as in the standard type of deep well pump. Double acting pump ends can only be used if the vertical distance is short.

By placing the pumps below ground level as suggested in the early part of the preceding paragraph, long pump rods are eliminated and the whole of the plant can be placed under suitable cover and can there be readily given proper supervision. However there are many cases when the pump must be placed down the well and be driven by rods from the surface. When so situated the barrels of the pumps should be made of brass or gunmetal in the smaller sizes or be "brass fitted" in the larger sizes, and in any case the pump rods themselves (*i.e.* not the well, or "spear," rods) should be made of bronze or similar material.

Having regard to the cost of constructing a well large enough to contain, and give access to, a well pump, pumps of this type are not ordinarily used for heads above 150′, and although such pumps could doubtless be made for any reasonable head, it is believed that 400′ is about the maximum for which they are constructed in practice.

If it is expected, or found by a trial boring, that water is not obtained within about 200′ below ground, a borehole pump would usually be provided in preference to one of the deep well type. It frequently happens, however that, by extending the boring, water is struck which will rise to within 150′ of the surface, and in such a case the storage capacity afforded by a deep well may be advantageous. (*Vide* account of Sheerness Water Supply in *R.E. Journal* for July, 1909). A decision as to whether to make use of a deep well, or a borehole, or a combination of the two, must be arrived at upon the merits of the case; but corresponding to the limit of 150′ as applicable to the deep well pump there is a normal limit of 300′ for the borehole pump, and although the boring itself may be considerably greater, it will not usually be justifiable to pump from a greater depth than 500′.

It is sometimes thought that a deep well pump will only work when above water. That is not so, but the trouble is that if it breaks down when submerged it may be difficult and costly to recover. A borehole pump, on the other hand, is constructed to work submerged and is so arranged that the rods, and bucket can be drawn up for inspection and repair, and the clack or bottom valve can also be "fished" up and replaced.

Deep well pumps are generally driven by rods off a "top gear," consisting of a well frame, crankshaft, gearing and possibly fast and loose pulleys for a belt drive. The driving power may be electric motor, oil engine, or steam engine, but in every case, unless the space available is insufficient, a belt drive should be used between the motive power and the top gear.

The "spear" rods need guiding at about 10' intervals to prevent swaying and other irregular movements. The type of guide will depend upon the design of rod adopted, but the simpler the guide the more likely is it to be satisfactory in operation.

In some cases the pump is fixed in a dry well excavated alongside the well proper. This entails extra cost, and seems to be quite unnecessary. With reasonable precautions there is no reason why the water in the well should be polluted either by oil from the pump gear, or otherwise, even though the pump is fixed in the well itself.

A characteristic feature of the Borehole Pump, compared with other reciprocating pumps, is the length of stroke relatively to the diameter of the bucket. The amount of space available in the bucket for valves is strictly limited and therefore rapid reversals in direction are inadmissible. Consequently, if a considerable delivery of water is required, a long stroke is essential. A "straight line" engine is the best for driving a long stroke borehole pump, and can be obtained cheaper than any flywheel engine of equal quality for the same duty. Moreover it can, if necessary, be readily fitted with suitable pausing gear which enables the valves to seat properly at the end of each stroke before the return stroke commences.

It is scarcely to be expected that a deep well pump will receive such careful attention as a surface pump, and in the case of a borehole the pump cannot be examined without withdrawing it; hence in neither case is it desirable to put more work upon the below ground pump than is unavoidable. If the total head, from water level to point of delivery, does not exceed 150' it may be effected by one lift, but even in this case if the size of plant exceeds 15 P.H.P., and certainly in most other cases when the total lift exceeds 150' it is preferable that the below ground pump should deliver the water into a sump or tank at ground level only. From this sump the water is pumped by an altogether separate pump to the distribution reservoir or other point above ground level. Both pumps may be driven off the one engine.

In all cases of pumping from wells or boreholes there is likely to be a good deal of grit in the water at first, and therefore, if the permanent plant must be used for dealing with this water, it is desirable to allow the bucket to be a comparatively easy fit in the pump barrel to start with; the slip of the pump may be high, for the time being, but the bucket and barrel will be saved from excessive wear. This suggestion only applies to bucket pumps.

In concluding this echo it is only right to say that a more liberal use has here been made of the scissors and paste-pot than in other cases, as "Inspector" has had but little to do with deep well pumps and nothing to do with borehole plant.

ECHO NO. 9.

CENTRIFUGAL PUMPS.

Although so far as is known, there is no really good literature dealing in popular language with centrifugal and turbine pumps, no comprehensive attempt to remedy the deficiency is intended here.

Since the introduction of turbine pumps there seems to be a tendency to regard such pumps as the best for all requirements. Before the advent of the modern turbine pump, centrifugal pumps could only compete satisfactorily and economically with reciprocating pumps when the conditions necessitated large quantities of water delivered against relatively low heads. For such requirements the centrifugal pump still holds its own, and the improvements in the designs of the centrifugal pump which led to the evolution of the turbine pump has enabled such pumps to be used with advantage under a considerably extended range of conditions, but by no means universally.

The head against which a centrifugal pump will deliver water depends upon the peripheral velocity of the impeller, the relationship between the two being deduced directly from the formula $V = \sqrt{2g.H}$

A lift of about 100′ was about the maximum for which ordinary centrifugal pumps were constructed, and although the usual lifts were considerably lower than this it was possible by coupling up two or more pumps "in series" to reach heads much in excess of 100′.

Although various manufacturers of modern turbine, or "high pressure" centrifugal, pumps claim special merits for their own type, it is questionable if there is much to choose, in any way, between the best of the different makes. The turbine pump seems to owe its development to a combination, of the "Venturi Law" and the centrifugal pump. There is little doubt that the efficient conversion of velocity into pressure entails carefully made and exceedingly smooth passages in the pump. It seems equally certain that the efficiency of a turbine pump depends greatly upon the correct form of the blades of the impeller.

In turbine, or high pressure centrifugal, pumps the series arrangement above referred to is still adopted for high heads, but in modern pumps the various impellers are enclosed in a suitably designed single casing.

Practical considerations limit the number of r.p.m. at which it is desirable to drive an impeller of a given diameter. This reason, amongst others, enables a single large impeller to be used for heads up to 400′ if the quantity of water to be delivered is large, but if the quantity is small, entailing the use of an impeller of small diameter, the head attainable by a single impeller, is more than correspondingly reduced.

A general rule may be deduced from the above considerations to the effect that a centrifugal (or a turbine) pump should only be used if the number of gallons to be delivered per minute is equal to or greater than the total head. The charming simplicity of this rule leads one to suspect its justification on scientific grounds, but it may nevertheless be taken as a useful general guide.

Apart from the limited use of centrifugal pumps for handling large quantities against low heads, *e.g.* drainage, irrigation, dock, and salvage work, circulating the cooling water for condensers, etc., their descendants, turbine pumps, are most largely used in connection with electrical power schemes. The speeds at which it is necessary to drive turbine (and also centrifugal) pumps render them suitable for direct coupling to electric motors, especially to A.C. motors the efficiency of which is best at high speeds.

