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ROYAL MILITARY COLLEGE OF CANADA.

"TRUTH, DUTY, VALOUR."

By MAJOR GENERAL G. WALKER, C.B., C.M.G., D.S.O., late Royal Engineers.

This is the Jubilee year of the Royal Military College, Kingston, Canada, and it has been suggested to me that, as I have some personal knowledge of the very early days at the College, and as the institution has been intimately connected with the Corps, I might write a few notes of those days. I have accepted the responsibility with some diffidence, as I am not a graduate of the College. Yet, as one who was very closely connected with one of the first R.E. Officers on the College Staff and, as I have I think a legitimate pride in that relationship, seeing how well the foundations of the Institution were laid, I feel I am justified in my temerity.

That the College is and has been a great Imperial asset is I think incontrovertible, when one looks back on the long line of distinguished British Officers it has produced; men who have gallantly upheld the honour of the Empire, of their own Home-Land and of their Alma Mater. It must not be overlooked also, that the fame of this Institution does not rest alone upon the exploits of its graduates who entered the Imperial Army. The history of Canada is full of the names of distinguished Administrators, Engineers, and Soldiers who owe their initiation into life to the old College.

The R.M. College of Canada was opened at Kingston, Ontario, in 1876. The first batch of Cadets numbered 18, who went by the name of the "old 18." Some of them were elderly I imagine, as I remember the Senior Cadet of that term well. His name was Homfray Irving. He was a small man and his mutton-chop whiskers, eyeglass and general appearance of solemnity and sedateness impressed me much, as it possibly did others. I wonder if I malign him, he could only have been about 20, but then I was only 8. At the recent Jubilee celebrations he, with three others of the "old eighteen" unveiled a commemoration tablet.

The Cadets who took Commissions in the British Army from this term, were, as far as I remember—A. B. Perry, R.E. (He broke his leg before joining and that so badly, that he resigned his Commission the following year, though he has lived to be the distinguished Commissioner of the North West Mounted Police, and after distinguished service in the War is now a Major-General.); C. O. Fairbank was the Gunner; Wise went into the 13th Hussars; Frere went into the Infantry. When Perry retired, his vacancy in the

Corps was given to A. H. Van Straubenzee, now retired as a Colonel. He belonged to the 2nd Batch and had been originally commissioned in the 101st Foot, later the Royal Munster Fusiliers, from which he was transferred to the Royal Engineers, vice Perry. The second batch at the College was headed by H. B. Mackay, who became a Royal Engineer. He was I think the "biggest man" the college possessed in those days, and all who knew him looked upon his early death in Africa as a great loss to the Service and State. W. H. Robinson, who was the next R.E. Graduate, was killed in storming a stockade in West Africa. Lang Hyde, the next, is still with us, but retired.

The above were the first four Sapper Graduates, but they have been followed by many others who have distinguished themselves. To name a few only, Lieutenant-General Sir George Kirkpatrick, now Commanding an Army in India, Major General Sir Philip G. Twining, Colonel Sir Percy Girouard, Major Generals Dudley Ridout, A. C. Joly de Lotbiniere, and Brig. Generals H. C. Nanton, G. S. Cartwright, W. B. Lesslie, and A. E. Panet. Another R.E. Graduate who requires special mention was W. G. Stairs, who was a great African explorer and accompanied H. M. Stanley on his last expedition. He was subsequently given a captaincy in the Welch Regiment and ultimately died in Africa while in command of an Expedition for which his services had been lent to the King of the Belgians.

Although this article deals with the College chiefly from the R.E. point of view it is worthy of note that the College has produced men like Lieut.-General Sir W. Heneker, recently commanding the 3rd Division; Major General Sir G. Cory, recently Deputy Chief of the General Staff in India, Major General C. Van Straubenzee now commanding a Territorial Division and Major General C.C. Luard, commanding in China.

The original Staff of the College were:—

Colonel E. O. Hewitt, R.E. Commandant. (Later Maj.-General and C.M.G., Commandant S.M.E. and Governor of the "Shop," where he died).

Major J. Bramley Ridout, 90th Light Infantry, Captain of Cadets and later Adjutant and Secretary, as the Cadet Companies increased in number; afterwards well known in civic life at Chatham and father of Sir Dudley Ridout (late R.E.).

Major Edgar Kensington, R.A. Professor of Artillery and Mathematics. (Later very well known at the "Shop" as Professor of Artillery. Father of Lieut.-Col. G. B. Kensington, O.B.E., R.E., retired).

Major Hawkins, R.A. Professor of Fortification. This officer was relieved in 1877 by Lieut. G. R. Walker, R.E. (my father).

Lt.-Col. Oliver, R.A., *p.s.c.* Professor of Tactics and Topography. Joined in 1877. Succeeded Colonel Hewitt as Commandant.

Mr. Ferguson, Professor of German; M. Duval, Professor of French; and Mr. Foreshaw Day, Professor of Drawing.

THE ROYAL MILITARY COLLEGE FROM THE AIR.

Showing the "Stone Frigate" on the right of the white parade. The Educational block facing the parade and the new living quarters on the left. At the point is Fort Frederick. On the point across the Bay is Fort Henry, down the slopes of which was the Toboggan Slide.

By kind permission of The Royal Military College of Canada Review and Log of H.M.S. Stone Frigate.

THE ROYAL MILITARY COLLEGE

The Staff gradually grew in numbers. In 1880, Lieut. M. H. P. R. Sankey, R.E., joined as Instructor in Fortification and assistant to Walker. He in later years became celebrated as an Electrical Engineer in England and was the father of Lt.-Col. C. E. P. Sankey, D.S.O., R.E., (retired). He died in London in 1926. Major "Sammy" Fairtlough, R.A., also joined Kensington, as his assistant, about this time. He died in Sierra Leone, in the nineties of the last century. Mr. Carr-Harris, father of Carr-Harris, R.E., was Professor of Civil Engineering. Mr. Baines was Professor of Science. Sankey left in 1882 and was relieved by Lieut. E. Raban, R.E., now Sir Edward Raban, K.C.B., K.B.E. Walker came home in 1883 and was succeeded by Raban, and Lieut. S. Davidson, R.E., went out in relief.

It is of interest also to note that the first graduate of the College to become Commandant, was Colonel Taylor, *p.s.c.*, Cheshire Regt., in 1905. The first Graduates to become instructors were Lieuts. A. G. Wurtele and J. B. Cochrane, both of the Canadian Army, in or about 1881.

Three members of the Subordinate Staff, should be mentioned; firstly, Regimental Sergt.-Major Mortimer, an old Horse Gunner, who had served in the Indian Mutiny, he was a small fiery man; secondly, Sergt. Morgan of the Scots Guards, the Gym. instructor, who joined in 1877; the third was Sergt.-Major Birtles, R.E., who took Field Works under my father, a man beloved and admired by all, a splendid type of the best that the Corps has produced.

The organisation of the College was based on a combination of the systems at the " Shop " and West Point. The youngest age of entry for cadets was 15. The Cadets were organised as a Battalion of two or three companies, each with its C.S.M. and Cadet N.C.O's., the Senior Cadet being called the Battalion Sergt.-Major. The course was of four years' duration. It was framed to afford a good Civil Engineering and Military Education.

The courses were :—

Civil Engineering. (Including a rather detailed course of Railway Construction and Bridging. A large number of the Cadets took up railway engineering as their life's work and succeeded in it. Girouard first got railway experience in Canada). Military Engineering. Artillery. Tactics and Topography, Civil Surveying and Astronomy. Mathematics (from Arithmetic to Calculus). Chemistry and Physics. Freehand Drawing and Sketching. French. German. Military Drill and Exercises.

As a larger number of Cadets went into civil than into military life, the education aimed at was to give a man a profession in civil life, so that he could earn money at once, and at the same time to lay the foundation well for military service if called upon. The value of this was apparent during the Great War.

My recollection is that the four years' course enabled the instruction in all departments to be very thorough and that the Cadets when leaving were much better equipped for life than those who went through the colleges at home. In fact a Kingston Cadet, joining at Chatham in those days, had but little to learn technically. They were trained Civil Engineers with an excellent Military training also. All they lacked was practical experience.

The status of the Cadet was that of the private soldier. He was in fact an enlisted man and subject to Military Law like a soldier. In this he differed from his brethren at Woolwich and Sandhurst, who were only subject to their College rules.

The uniform, to use the words of the Army List, was "Scarlet, facings blue." It was very effective. A well laced red tunic for full dress and a red frock for work. The tunic is still retained and looks very smart. An "infantry grey" great coat with a red collar completed the rig.

The head-dresses were, full dress, a white helmet; undress, a round forage cap, similar to that which was worn at Woolwich. In winter the Cadets wore grey astrakhan caps and seal-skin gloves. The B.S.M's. and C.S.M's., however, wore astrakhan collars to their great coats and astrakhan gauntlets. A most effective get up.

When I first knew Kingston (1877), there were only three College buildings. The old "Stone Frigate" block, in which the Cadets lived, had been the winter quarters of the old Naval Establishment, abolished after the war of 1812; the new administrative and educational block, which was just finished, and a gymnasium. There were a couple of Instructors' houses and quarters for servants in the grounds.

The site was ideal, albeit rather treeless and bleak. It was isolated by water from the town and yet was close enough for convenience. There was ample ground for games. The Cadets played both cricket and Rugby football, tennis was in its infancy and golf unknown. They excelled in football, the cricket in those days was only mediocre I fancy. However, in summer the principal sport was boating and sailing, for which the Lake (Ontario) gave unrivalled facilities. I call it "the Lake," it was really a sea, on which any kind of weather might be expected. As a result, there were few cadets who were not really good watermen. In winter-time there were winter sports of all kinds. Snow shoeing, tobogganning at Fort Henry, skating and ice yachting. The Cadet Battalion used to be drilled on snow shoes on the snow-covered ice; rather a thrilling sight, to see them paddling round like a huge flock of ducks with enormous feet.

I think the discipline amongst the Cadets themselves was high. I have been told that the ceremony of "Initiation" for the last joined was one that could not be trifled with. Otherwise the life was very like the "Shop." Anyhow the results of the system were excellent and the graduates were turned out tough, reliable and self-reliant members of society. I doubt if you can ask anything more from an educational establishment.

I have said above that the R.M.C. Kingston is an Imperial asset. I think that anyone who met Canadian Troops during the Great War will agree with me. Wherever one met them they were good and wherever one met them one found Kingston graduates in high positions. The tone of the troops was the tone of Kingston; reliability and self reliance and the saving grace of humour. I will conclude with one war story of a Canadian Officer, who was serving under me in Ypres. He was a graduate of Kingston and a Mining Engineer, serving with a British Tunnelling Coy., R.E. He was a real tiger and feared nothing that walked.