As a pumping engine the efficiencies of centrifugal and turbine pumps compares unfavourably with corresponding figures for reciprocating pumps, except when large quantities of water have to be pumped against very low heads. All centrifugal and turbine pumps attain their maximum efficiency, for every speed at which they are driven, for a definite number of gallons and for a definite head. If we take the total head as being dependent on the speed, or conversely, then if while the speed remains constant, the head varies the output of water will vary greatly—especially in the case of centrifugal pumps, less so as regards turbine pumps. Alteration of head may for instance, occur by a change in the level, of the water on the suction side, and if, for example the normal suction lift of 15′ is reduced to 5′ the effect will be a very greatly increased delivery of water from the pump and a *considerable increase in the B.H.P. required to drive it at a constant speed.* This peculiarity means that the motor, or other thing which drives the pump, must have a considerable margin of power, *or else the delivery from the pump must be controlled by a sluice valve* whereby the total head against the pump can be increased to compensate for a reduction of head on the suction side.

If "H" is the total head in feet, "G" the gallons delivered per minute, and "R" the revolutions per minute at which the pump is driven then two of these three quantities are related to one another, approximately, by the following expressions, the third quantity being constant.

G varies as R.
G „ „ $\sqrt{H}$.
H „ „ R^2.

Although a turbine (or centrifugal) pump will handle gritty water it will not do so without wear. If the head is high, entailing a high peripheral velocity of impeller, the wear on the blades will soon bring down the efficiency of the pump.

When once started, a centrifugal pump will operate satisfactorily with any ordinarily "lift" on the suction side, but both it, and its suction pipe, must be fully charged with water before the pump is started. To facilitate this charging the suction pipe should have a foot-valve, and a sluice valve should be fixed in the delivery pipe close to the pump. The sluice valve also performs another useful purpose; if it is closed, as it should be, when the pump is started, the pump is prevented from discharging any water and consequently the load on the pump is small. This enables the pump to be started up "light" and then by gradually opening the valve the load is brought on quietly. Further if the valve is closed before the speed of the pump is reduced there is a reasonable chance that a full charge of water will be retained in the rising main, which will probably facilitate "charging" before the work is again started.

Echo No. 10.

POWER PUMPS.

By the term Power Pump is meant a pump of that class which has one, two, or three, rams or pistons, driven off a crankshaft which is in turn driven by some source of power exterior to the pump itself.

Generally speaking some form of single reduction gearing forms an integral part of most power pumps, but if the head is a low one and the pump is small it may be possible to omit the gearing. On the other hand in the case of large pumps working against high heads it may be necessary to provide double reduction gearing.

Power pumps may be of the vertical or of the horizontal type and although standard power pumps are made in the vertical form for high heads and large outputs some makers prefer the horizontal pattern if the output is considerable, especially if the head against the pump is large. This seems a sound principle to follow, for whereas the vertical type is the more economical in floor space the horizontal type can be made more rigid and is, in the larger sizes, more readily accessible. If this view is accepted then it may be taken as a guide that wherever the available floor space permits it is preferable to use a horizontal type of pump for all heads over 350′ and for three throw pumps with rams over 6″ diam. × 9″ stroke. It is not intended to include hydraulic pressure pumps in this generalization; although such pumps are constructed for working against very high heads (or pressures) the quantity of water to be pumped is, as a rule, relatively small, and in practice it is apparently preferable to make these pumps in the vertical form.

The simplest pumps of this class have hollow rams similar to the trunk piston of an ordinary internal combustion engine. Such pumps are suitable for heads up to about 350'. For higher heads the outer end of the ram should terminate in, or be rigidly coupled to, a cross-head, which moves in suitable guides similar generally to the crosshead guides of a steam engine. There is a considerable variety in the designs followed as may be seen on reference to the catalogues of different makers.

As to whether the pump to be installed should be single throw, two throw, or three throw will ordinarily be settled by the quantity of water to be pumped. It may happen however that it is important either that large fluctuations in the flow of water must be avoided or that uniformity in the load against the driving agency is desirable; in such cases the merits of the three throw pump over the other classes deserve consideration. It would generally be desirable to adopt the three throw pump for water supply purposes, or for boiler feeding.

The bearings generally should be adjustable and, if the pump is to be fixed in an out of the way place, should be readily renewable. For the smaller sizes of pumps with hollow rams less than 6" in diameter the gudgeon pin bush is not usually adjustable, and in some designs with white metal main bearings the bearing metal is run direct into the recesses, formed for the purpose, in the framework of the pump; neither of these practices is to be recommended for a pump used for a permanent water supply far removed from workshop facilities.

Cast-iron rams are good enough for most cases, but brass-cased, or gunmetal, rams can be fitted if necessary, as in the case of other ram pumps.

In the case of 3-throw pumps the number of bearings to be provided for the crankshaft depends partly upon the size of the pump and partly upon the head to be worked against. The practice of different makers varies so much in this respect that no definite limits can be given; the smallest pumps have only two bearings, and the largest have four, or even five, crankshaft bearings, both in the vertical and horizontal types.

In the case of single reduction spur gearing although some makers employ cast iron both for the spur wheel and the pinion, the standard practice of other firms is to make the pinion of steel. Since the wear which is distributed over the many teeth of the spur wheel is concentrated on the few teeth of the pinion a case-hardened forged steel pinion is preferable to one of cast iron for a permanent job.

A small point in the working of hollow plunger power pumps which is apt to be neglected is the lubrication of the gudgeon pin. In horizontal pumps of this type a lubricator can be secured to the connecting rod and the oil carried by a small pipe, clipped to the rod, to the gudgeon pin bearing. In pumps of the vertical type the bottom of the plunger may be filled with oil to a depth sufficient to insure the lubrication of the moving parts. But in these pumps the plunger is sometimes made so short that its top edge comes just below the level of the top surface of the gland when the plunger is at the bottom of its stroke and if the stuffing box has been packed rather full. When this happens some of the leakage past the packing trickles over inside the plunger at every stroke and the water soon displaces the oil from the neighbourhood of the gudgeon pin.

The *Water Supply Manual*, already referred to, suggests the desirability of providing power pumps with a by-pass. In the case of pumps positively driven by oil engine or electric motor such a device is a necessity unless there is a friction clutch between the pump and the driving agency. In the case of a pump driven by a steam engine, or by belting and fast and loose pulleys off either an electric motor or an oil engine a by-pass is not required for sizes below 25-P.H.P. and its provision only adds needlessly to the cost of the pump. A steam engine can always be started up quietly under load, and in the case of a belt drive with striking gear the oil engine or electric motor can be started up "light." Large pumps would however usually have a by-pass, and when direct driven by A.C. motors of 50-B.H.P. and upwards a by-pass becomes a necessity, more particularly so when the head against the pumps is a high one.

As is the case with other types of pump, the efficiency of a power pump increases with the size. The following figures may be taken as a guide :—

P.H.P.	Efficiency.
Below 5	50 per cent.
5	60 "
10	65 "
25	70 "
100	75 "

Echo No. 11.

AIR PUMPS.

Mention must be made of the "Edwards" air pump as that type of pump is so universally used now. It is believed that this pump made its *début* on "tramp" steamers, but to the average landsman it is probably best known as a valuable accessory in electric power stations. In such stations the Edwards air pump is generally operated at fairly high speed, 150 r.p.m. or so, but it may be useful to know that this type of pump will also give satisfaction at speeds as low as 20 r.p.m.

The "Worthington type" surface condensing pumping engines manufactured by Messrs. J. Simpson & Co. of London and Newark are fitted with air pumps of the "Plunger" type, with cast-iron plungers working in gunmetal sleeves. The oil carried over from the steam cylinders with the exhaust steam adequately lubricates the moving parts, and it is found that this type of air pump can be relied upon to give every satisfaction under those conditions. The wear is small and repairs are easily carried out.