We were having a lot of trouble with water in shafts and galleries, owing to inadequate means of tackling the difficulty. One particular shaft, in one of the Brigade Areas, was giving a lot of trouble. The Brigadier was as much concerned as I was. In the middle of one very wet night the accursed shaft collapsed, not for the first time, and the Canadian Officer went straightway to tell his Brigadier. He arrived at Brigade Headquarters about two a.m., knocked up the Brigade Major and asked to see the General.

When he was introduced into the presence, the Brigadier asked what was up and received the reply " General, that 'Goddam' Hole has fallen in again." The Brigade Major, who was rather of the crusted variety, nearly fainted and the Brigadier roared with laughter and, having refreshed his visitor, dismissed him with some words of encouragement. He christened the youth the " Goddam Fella," by which name he was generally known thereafter.

In conclusion I must acknowledge my indebtedness for some of the details in this paper to Quarter Master and Major T. H. Tennent, O.B.E., R.E. (retired), at whose suggestion, in fact, the article has been written.

Major General Sir Dudley Ridout has added the following note:— General Walker has not mentioned what an extraordinary influence his father had on the cadets and what we all owe to him. All the R.E. Instructors were really " Giants "—and it was to men like Sankey, Walker, Raban, Stuart Davidson, that the earlier cadets owe so much.

THE RAISING AND LENGTHENING OF CARDINGTON AIRSHIP SHED AND OTHER WORKS.

By A. R. Gibbs, Esq., A.M.Inst.C.E., A.M.Inst.M.E., of the Directorate of Works and Buildings, Air Ministry.

The British Government decided in 1924 to proceed with the construction of two great airships, each of five million cubic feet capacity. This is more than twice the cubic capacity of any previous ship, and, no existing accommodation being suitable, the following "ground" works became necessary :—

(a) *Cardington, Bedfordshire.*
Enlargement of the existing airship shed, provision of a Mooring Mast and incidental works.

(*b*) *Ismailia, Egypt.*
Provision of a Mooring Mast and incidental works, and construction of hydrogen producing plant.

(c) *Karachi, India.*
Construction of a new Airship Station, provision of an Airship Shed, Mooring Mast and subsidiary services.

These works, which entail an expenditure of about £500,000, devolve upon the Directorate of Works and Buildings, Air Ministry, and are being carried out to meet the airship requirements of the Directorate of Airship Development.

The purpose of this article is to give an account of the enlargement of the Cardington Shed in particular, with a brief description of the works as a whole. Some of the works referred to at (*b*) and (*c*) are not yet completed.

Cardington Airship Shed.

Description of the original shed.

The original shed was built for the Admiralty in 1916-17 and consisted of a steel framed structure, the cross section being in the form of a three-pin arch supported on "A" frames, as shown in Fig. 1.

The width between centres of pins was 181 feet 6 inches, width over all 254 feet, height to lower pins 63 feet 3 inches, minimum clear height at centre 110 feet, length 700 feet.

Capacity above floor level 17,100,000 cubic feet.

The framing was covered with painted ungalvanized corrugated sheeting, with the exception of the walls to the annexes, which are "Hyrib" covered with cement mortar. Both ends of the building were fitted with sliding doors covering the entire height and width of the main transept; further particulars of these doors are dealt with later. The approaches to the shed were protected against prevailing winds by screens 70 ft. high and 700 ft. long.

Alterations decided upon.

In order to accommodate the new airship it was necessary to increase the length of the shed by four bays, viz., 112 ft., and increase the height by 35 ft. It was considered in the light of past experience that there was no necessity for doors to be fitted at both ends, and also that the screens were unnecessary. The sheeting of the shed was in bad condition and consequently was not re-used.

A general plan of the extended shed is shown in Fig. 3.

Tenders invited.

General designs and tenders for the enlargement of the shed were called for from competent firms, and the tender of the Cleveland Bridge and Engineering Co., Ltd., of Darlington, was accepted. The details of the construction proposed were examined in the Air Ministry.

Method of obtaining increased height.

Many ways of increasing the height presented themselves. It is understood that the contractors gave detailed consideration to a scheme for raising the shed bodily by a system of hydraulic jacks. This scheme was not pursued, in view of the considerable increase in height adopted, viz., 35 ft.; moreover, the existing building was an entirely bolted structure and lent itself to easy dismantling.

The contractors were at a disadvantage, inasmuch as they had not erected the original structure, and had no knowledge of the actual setting out of holes, etc., in the members against which the new steelwork had to be bolted. The wisdom of dismantling the shed was confirmed in practice when it was found necessary to correct irregularities in the original structure, built during the progress of the war, when skilled labour was not easily obtained.

The method adopted is shown in Fig. 2, where it will be noted that the vertical columns are strengthened and increased in height. The spandril pins of the arch are carried 35 ft. higher than in the original building, but otherwise the roof remains unaltered. Stability is provided for by the new raking struts running from the raised springing points of the arch down to new blocks of concrete constructed outside the existing foundations.

These raking struts are braced to the existing framework to give them lateral strength.

Further diagonal and horizontal bracings have been introduced between the main transverse ribs of the building in its longitudinal planes to supply them with additional rigidity, necessitated by the increased height. These bracings are indicated in Fig. 7.

The original shed had a comparatively flat top to the main door openings, having been designed to accommodate two airships of the R.33 type. In order to give greater height in the centre (for the new single ship) it was decided to remove the wind girder which supported the end sheeting over the doorway, and to carry this sheeting by smaller framing.

This gave an additional headway at the centre of about eleven feet, which, added to the 35 ft. gained by raising the roof, gave a total increase at the centre of the doorway of 46 ft. This is, therefore, the effective increase in height of the new building over the old.

The increased height meant greater loads, and the foundations under the existing inside columns were, therefore, increased from 7 ft. 6 in. by 7ft. 6 in. to 11 ft. 6 in. by 11 ft. 6 in. A trench was cut round the existing concrete to its full depth, the concrete being hacked and roughened on all sides so that the entire surface should form a good bond with the new concrete. The new concrete, consisting of one Portland cement to six of aggregate, was then deposited and vertical and horizontal reinforcement was inserted, so as to ensure that the new and old concrete should act as one homogeneous mass.

The foundations at the south-west end are on gravel, but towards the north-east end the clay rises to within a foot or two of the surface and most of the foundations are, therefore, in clay, the depths averaging about 6 ft. The load on the virgin soil does not exceed 1½ tons per sq. ft.

Lengthening the Shed.

The lengthening of the shed was a simpler matter than the raising of it, as it was possible to adopt a design distinct from the existing shed. The arch rib with one or two improvements is identical with those in the original structure, but the new "A" frames are naturally of a less complicated form than those formed of new and old work. A section through the extension is given at Fig. 5.

Designing Data.

The shed, as rebuilt, has been designed to the following data:

Wind. Thirty-five lbs. per sq. ft. horizontal on roof, 30 lbs. per sq. ft. on sides, ends and doors.

The normal pressure on sloping surfaces was calculated by Prof. Unwin's formula. The above loads were considered sufficient to cover any effects of suction on the lee side.

Snow. Five lbs. per sq. ft. of surface covered (this was taken in addition to wind).

Stresses in Steel.

Tension. The tensile stress was calculated on the nett area, *i.e.*, after deducting holes, and is not greater than 7 tons per sq. in. for dead weight of structure and 8 tons per sq. inch for wind and snow.

The above corresponds to a factor of safety of 4 for dead weight and $3\frac{1}{2}$ for wind and snow.

(For simplicity, wind and snow loads were reduced in the calculations for steelwork to a dead load basis by multiplying by $\frac{7}{8}$).

Compression. The compressive stress on the gross section is not greater than 85 per cent. of the corresponding tensile stress (*e.g.*, 85 per cent. of 7 tons=6 tons) nor more than that corresponding to the ratio given by Fidler's formula for compression members.

Reversal of Stress. In no member subject to reversal of stress does the range exceed 12 tons per sq. in.

Shearing. The shearing stress on rivets or turned bolts of a driving fit does not exceed three-fourths of the permissible tensile stress, *i.e.*, $5\frac{1}{4}$ tons; double shear was taken as $1\frac{3}{4}$ times single shear, viz., 9 tons.

For black bolts the permissible stress was decreased to 4 tons and 7 tons per sq. in., respectively.

Bearing. The bearing or bending stress on rivets or turned bolts of a driving fit does not exceed 10 tons per sq. in.

Struts and Columns. Claxton Fidler's formula was used. Struts were generally assumed to be fixed at one end and hinged at the other, unless they were hinged at both ends.

Quality of Steel. The steel used was in accordance with the *British Standard Specification for Girder Bridges,* Parts 1 and 2, No. 153, and manufactured by Process A.

Calculations.

The original framework of the shed, from a practical point of view, was a determinate structure. There is, of course, some doubt as to the distribution of the horizontal thrust between the two legs of the annexe, but this is not a difficult matter to deal with in practice. The addition of new steelwork to the existing framework was a more difficult problem. It was not possible to design the new raking strut economically without bracing it to the existing steelwork. Fig. 4 illustrates the framework in outline and shows the method adopted in making the calculations, together with resultant stresses.

The trestle as heightened is treated as a unit, and the loads applied at panel points as shown. The members shown dotted were assumed not to assist when arriving at the stresses in other members. The possibility of the whole of the load coming down the new raking strut, instead of being divided between the raker and the outer vertical member of the porch annexe, was investigated and provided for.

Manner of Procedure.

The contractors commenced work at the north-east end of the shed, and after laying extensions to the Air Ministry railway sidings, proceeded to erect a Butters' steam crane, with 140 ft. jib, on a 40 ft. steel staging. This crane could lift 7 tons at 90 ft. radius and was used to erect the great steel travelling stage shown in Photo 1.

The large stage was 100 ft. wide, 80 ft. deep and 120 ft. high, and contained 230 tons of steel; it was built on a double track, 90 ft. centres, and was moved forward by means of wire ropes operated by winches secured to the longitudinal sleeper tracks. Two 10 ton Morgan steam cranes with 110 ft. jibs were mounted on top of the staging. These cranes lift 10 tons at 70 ft. radius.

Incidentally it may be mentioned that one of these cranes was first erected on the ground, and used to erect the steam crane with 140 ft. jib previously referred to.