In Echo No. 17 mention is made of the necessity for providing some means of exhausting the air from the suction chamber therein referred to. Where steam is not available, some form of vacuum pump would be required if exhausting arrangements were essential. Such pumps are readily obtainable for driving by hand or by power.

Recently high speed centrifugal pumps of special design have been employed as air pumps. The Leblanc pump may be quoted as an example. In order to enable this type of pump to operate as a vacuum pump it is necessary to supply it continuously with a certain amount of injection water whereby the air is trapped and so discharged by the pump. The injection water can be used repeatedly over and over again.

(*To be continued*).

TRANSCRIPT.

THE ROYAL ENGINEERS OF THE TERRITORIAL FORCE.

Reproduced, by kind permission of the Editors, from No. 2,382, Vol. XCII., of *Engineering*.

THE importance of the engineer services to the efficiency and well-being of an army in the field can hardly be overestimated. Modern inventions and methods of warfare all tend to magnify the *rôle* assigned to the engineer. The more science is brought to bear upon, and adapted to, the service of war, the greater is the part played by the technical corps of an army. It is, however, often not thoroughly appreciated how all the specialized branches of the army—artillery, engineers, medical corps, and even cavalry, are designed and used really in the service of infantry, "the pith and strength of battle." The infantry is the arm which has ultimately to decide the conflict, and to fight and win or lose battles. The *raison d'être* of the other branches of the Service is to cover, protect, and assist the infantry when and where required, and to enable it to maintain the position taken up, or, if necessary, to perform similar duties during a retirement.

Each arm—cavalry, artillery, and infantry—has a power peculiar to itself, yet is dependent to a greater or less extent upon the co-operation of the other arms. They all require and rely on the assistance of the Royal Engineers, whether in the arrangements for camps and bivouacs, building and demolition of bridges, communications, provision of entrenchments and fortifications, to name a few of the duties devolving upon the engineer corps.

General Sir John French, G.C.B., Inspector-General of the Forces, in the course of his address to the cadets at his recent official inspection of the Royal Military Academy at Woolwich, especially emphasized the increasing importance and greater necessity of the services of a highly skilled corps of Royal Engineers, under modern practice and conditions of war. The British Army at present is allotted a smaller proportion of engineers than is the case in many of the great foreign armies. During the South African and Manchurian Campaigns the necessity of highly-trained and efficient engineer services was more marked and realized than ever before. Whilst the great principles of war remain, as always, immutable, modern weapons and conditions have revolutionized the practice; and consequently the art of the engineer, and, indeed, of all the so-called scientific or technical services, is called upon to an extent not previously contemplated. The Territorial Army is an integral part of the Empire's defences, as our military forces are now organized. We desire to direct the attention and interest of engineers in civil life to the Royal Engineers of the Territorial Force.

The organization of the Territorial Force is that of an army intended for war. It provides for fourteen divisions, with the proper number of corps and army troops. A division at full strength consists roughly of 20,000 officers and men. To each division is allotted its quota of Royal Engineers, in accordance with the establishment, known as the Divisional Engineers, consisting of two field companies and a telegraph company. In addition to the Divisional Engineers, whose headquarters are situated in various parts of the country, there are wireless, cable, and air-line telegraph companies. These latter may be said to be divided into five groups—one group in each of the London, Northern (Leeds), Scottish (Glasgow), Southern (Birmingham), and Western (Liverpool) commands. There is a balloon company, with headquarters in London, and a railway battalion at Crewe. The force further includes fortress engineers, and works and electric-light companies, situated in different parts, and electrical engineers in London.

In the monthly army list, published by authority, and obtainable through any bookseller, price 1s. 6d., will be found a complete list of the various Royal Engineer units of the Territorial Force, with the addresses of the various headquarters and names of officers serving. It will be seen that a complete organization has been worked out and established, and that opportunities exist for engineers to assist in the defence of the country by serving in the Territorial Army, and particularly in the Royal Engineers branch of that force.

Now it seems clear that officers of the Royal Engineers in the Territorial Force ought to be engineers in civil life, apart from any military training, or at least ought to have had a sound engineering training. The regular Royal Engineer officers are the most highly trained and carefully selected of all the officers of the Army. We understand that in the Territorial Royal Engineers large numbers of the commissioned ranks are without any engineering training, or experience, in civil life, obtained directly from following some branch of engineering or any of the allied vocations.

We realize the difficulty there is in obtaining a full supply of suitable candidates for commissions in all branches of the Territorial Force. We admire the energy and patriotic spirit of those who, having no connection with engineering, hold commissions in the Territorial Royal Engineers. Under present circumstances, no doubt, without them the force could not have been raised. In our opinion, however, it is a *sine quâ non* that if the Territorial Engineers are to approach and maintain the required standard of efficiency they should be officered by men with engineering training in civil life. In some few instances we believe commanding officers of engineers insist on some engineering or allied qualification on the part of candidates they recommend for commissions under their command. This course, instead of being the exception, ought to be the rule. An ample supply of men with the necessary qualifications is available; nobody can seriously dispute this. Anyone sufficiently interested may, by application, obtain a very good knowledge from the manual of military engineering and certain drill books, and up to a certain point may make himself a good officer. But he is not and cannot pretend to be either an engineer or an engineer officer in the proper sense. It would be easy to enlarge at length on the subject and point out many reasons why Territorial Royal Engineer officers ought, from every point of view, to have had some training and experience to fit them for their duties other than that obtainable on the Stock Exchange, in a lawyer's office, or other spheres of life totally removed from anything connected with engineering, buildings, or allied employments. We have not, however, space to do more than draw the attention of engineers to the matter. Most men have friends in the Territorial Force, and it is a simple matter, for anyone who will take the trouble. to find out full particulars.

The question of expense is sometimes a difficulty, but it is often exaggerated. The pay and allowances received when in camp will more than cover the annual expense incurred. On first joining probably an expenditure of £20 to £25 will provide all that is necessary in the way of uniform, etc., at any rate, for the first few years of service. After, say, a couple of years or so, a few extra pounds may be expended to make the kit more complete. The old extravagant methods and notions that existed in many volunteer regiments, and the constant drain on the pockets of officers in subscriptions to various regimental institutions, suppers, etc., are things of the past. Of course, a few regiments still exist in which it is somewhat expensive to hold a commission, but they are decidedly few, and even in these expenses have been reduced from what they were in volunteer days. Much useful information to anybody thinking of applying for a commission in the Territorial Royal Engineers, or any other branch of the force, is contained in the *Regulations for the Territorial Force and for County Associations*, 1910, obtainable for 6d. from any bookseller. Conditions of service, particulars as to pay, training, necessary uniform, with much other information, together with a copy of the Territorial and Reserve Forces Act, 1907, are included in this official publication.

Any candidate for a commission can obtain any particulars he may wish for from the secretary of his County Association, or from the adjutant of a local corps. A man who is thinking of applying for a commission will probably know some officer who will advise him, or tell him, how to set about it. In the event of his not knowing any Territorial officers, he should make an appointment to see the Secretary of the County Association, or the adjutant of the corps or regiment in which he wishes to apply for a commission. The adjutant will give any information, and explain the regulations and conditions of service, and arrange for an interview with the colonel or officer commanding. If the latter, after making enquiries about the candidate, considers him suitable, he will, when a vacancy occurs, recommend him for a commission, which, in the ordinary course, he will then receive.

No member of the Territorial Force can be compelled to serve, unless he volunteers to do so, outside the United Kingdom of Great Britain and Ireland. He must attend the minimum number of drills per annum laid down, which, in the Royal Engineers, is forty-five before the end of the first year of service, and fifteen in subsequent years, and he must also go into camp with his unit once a year for not less than eight days, and not more than fifteen days. If, however, some real and *boná-fide* reason arises why he cannot attend camp, the officer commanding can, in his discretion, grant leave of absence, and this is never in practice unreasonably withheld. During camp training all ranks receive Army rates of pay and allowances. A second lieutenant Royal Engineers draws 15s. 1d., increased to 17s. 1d. when he has passed for promotion to lieutenant; a lieutenant, 18s. 4d.; and a captain, £1 5s. 8½d. a day; but to be eligible to draw pay and allowances the minimum number of drills for each year must have been completed before going to camp. A drill consists of one hour's instruction, and any number of drills up to three may be performed in one day.

Before promotion to the rank of captain, the officer must attend a course of one month's duration at the School of Military Engineering at Chatham. This course may, however, if necessary, be spread over two years, a fortnight being taken at a time. Travelling expenses to and from Chatham are paid, and the officer receives the rate of pay and allowances, at Army rates, of his rank whilst attending the school of instruction. Further, if he passes a satisfactory examination at the termination of the course, an outfit allowance of £20 (in addition to pay, etc.) is granted, which goes a long way to meet the expenses incurred in buying uniform immediately upon receiving his commission.

In the event of great national emergency, and after the Army Reserve has been called to the colours, the King may issue a proclamation embodying the whole or part of the Territorial Army. In this event those called upon would be obliged to respond or be treated as deserters. The proclamation would not take effect if both Houses of Parliament presented a petition praying that the force should not be called up.

Arrangements are made whereby an officer who has temporarily to change his place of residence can be attached to a local corps for the performance of the necessary drills, or in the event of the change being permanent, can, when a vacancy occurs, exchange into another corps, provided the various commanding officers concerned approve the transfer. In the event of an officer having to go abroad, and wishing not to relinquish his commission, he may be seconded for four years from the termination of his first year's absence, if recommended by his commanding officer. If residing in a British Colony, or in Egypt, the officer may, on being recommended, be attached to a regular or local corps, for not more than two years in succession, for the purpose of carrying out any portion of his annual training. All officers of the Territorial Force are interested in and enjoy the work. Many are very keen and efficient, and devote much time to their military duties and education. The attendance required by the regulations is not enough to make a good or useful officer. The great majority do far more than the minimum laid down. These men find they can do it and choose to do it, and it is therefore difficult to believe that, with few exceptions, others cannot do likewise. Instead of a shortage of officers, there ought to be a list of candidates waiting for commissions in the Territorial Force, and particularly in the engineer branch. All ranks of the Territorial Army are, under the Act of 1907 constituting the force, exempt from jury service.

REVIEW.

PERMANENT FORTIFICATION.

By MAJOR VON BRUNNER. Translated for the General Staff by CAPT. R. WALKER, R.E.

THIS book has been selected for translation, as being a standard text-book in the Austrian Service, which has passed through seven editions.

It has been written for use in the Imperial Military Training Establishments, and for the instruction of officers of all arms. It does not therefore aim at being an exhaustive treatise on the subject.

The book contains only 99 pages, but the author, by confining himself strictly to the most modern practice of fortification, and by omitting all historical information and descriptions of more or less obsolete types of forts, has succeeded in condensing as much instruction as possible into the space available.

The greater part of the book is taken up with the protection of land fronts of fortresses, only 14 pages being devoted to coast defences. This latter portion has been abridged from the original, which is perhaps to be regretted, as it is the branch of the subject which is of more direct importance to the British military engineer. There are very few modern works on fortification written in the English language and some of these deal rather with principles than details of construction, and in some cases advocate particular theories. A book therefore which describes existing practice, and furnishes particulars of the types of works which are actually constructed on the Continent at the present time, is likely to prove very useful.

The illustrations are incorporated with the text and are necessarily of small size. They are however in most cases reductions to scale of working drawings, and the scale, and where necessary the levels, are given. They would therefore be of considerable assistance in preparing the designs for similar works.

General particulars are given of iron turrets and cupolas, and in accordance with Continental practice these are introduced into all the designs of permanent works for land defence. Other features of the typical designs of detached forts are simplicity of trace, the substitution of steel palisades for the escarp wall, the reliance on counterscarp galleries for the defence of the ditch, and the provision of parapets only for the use of infantry in the final stages of the siege.

A section of the book is devoted to the use of fortification in mountainous regions and the design of barrier forts and auxiliary arrangements for the defence of mountain passes.

In the coast defence section the proposals for the protection of harbours from naval attack are of the most complete description, and include not only heavy guns up to 12" calibre, but also light and medium armament, defence lights, an outer defence of naval mines, a minefield at the entrance to the inner harbour, a boom where practicable, and batteries on shore for discharging locomotive torpedoes.

It may be noted that though armour protection is advocated for coast batteries it is considered relatively of less importance for them than for land defences, more especially in the case of coast batteries on high sites.

Coast fortification even to a greater extent than land fortification consists largely in the proper employment of engineering appliances of a mechanical nature, and it is not possible in the small space occupied by this portion of the subject for the author to do more than mention the general arrangements recommended for defence.

For particulars of the various appliances, which are proposed for employment, it will be necessary to consult other books.

Permanent Fortification for the Imperial Military Training Establishments and for the Instruction of Officers of all Arms of the Austro-Hungarian Army. By Moritz Ritter von Brunner, Major, Engineer Staff, Austro-Hungarian Army. 7th edition; completely revised, 1909. Translated for the General Staff, 1911. Price 4s.; 99 pages.

NOTICES OF MAGAZINES.

NEUE MILITÄRISCHE BLÄTTER.

April, May, June, July, 1911.

(1). IS GERMANY IN NEED OF A FLEET?—A long and interesting article is given under this heading, discussing the *pros* and *cons* of a large sea force of which the following is a brief *résumé* :—

Forty years ago Germany was an almost exclusively agricultural state, to-day industry and commerce have increased enormously in importance. Forty years ago the population of Germany was 40,000,000 souls, to-day it is 65,000,000, and is increasing yearly at the rate of 900,000. The increased industry and commerce have created new needs. Raw stuffs are required which home products alone cannot supply; more food stuffs are required to feed the increased population; consequently the mercantile marine has increased in importance.

Forty years ago England alone ruled the seas and had all the overseas trade in her hands, since then she has had to fight the Germans in the fields of trade and between them England and Germany share the trade of the world.

Thus the protection of her trade and trading vessels is Germany's first reason for the possession of a fleet: the protection of her coast is a second reason. It is not uninteresting to notice that the author lays down that this protection is best carried out by offensive action on the high seas, and adds that it is to the above causes, and not to any ideas of attacking England, that the fleet owes its existence.

An objection was recently raised in the Reichstag that the fleet merely caused an increase in the British Navy corresponding to increases in the German fleet, and thus led to the expenditure of more money than ever on armaments. Further that the increase in importance in the navy was having a bad effect on the army, which always had been and always should be the backbone of Prussia's might. It was also stated that, whereas England had to keep up a large fleet because all her food stuffs came from over the seas and therefore loss of sea power would mean starvation to her, Germany could get supplies both overland and from the country itself.