The travelling stage was first moved forward into a convenient position for dismantling the doors at the N.E. end, the steelwork of which was lowered to the ground and dissembled for transport to Darlington, where much of the framework was adapted to form the frames for the new permanent end of the extended building. The stage was again moved forward, and the removal of the main arch ribs which form the roof was commenced, the stripping of the sheeting, purlins, etc., being kept in advance of the dismantling of the framework. The main ribs were removed in sections and stacked at the side of the shed or laid down flat on the concrete floor.

This process continued down to the south-west end of the shed, as shown in Photo 2. While this was proceeding the 5 tons Butters' crane was removed from the 40 ft. stage and re-erected on the ground at the opposite end of the shed in a convenient position for dismantling the S.W. doors; these doors were then forwarded to Darlington for reconstruction.

After remodelling at the contractors' works the doors were re-erected, partly by means of the stage and partly with the 5 tons jib crane (see Photo 3). Whilst the work already described was proceeding, the new concrete foundations were put in, and the vertical columns under the arch pins were strengthened by the addition of a 9in. by 3in. channel, bolted on the face of the existing column, the holes in the existing work being drilled *in situ;* and new steel-work was fabricated at Darlington.

Drilling on the site was carried out with electrically-operated drills, and rivetting was performed with pneumatic rivetters.

After completion of the new main doors, the new raking struts, annexe bracings, etc., were erected by means of the stage for a length of about 300 ft. The top of the stage having been raised 35 feet by an additional platform. (See Photo 4.)

The staging was then brought forward again to the S.W. end, and the arch ribs, subsidiary bracing, sheeting, etc., for this portion of the building were completed while the stage worked once again towards the N.E. end.

This procedure was adopted as the Airship Authorities desired to utilize the first 300 ft. of the shed as early as possible. The erection of the raking struts, re-erection of main ribs, etc., was carried out in an almost identical manner to that described hereafter for the lengthening of the building.

The order adopted for the erection of the trestles in the extended length of the building can be followed from the photographs. In Photo 5 the inner vertical column nearest the foreground has been erected to a height of about 45ft., and on the extreme right of the photograph can be seen the first portion of one of the rakers which has just been placed in position by the crane. The next stage in the erection of a trestle can be observed from Photo 6, and the erection of the top section of the trestle is shown in Photo 7.

The three pin arch rib was erected throughout in four sections, no section weighing more than about 5 tons. The cranes were capable of lifting one-half section of the rib into position in one piece, but the contractor considered it more satisfactory to handle lighter loads. Photo 8 illustrates the procedure adopted. It will be observed that the first section has been raised into position and the pin connecting it to the top of the "A" frame has been inserted, while the other end of the section is temporarily supported on the top platform of the stage.

The crane has lifted the second section of the rib from the ground, and is just about to lower this portion into position, while the men are waiting to insert the connecting bolts. The two cranes on the stage enable the two sides of the rib to be erected simultaneously.

The erection of the fixed end of the shed was carried out by means of the stage, on similar lines to those adopted for the "A" frames and, therefore, calls for no detailed description.

The dismantling of the temporary plant followed the reverse procedure from that adopted for its erection. The 7 tons crane with 140ft. jib was erected once again on its 40ft. staging by means of the travelling stage. This latter was then dissembled by the former, and subsequently the former itself was dissembled by one of the jib cranes which had been removed from the top of the stage.

Main Doors.

The doors to the original shed were of the self-supporting or ballasted type, in four leaves, and were operated by means of a capstan on each leaf.

The doors took about half-an-hour to open, and required the efforts of a large number of men.

The loads on the wheels, under the worst assumed conditions, viz., 30 lb. per sq. ft. wind, amounted to about 60 tons per wheel, and under the most favourable conditions, *i.e.*, without any wind, 33 tons per wheel.

These high loads made the operation of the doors difficult, and rendered it impossible to retain the existing base framing for the heightened doors; opportunity was, therefore, taken to entirely remodel them.

The new doors are of similar type to the old, but being 46ft. higher demanded an increased width of base and track. The old track, consisting of single lines at 36ft. centres, was taken up, and a new one put down consisting of two 3ft. 6in. gauge ways at 60ft. centres. Each rail is formed out of a 3½in by 1½in. billet machined and rivetted to a girder (running the whole length) consisting of two 10in. by 3½in. channels with a 9in. by ½in flange plate. The 3ft. 6in. gauge is maintained by transverse bearers of 4in. by 3in. by ⅜in. angles at about 3ft. centres, the whole being embedded in concrete as shown in Fig. 8.

It will be observed from Photo 3 that there are four leaves to the new doors, and each leaf consists of horizontal girders carrying a facing of galvanized corrugated sheeting, the girders being supported by two tall "A" frames. The four legs of the "A" frames are secured to the horizontal girders forming the base frame or platform of the doors, and stability is ensured by the concrete filling deposited *in situ* between the main girders of the base frame. The total weight of each leaf, including the platform and ballast, is carried by four pivots, secured to the platform, and each of these pivots rests in the pocket of a steel casting bridging the bogie frames, the pivot allowing sufficient movement to ensure that the load from each leg is carried by a bogie, and distributed evenly over the four wheels (see Fig. 8). This arrangement avoids the difficulty experienced in the earlier types, where the rigidity of the base, and arrangement of the wheels, prevented an even distribution of the loading. The wheels are double flanged 2ft. 6in. diameter tread, made of cast steel with roller bearings in gunmetal cages. The wheels have turned treads and are fitted with hard steel bushes. The shafts are provided with hard steel sleeves shrunk on.