The arguments against this objection were that although the internal industry of Germany is considerable, it is to a large extent dependent on the supply of raw material which comes from outside. Were this to cease numbers of factories would have to close down, and unemployment would be rife in the land. This means that Germany must have a fleet to protect her overseas trade.

It were equally sound, it is objected to the arguments of this deputy, to abolish the army on the grounds that a war with France is no longer likely, the peace of the whole world being ensured on the principle of a "commercially united Europe."

That this unification will ultimately take place, ends the writer, there can be no doubt, but it will not be till after many fights.

Engineers and Pioneers.—This article is an appreciation of the engineers' and pioneers' present position in the Germany Army.

Up to the present it has been rather the custom to look down on the engineer officer, mainly, perhaps, because of his necessary connection with things that are not purely military, in a word on account of his "D.O. work." The necessary result of such employment is to lead the officer to forget more and more that he is a soldier and hence deprive him of that spirit of the offensive with which every fighting man should be imbued. Permanent practice in the building of defensive works and fortifications tends to make him think of defence alone. It must, however, be remembered that a fortress is after all but an artificial means of strengthening a place, and thus reducing the number of men required to defend it so that more men can be employed in the field armies at some more threatened spot. It is therefore almost a weapon of offence, and the modern method of fortification increases this characteristic in that modern fortresses consist of battlefields strengthened at intervals by permanent works. All these factors are now bearing fruit, and the true use of the engineer is being slowly discovered as is shown by his attachment at present to the staffs of higher units on manœuvres.

Of late it has been the custom to call the pioneers the fourth arm. This practice is as false as that of designating them as the "technical arm." An "arm" possesses a distinct weapon; the infantry are armed with the rifle, so are the pioneers and communication troops, therefore it is only fair to consider them as infantry. They have received, it is true, a special training, but this does not authorize the use of the new appellation any more than does the statement that the spade is their weapon. A spade is a tool, not a weapon, and besides this its use is no longer confined to the pioneers only, every infantry soldier carries one.

Napoleon said: "A gun, bread, ammunition and entrenching tools, are things without which a soldier should never be." Modern tactics have merely increased the importance of taking and making cover. The days are now long since passed when the pioneer company was automatically detailed as escort to the guns; the F.S.R. lay down:—"Pioneers should as a rule accompany the advance guard." And again:—"Pioneers will also as a rule be allotted to the outposts, to strengthen the position, block approaches, etc."

Pioneers must necessarily specialize amongst themselves; thus we already possess infantry and cavalry pioneers, the special task of the latter class being the rapid crossing of streams by means of light bridging material. Moreover the day will soon come when the artillery pioneer will spring into existence.

Finally, in fortress warfare the pioneer is even more indispensable than in the field, and it is a very great pity that the bridging trains are not given teams in peace time to drag their bridging equipment, a neglect which cannot fail in the highest degree to adversely influence their efficiency in war.

CHANGES IN THE ADMINISTRATIVE SERVICES OF THE RUSSIAN ARMY.—The percentage of employés of various ranks of the administrative services in the Russian Army is 50 per cent. smaller than in that of any other European nation.

The work they carry out includes that done by our A.O.D. and A.S.C. with this difference that hitherto no arrangement has been made to allot any of the staff of these services to the higher units. This is the first change that is being aimed at, and to supply the *personnel* which will be required to effect this reform it is proposed to obtain the services of officers of the army. They will receive a special course of instruction, partly theoretical and partly practical, which will last three years. Regulations still remain to be made as to the rank these officers will hold, the conditions of service, promotion, retirement, etc., as up to the present there has been nothing laid down on these subjects, and what few rules exist are merely local.

The minor positions in this corps will continue to be occupied by men of little education as before, only the higher ranks are being changed, or, more properly speaking, established.

THE COLONIAL ARMY OF FRANCE.—Public interest in France has recently been focussed on the colonial army, the more so as portions of this force have been employed in the recent campaign in Morocco, so that it is, perhaps, not amiss to give a short account of its strength and composition.

The French colonial possessions are 11,000,000 of square kilometres in area, and contain some 50,000,000 inhabitants.

Not including Algeria and Tunis, which curiously enough do not count as colonies, they are composed as follows:—(1) Indo-China; (2) West Africa; (3) East Africa; (4) The Antilles; (5) the possessions in the Pacific (New Caledonia and Tahiti).

The object of the colonial forces is to garrison and protect these colonies, and, in case of need, either to protect France or take part in oversea expeditions.

These troops are quite independent of the rest of the French Army and possess their own body of officers and their own administration. The army in France comes under the War Minister, but the troops situated in the colonies are under the Colonial Office as regards their administration, repartition and employment. They are composed partly of French (white) troops and partly of native levies.

Firstly as regards the white troops. These consist of infantry and artillery, of which an army corps (36 battalions and 3 artillery regiments) is in France, garrisoned at Paris, Rochefort, Toulon, Brest and Cherbourg and the remainder are in the colonies. Some companies of A.S.C. drivers (compagnies de conducteurs) are also attached to the artillery. With the exception of a few native troopers in West Africa, there is no cavalry.

The total strength of the troops in the colonies is 54,000 men, of which 34,400 are natives and 19,600 whites. To these may be added a few troops of the regular French Army belonging either to the Foreign Legion or to the Engineers. If to the above be added the native Algerian and Tunisian levies, a total of 100,000 men is reached.

The native troops are partly obtained by conscription and partly by enlistment. There are a few native officers, none of whom ever rise however above the rank of lieutenant and are, even then, always considered as junior to the white officers. The native N.C.O.'s are obtained on the same system as that in vogue in the French Army. A school for native N.C.O.'s was founded in Indo China in 1906.

The length of the tour of foreign service of the white troops varies from 20 months to 5 years in the case of the officers, and from 20 months to 4 years in the case of the N.C.O.'s and men. The most peculiar characteristic of this force is its subjection to two masters, the War Office and the Colonial Office. It is believed that this will shortly be altered, although no one can say which of the two will be the ultimate head.

A further suggestion is that the Colonial and French Armies should intermingle more. The only practical solution to this at present seems to be to make the officers of both armies interchangeable, as such a step would greatly aid the difficulty in solving the *impasse* mentioned above.

The army of occupation in Northern Africa consists of the 19th Army Corps. Its strength is 75,000 men, far too great a number to be placed under the sole command of one army corps commander. It is suggested that this army corps should be divided into three, and thus its organization would be made more suitable for any oversea expeditions, or for the eventuality of portions of it being called upon to defend the mother country.

A last point is that which was brought before the public by Colonel Mangin in his book *La Force Noire*. In this he proposed that the colonies should be made to supply a greater proportion of levies than at present for their own defence, thereby releasing at least 30,000 French troops who would thus be able to fight in Europe. It remains as yet to be seen whether Colonel Mangin's ideas are practical or not; at the present moment there is an experimental body of natives of Senegal, part of which has been on service in Morocco, which as far as is known has proved a success.

A. H. SCOTT.

REVUE MILITAIRE DES ARMÉES ÉTRANGÈRES.

June, 1911.