Each pair of leaves weighs 222 tons, and carries about 248 tons of concrete ballast, making a total load of 470 tons for each half of the door, or a total of 940 tons for the whole door. With no wind, the load on any wheel would not exceed 15 tons, and with a wind of 30 lb. per sq. ft. the maximum load would not be greater than 30 tons per wheel. An illustration of the bogies is given at Photo 9.

Although the door is divided into four leaves for the purpose of articulation, the two leaves on each side of the centre line are linked together and operated as one. Each pair of leaves is operated by hand power and chain gearing, six men being able to open the two leaves in about ten minutes. The chain by which each pair of leaves is operated is situated under the base frame on a longitudinal line between the two bogie tracks and is anchored at each end. The chain passes up through the base of the door on to a winch fixed on the door frame.

The completed Shed.

The completed shed has a floor area of 4¾ acres and a capacity of 26,600,000 cubic ft. The clear width is 180ft., up to a height of 98ft., the maximum clear height at centre being 156ft. 8in The total height to crown pin 174ft. 6in. and height over all 179ft. 6in. The total inside length of the shed is 812ft. The floor is of concrete and fitted with mooring rings and trenches for carrying the pipes for watering, gassing and fuelling the ship. The sides of the shed are sheeted with 20-gauge galvanized corrugated sheeting and the roofing is covered with 22-gauge 3½in. pitch Robertsons' protected metal.

Eleven doors are provided to the shed to give access thereto for men and materials. One door, 18ft. 6in. by 18ft. 6in., is placed in the end of the building for the transport of larger material.

The building is lighted by five rows of glazing each side of the shed and also at the new end. The existing anti-actinic glass was replaced, but the ordinary wired rough rolled plate was used in the new glazing to save expense, as it is considered that, in the future, the time during which a ship is in the shed will be small compared with the time spent at the mast and in flying.

Artificial lighting is provided by ordinary electric lamps in gas-tight fittings. Portable flood lights are to be provided for illuminating any required portion of the ship.

Three internal longitudinal gangways run the whole length of the roof, and access from one to the other can be obtained by means of any of the three transverse gangways. Access to the lower gangways is given by three staircases on each side of the shed. An outside ladder is provided down one of the raking columns to the N.E. end, with a doorway at the top leading to the gangway, to provide a way of escape in case of emergency.

Two outside runways are provided at the eaves of the roof to carry cradles for painters, glaziers, etc. Six internal runways are supported from the roof, each of which runs the whole length of the building, and is capable of lifting four tons vertically, and withstanding at the same time a horizontal component of one ton.

Opening and closing louvres have been fitted the whole length of the shed, for ventilation and to prevent accumulation of gas escaping from the ship.

The roof is drained into pressed steel gutters at eaves level, and from thence into six mild steel tanks situated in the roof; each tank is of 7,000 gallons capacity and is joined up to service pipes connected to eight fire hydrants.

The total weight of steelwork in the framework of the completed shed amounts to about 3,720 tons, exclusive of foundation steelwork.

The cost of the alterations is equivalent to about 2½*d.* per cubic foot of added capacity.

The work has been executed most satisfactorily by The Cleveland Bridge and Engineering Co., Ltd., of Darlington. It was commenced in October, 1924, and completed in May, 1926, and it is pleasant to record that although the work has been carried on in all weathers, no serious accident has occurred.

MOORING MASTS.

The mooring masts are steel-framed structures 200 ft. high, the eight supporting columns forming at the base an octagonal plan 70 ft. across. The passenger platform, from which passengers will embark, is 40 ft. diameter and 170 ft. above the ground. Above the passenger platform is a circular turret 25 ft. diameter, with a conical roof in which is housed the mast head and its machinery. The mast is designed to safely withstand a pull from the ship of 30 tons in any direction.

The machinery house, at the base of the mast, houses three steam winches, each capable of exerting a pull of 15 tons. These winches are provided with remote controls to enable them to be operated from the passenger platform at top of mast. Pumps are installed for pumping ballasting water to the ship at a rate of 5,000 gallons per hour, and a 12-in. gas main runs up the mast for the re-gassing of the ship.

A photograph of the mast at Cardington is shown at Photo 10.

A ten-thousand-gallons fuel storage installation is arranged at the base of the mast, the tank being in an underground concrete chamber. The pump for this installation is capable of raising 2,000 gallons per hour of petrol or other fuel to a height of 400 ft.

The mooring masts for all three stations are similar, and in each case the incidental works include the laying of long lengths of gas and water mains, road, etc.

Hydrogen Producing Plant, Ismailia.

The Silicol system, which has been adopted for the hydrogen producing plant, depends upon the chemical re-action which takes place when powdered ferro-silicol (stirred with water) is gradually admitted into a chamber containing a hot strong solution of caustic soda. This re-action is very rapid and produces a very pure hydrogen, leaving a sludge formed of sodium silicate and uncombined soda. The proportion of silicol to soda generally used for gas production is about one to two.

The chemicals from which the gas is manufactured in this system are expensive, but the initial cost of the plant is much less than for the iron contact system. For intermittent use and during an experimental period, it is, therefore, economical. In the installation at Ismailia the gas producers have been made in two distinct units, so that the plant can be worked at half capacity when so desired. When both plants are working it is rated to produce 60,000 cubic feet per hour or a million cubic feet per day.