(1). THE AUSTRO-HUNGARIAN ARMY AT THE EVE OF TWO YEARS' SERVICE.— There is a great increase (500 million crowns) in the army and navy estimates of the Austro-Hungarian Empire for the year 1911 over those for 1910. Both the navy and army come under the same department (the War Department) and a large percentage of the increase is allotted to the navy. This is to be strengthened, both for the greater protection of the mercantile marine, which is daily increasing in importance, and for the protection of the coasts of the Adriatic. Thus in 1916, the strength of the Austro-Hungarian Navy will be:—13 battleships; 9 cruisers; 18 torpedo boat destroyers; 48 torpedo boats; and 12 submarines.

As regards the land forces, the estimates are less generous. Only 20 million crowns are allotted to them. The importance of this sum is, however, not so much its size as the purpose for which it is to be used, viz.:—The preparation of a military reform. The main details of this reform are:—The adoption of two years as the colour service for the infantry and artillery, and a considerable increase in peace establishments (from 103,100 to 159,000 men). As a corollary to this increase of the common army of both states, a proportional increase in the Landwehr of each nation is to be expected, amounting to 8,250 in the Austrian Army and 12,500 in the Hungarian Honved. This will bring the strengths of these bodies up to 28,000 and 25,000 respectively.

Before proceeding further it is necessary to explain the peculiar formations which exist in the Austrian Empire. Quite apart and distinct from the "Imperial and Royal" Army, which is common to both states, each country possesses a Landwehr formation, in which the time of service is 2 years with the colours, and 10 with the reserve. The origin of these bodies is the "Ausgleich" of 1867, which declared each state to be autonomous and gave it a parliament of its own. As a result the Austrian Landwehr and the Hungarian Honved sprang into existence.

The growth of the latter was more rapid than that of the former, and it rose in 1890 to its present strength of 12,500 men, *i.e.* 28 infantry regiments of 2 or 3 battalions each and 10 cavalry regiments, the only increase of late years being the addition of a machine-gun detachment to each infantry regiment and 2 detachments for the 10 cavalry regiments.

The Austrian Landwehr on the other hand, although it did not make at first such sudden strides as the Honved, is now the stronger of the two (19,750 men), and consists of 119 battalions each with a machine-gun detachment, 6 cavalry regiments, and 8 howitzer brigades. Five of the regiments were in 1909 and 1910 transformed into Alpine troops to supply a long-felt want. It will be noted that neither of these formations possess any engineers, departmental troops or artillery worth speaking of.

The present laws fix the length of service in the common army at three years with the colours, and seven with the reserve; the remainder of the soldier's service being spent in the Landwehr and Landsturm until, at the age of 42 he is exempt from all military duties.

The strength of the army has remained the same since its formation:

viz.: 103,100 men. The reason for this stagnation is mainly to be found in the unwillingness of the Magyars to come forward and serve, and the support they get in this dilatoriness from their parliament. This results in their serving almost entirely in Hungarian regiments, attending Hungarian military educational establishments and using Hungarian as the official language in the corps they serve in.

The principal changes have taken place in the field and fortress artillery, those in the engineers being mainly the creation of cadre formations intended to expand largely in time of war. The arms which have suffered principally during this stagnation are the infantry and cavalry, especially the former, with the result that at the present moment, to mobilize a company of infantry it is necessary to call out lots of reservists of seven successive years.

In the matter of *matériel*, the army has made important progress, all the latest technical improvements, such as telephones, signalling equipment, wireless telegraphy stations, field cookers, mechanical transport, aeroplanes, or, in a word, anything demanding only expenditure of money, having been lavished on it. The navy has not, however, been forgotten, its strength being increased from the original 2,800 to 4,000 men.

The Bosnian crisis and subsequent partial mobilization in the winter of 1908—1909, showed up the defects of the present system, and both socially and economically disorganized the Empire. On the other hand it served to test the real unity which exists between the different races, and proved that all were willing to unite against a common foe.

Since this crisis two years have passed, and as yet no active steps have been taken to increase the peace footing of the common army. The present labour party in power, however, which succeeded the independent party, considers the question of imperial defence as one of the first importance and, it is more than likely therefore that the two years law will be passed.

Of the proposed increase of 55,000 men, only one-seventh will be allotted to new formations—mostly technical troops—the remainder will be employed in bringing the cavalry and infantry up to their proper establishment of 150 troopers per squadron and 93 men per company of infantry. In the words of the present War Minister, the object of the increase is not to attempt to catch up at one bound the enormous distance Austria lags behind the other Powers in things military, but merely to fill up holes in the present organization; in fact not to increase the army, but to consolidate it.

MILITARY NEWS OF DIVERS COUNTRIES:—

BELGIUM.—The Military School of Aviation has been opened at Brasschaet. Its staff consists of two lieutenants, one as technical instructor, and the other as practical instructor. The course is being followed by four subaltern officers. The aerodrome is some 2 kilometres long and 500 metres broad. The Belgian Government possess two biplanes (both Farman) and five hangars of which two are movable.

ITALY.—*The Duties of the Inspector-General of Engineers.*—The following come under this officer:—(1). The general officers attached to the inspection as inspectors. (2). Commanding officers of engineers as far as the training of the men, and the technical administration of commands is concerned. (3). The workshops of the engineers. (4). The troops allotted to the destruction of communications. (5). Military pigeons. (6). The historical museum of the engineers.

RUSSIA.—The results of the course held at the Military School of Aviation at Sebastopol, which ended in May, 1911, have been published. 23 officers have been trained (6 infantry, 1 gunner, 9 sappers, 4 cavalry and 3 naval officers)—of these 8 obtained a pilot's certificate (5 on Farman and 3 on Blériot machines). The following are the advantages granted by the Government to military aviators:—(1). An allowance of 1 rouble (two shillings) to every soldier for each day in which he takes part in a flight. (2). A monthly allowance for each month in which they have been for at least six hours in an airship to the following officers at the following rates:—"Captain" of the balloon, 150 roubles; his assistant or chief mechanic, 90 roubles; to each mechanic, 30 roubles. (3). A monthly allowance to the officers of the aviation sections of the balloon companies of 200 roubles per officer, 72 roubles per ensign for those months in which they have flown for at least six hours. (4). An annual allowance for the *personnel* of the above-mentioned sections who have served at least three years in them, and flown at least 50 hours per annum, of 300 roubles per officer, and 120 roubles per man. Once this allowance has been obtained, it is remitted to the individual even if he retires or is transferred to the reserve; in case of death it is given to his family over and above the ordinary pension to which they are entitled to. As regards pensions, any individual injured in a flight is entitled to the same pension as if wounded on service, the same applies if his health has been affected by flying and there are definite pensions which in the event of his demise are given to his next-of-kin.

The peace strength of the Russian Army in 1911 for fixed at 455,000 men, which is less by 1,535 men than the peace establishments for the years 1908, 1909, 1910.

TURKEY.—*Organization of the General Staff of the Ottoman Empire.*—The General Staff of the Ottoman Empire is divided into seven departments as follows:—(1). Manœuvres and training, military history, editing of the fortnightly military paper. (2). Study of foreign armies. Correspondence with military attachés. Officers sent to foreign countries. (3). Mobilization. Concentrations. Fortifications. (4). Movements and quarterings in peace. Correspondence with the Sublime Porte and The Vilayets.. (5). Military law. Organization. (6). A.A.G.'s department. Personal affairs of staff officers (appointment and disposal of officers). (7). Topographical department.

Ministerial Circular of December, 1910, *on Staff Officers.*—(1). A staff officer is only to be considered such when actually serving on the staff. (2). Officers who previous to the new regulations on the supply of officers for the General Staff have been given the rank of staff captains will have to be exercised in regimental duties and the handling of troops in the field. They will be considered as regimental officers of the arms they are attached or posted to. (3). Officers who have qualified for service on the General Staff will as required be employed on the staff once or more often, account being taken of the tasks referred to in para. 4. (4). In order to keep up the knowledge of officers qualified for service on the staff, but serving as regimental officers, tactical problems will be set them by the Chief of the General Staff, and marks allotted for their solutions of the same. These marks combined with the confidential reports rendered on them by the officers under whom they are serving will be taken into account when selecting these officers for staff work.

The N.C.O.'s of the Turkish Army.—N.C.O.'s are divided into extended and non-extended men, the former being those who continue in the army after their legal term of service is expired. The ranks are as follows:—Corporals (bachi), sergeants (tchaouch) and sergeant-majors (bach tchaouch). The N.C.O.'s are supplied as follows:—(1) From the N.C.O.'s schools, or (2) selected from the ranks, after passing an examination. The N.C.O.'s schools train young men of 18 to 21 years with a taste for soldiering. The course lasts two years and the successful candidates then come out with the rank of corporal. Preparatory schools for the N.C.O.'s schools also exist which prepare boys of 15 to 18 for the N.C.O.'s schools—the course lasts from one to three years according to the aptitude of the pupils. A school of each type is to be established at the headquarters of each military district, administered by a major or lieutenant-colonel in the case of the higher and a major or captain in the case of the lower schools. Pupils of the N.C.O.'s schools must serve at least six years, those of the preparatory schools at least eight from the time they leave the higher school. The sons of soldiers are admitted in preference to those of civilians. The pupils are paid by the government. After six years' service N.C.O.'s can extend for three years, the right to extend being a privilege granted to men of good record. At the end of this time they are ensured a post under the government outside the army.

A. H. SCOTT.

RIVISTA DI ARTIGLIERIA E GENIO.

May, 1911.

FRANCE.—*Technical Exercises for the Engineers.*—From the *France Militaire* of the 7th and 16th May, we learn that the annual exercises in navigation and bridging of the 3rd Regiment of Engineers have lately taken place near Estcourt-Saint-Quentin, 20 k.m. from Arras. Up to the 23rd April, all the necessary material, transported by water, had arrived at the station of Bequerel where the three battalions of the regiment were successively practised in the construction of several bridges.

Similar exercises for the 7th Regiment of Engineers were held at Besançon sur Doubs and were continued up to the 25th May, and other very important exercises in mining were carried out by the sappers of the engineers at the fort Montbérault at 8 k.m. from Laon.

Aeronautics.—From the same journal of the 9th May, it is reported that 40 soldiers, carpenters by profession, were transferred to be employed in certain laboratories for the repairs to aeroplanes, and for similar duties 60 soldiers selected from the various arms and of the following professions, viz. cartwrights, carpenters, and aeroplane constructors, were transferred for practical experiments.

The experiments took place for 30 men at the aeronautical depôt at Versailles, and for the other 30 in the laboratories of the aeronautical depôt at the camp at Chalons. The first 20 classified in the examinations will be transferred to the 25th Battalion at Versailles, and to the detachment of aerostats at Reims. The others are remanded to their corps.

New Edition of Instructions for the Engineer Services.—The same Journal of the 11th May states that the 2nd edition of *Instructions for the Engineer Service* was published on the 1st February, 1911, and contains the general dispositions of the headquarter staff of the engineers, the classification of fortified places, and the service of the school of engineers, etc.

This new edition shows that the engineer arm is thoroughly fulfilling its new and important duties, has lost none of its prestige, and is always in touch with the daily life of the army. The price of this publication is 5 lire.

GERMANY.—*The New Instructions for the Use of Explosives.*—These instructions, which have been compiled under the care of the Inspector-General of Engineers, are intended to supersede those of 1903.

The rapid development of means of communication of every kind has conferred upon works of destruction a greatly increased importance. Further, the Siege of Port Arthur has brought prominently forward not only the employment of mines in siege warfare, but also the necessity of instruction in the use of explosives and mining work, and of adopting the best tools and material.

The new instructions contain a short introduction and eight chapters with the following titles:—(I.) General methods of demolitions by means of explosives. (II.) Explosives. (III.) Methods of ignition. (IV.) Demolitions. (V.) Mines. (VI.) Measures of precaution. (VII.) How to render ineffective explosives and ammunition. (VIII.) Composition and storage of material.

The instruction is chiefly intended for the pioneers, who are exercised in the use of explosives during the whole year, and for the battalions that have siege parks and are particularly exercised in mining warfare. A certain number of men in the other battalions who have special aptitude for the work are also instructed. Explosive 92 which is insoluble in water and is less sensible to mechanical action, is substituted for Explosive 88 now in use. It has the same properties as Explosive 88, but has the advantage of being usable in water, and of being contained in an impermeable covering.

A new electric apparatus for ignition has been adopted which is safer than that formerly in use.

Land mines (fougasses) are shown to be an effective means of defence when employed on a large scale; the instructions are illustrated with diagrams.

The necessity of rapidly constructing mining galleries of great length (100 to 200 m.) is recognized, as also the importance of well-conceived arrangements for aeration and illumination, and of thoroughly instructing the troops in this kind of work. The allotment of wires and firing apparatus of the pioneer companies is increased.

The new German instruction has been compiled to conform with the exigencies of modern warfare, and contains many technical lessons which are deserving of study.

Automobiles in the German Empire on the 1st January, 1911.—According to information taken from the *Revue Militaires des Armées Étrangères* of last May, the number of automobiles of every kind existing in the German Empire on the 1st January, 1911, is 57,805, showing an increase of 7,864 (of which 1,308 are heavy motor cars) since the 1st January, 1910.

The increase of heavy motor cars is thus distributed:—270 carriages of 8 H.P.; 387 of 8 to 16 H.P.; 627 of 16 to 40 H.P.; 99 of over 40 H.P. In motor cycles there is a diminution of 75. The increase of autocars above 16 H.P. (726 in 1911 and 319 in 1910) has a special importance from a military point of view.

1.—CARRIAGES FOR PASSENGERS.

	Motor Cycles.	Automobiles.				Total.
		Up to 8 H.P.	8 to 16 H.P.	16 to 40 H.P.	Over 40 H.P.	
Prussia	10,365	7,130	6,376	5,036	294	29,201
Bavaria	2,687	1,245	872	747	54	5,605
Saxony	2,442	1,543	902	712	27	5,626
Würtemberg	1,103	562	379	288	20	2,352
Baden	952	546	397	324	17	2,236
Other States	1,978	1,707	934	702	34	5,355
Alsace-Loraine	1,057	1,025	651	368	2	3,103
Total	20,584	13,758	10,511	8,177	448	53,478

2.—CARRIAGES FOR HEAVY TRAFFIC.

	Motor Cycles.	Automobiles.				Total.
		Up to 8 H.P.	8 to 16 H.P.	16 to 40 H.P.	Over 40 H.P.	
Prussia	54	1,026	519	791	71	2,461
Bavaria	20	229	188	173	15	625
Saxony	17	160	68	100	7	352
Würtemberg	4	53	69	93	12	231
Baden	1	39	37	53	12	142
Other States	22	148	84	122	11	387
Alsace-Loraine	3	40	34	52	—	129
Total	121	1,695	999	1,384	128	4,327

THE CONCEALMENT OF FORTIFICATIONS.—By Lieut.-Colonel Maglietta, Engineers.—The art of concealing fortifications has long occupied the attention of the superior military authorities, and the method that generally has been specially recommended is that of planting trees around the works.