The plant is installed in a steel-framed building, and the lifts, pumps, stirring gears, etc., are electrically operated. Storage accommodation is provided in adjacent buildings, silicol being stored on the one side and caustic soda on the other. The installation includes a gas holder, water cooling tower, etc.

The plant has been designed and constructed by S. Cutler and Sons, Ltd., of Millwall, who have had considerable experience in this type of plant.

Karachi Airship Shed.

The airship shed at Karachi will be constructed of three pin arch ribs of 230 ft. span, the top pin being 200 ft. above ground level. An outline of the main rib, together with the Cardington main rib, is shown at Fig. 9, compared with well-known structures. The structure, when completed, will be the largest of its kind in the British Empire.

CONCLUSION.

The whole of the works described in this article are being carried out under the direction of Major-General Sir William Liddell, K.C.M.G., C.B., Director of Works and Buildings, Air Ministry, and H. E. Oakley, Esq., C.B.E., M.INST.C.E., Deputy Director of the same Department. The writer is in charge of the Airship Development Section of the Directorate and directly responsible for the administration and execution of the works.

The Resident Engineer for the works at Cardington was Captain R. D. Thomas Jones, R.E. Reserve, M.INST.C.E., M.INST.M.E.

In conclusion, the writer wishes to record his thanks to the Air Council and the Director of Works and Buildings for permission to publish the particulars given in this article.

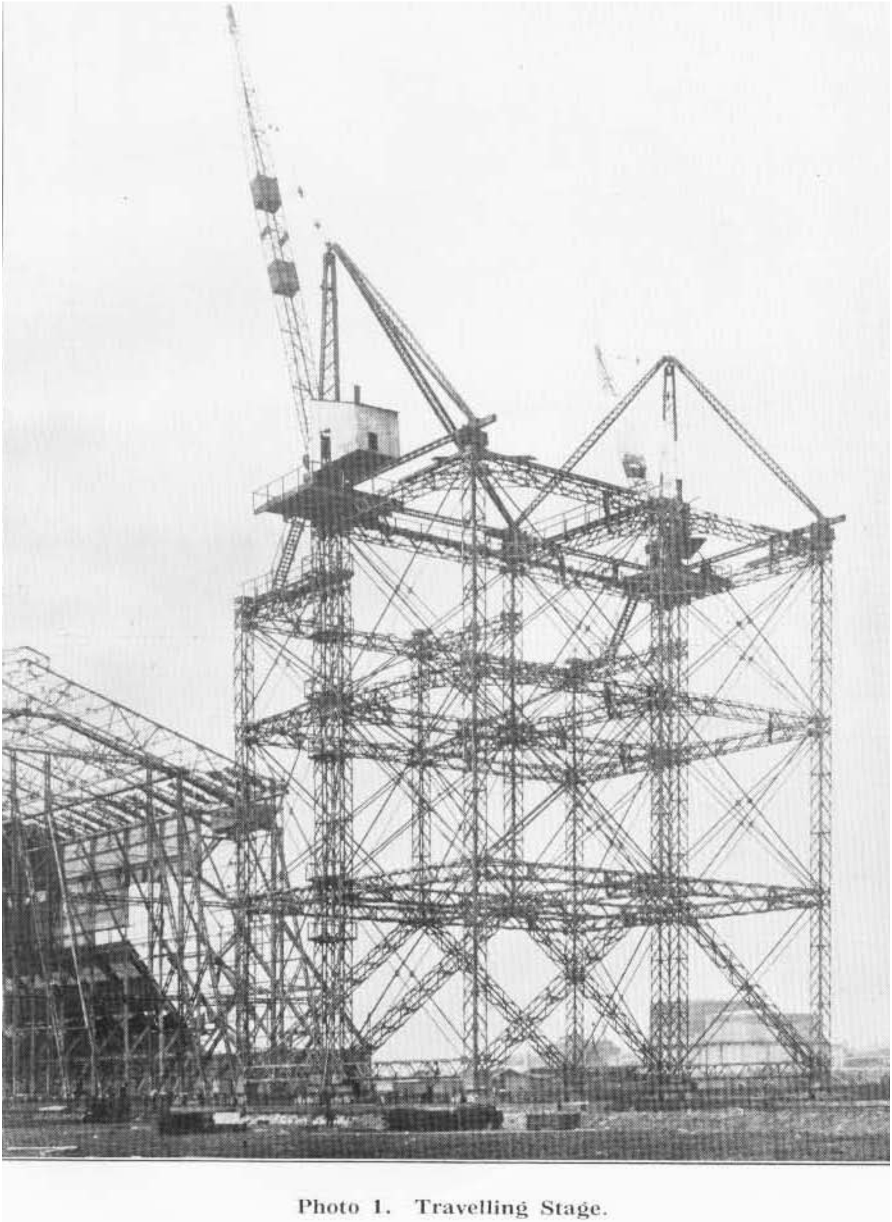


Photo 1. Travelling Stage.