It cannot however be said that this important problem has been satisfactorily solved, or that everything possible has been done. The study of this subject has remained a dead letter, and its importance has not been sufficiently recognized either as a means of affording protection from the enemy, or as to expense since a well-planned concealment of a fortification always corresponds to a reduction in the number of armoured and cemented works.

Trees have several disadvantages, as the cost of maintenance does not compensate for the small benefit that might be derived in a more economical way. Moreover the trees impede the view and this sometimes causes great inconvenience.

Without however entirely disregarding the theory of the trees, which in some cases may be desirable not as the chief means of concealment but as an auxiliary thereto, it is argued that the study of concealment should be specially treated in the preparation of plans for fortifications. The concealment should be such as to render it more difficult for the enemy to deduce the profiles of the works either from photographs or by means of spies.

It is generally accepted that, in order to be properly concealed, works should occupy as small a space as possible, and should also be as low as possible. Instead of this evident and indisputable proposition, we see works constructed which are ironically called low, but which have a command over the sea of 8 or 9 m.; we see towers or turrets for signalling or other purposes, raised to a height as much as 42 m. in the interior of a work, and along a line of rocks. The reasons given by the artillery for such a command is that, as the horizon increases 1 kilometre for each metre in height, they are able to see to throw their projectiles with greater effect.

The author does not believe that all this is necessary to make good firing practice. He advocates a system of batteries and emplacements concealed in caves, but the description is sometimes difficult to follow, and it would appear to be only applicable under certain conditions of the soil and contours of the ground.

E. T. THACKERAY.

CORRESPONDENCE.

DRIFT OF A BULLET.

Dear Sir,

May I suggest that Colonel de Villamil and Capt. Edgeworth expend a little further consideration on the following two points raised by them:—

(*a*). Whether the viscosity of the air is the only factor that can affect the rolling motion of a bullet.

(*b*). Why upward pressure should be applied to the nose of a bullet or gyroscope, when every known fact tends to show that the resultant force produces a downward movement of the nose.

I do not suggest that rolling motion is the only factor causing drift, but that up to date it is the only factor capable of logical and scientific explanation.

Yours faithfully,

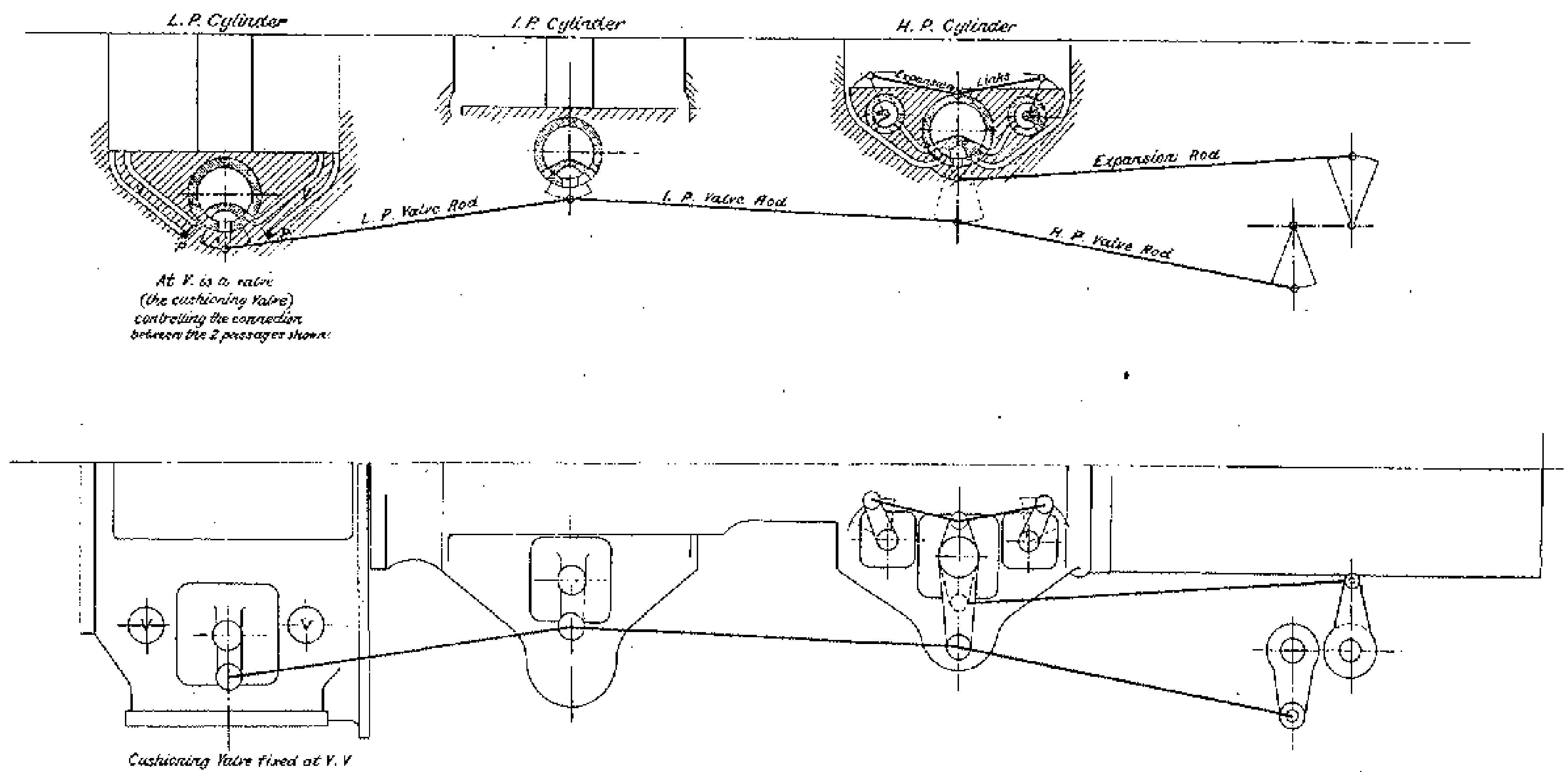
A. R. Carey,

The Editor, *R.E. Journal.* *Major, R.E.*

ECHOES FROM THE ENGINE ROOM.

WORTHINGTON TRIPLE EXPANSION PUMPING ENGINE.

SKETCH OF CORLISS VALVE GEAR.



LATEST PUBLICATIONS

OF THE

R.E. INSTITUTE.

REINFORCED CONCRETE, by Captain J. G. FLEMING, R.E.
2s. 6d., post free.

ELEMENTARY NOTES ON WIRELESS TELEGRAPHY.
6d., post free.

ABBREVIATED NOTES ON MILITARY ENGINEERING.
6d., post free.

HISTORY OF SUBMARINE MINING IN THE BRITISH ARMY, by Lieut.-Colonel W. BAKER BROWN, R.E.
6s., post free.

The above prices apply to Members and Associate Members of the R.E. Institute, and to Warrant, Non-Commissioned Officers and Sappers of the Corps only. Others requiring these Publications should apply to the Agents—Messrs. W. & J. MACKAY & CO., Ltd., CHATHAM.