CARDINGTON AIRSHIP SHED

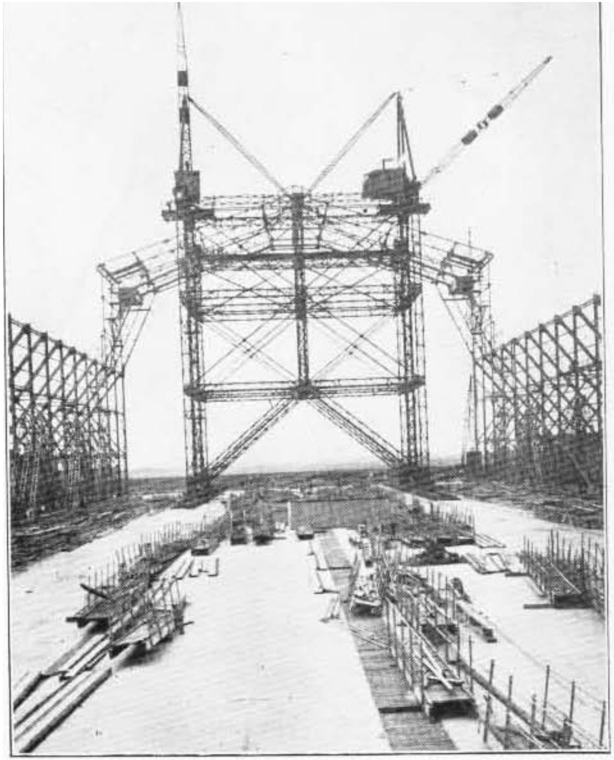


Photo 2. Shed, Roof nearly completely removed.

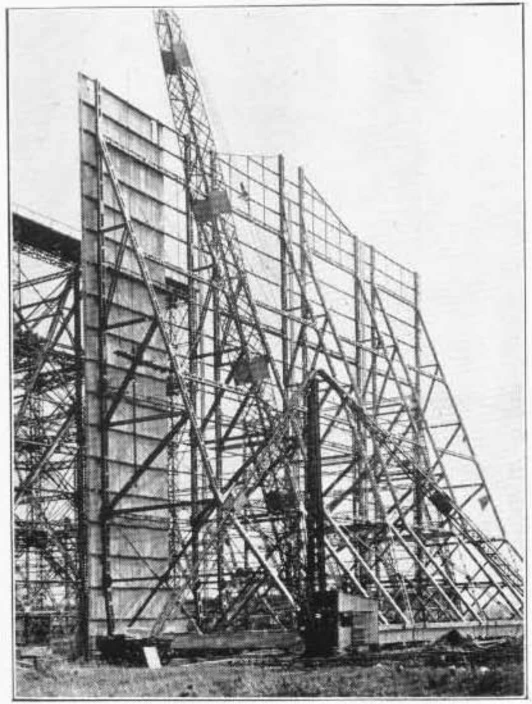


Photo 3. Five tons Jib Crane and Main Doors in course of erection.

CARDINGTON AIRSHIP SHED

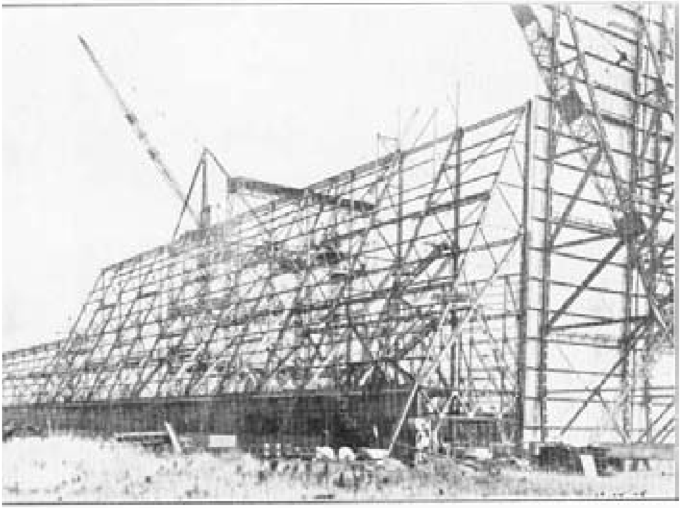


Photo 4. Shed, showing new Rakers to old portion of Shed in course of erection.

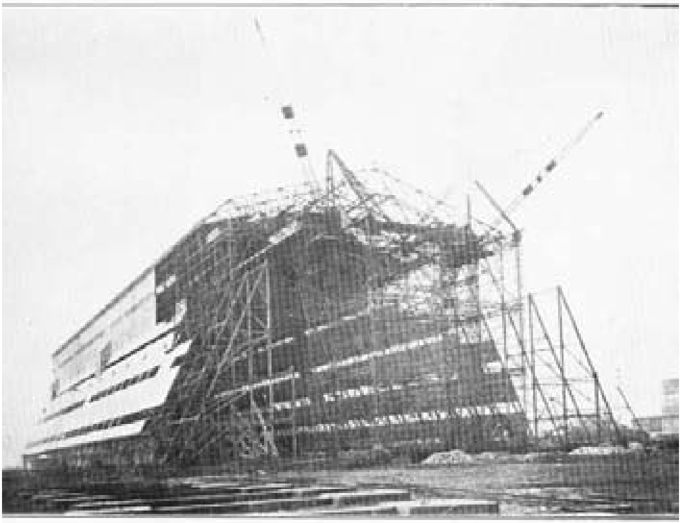


Photo 5. Shed, showing new "A" Frames to extensions in course of erection.

CARDINGTON AIRSHIP SHED

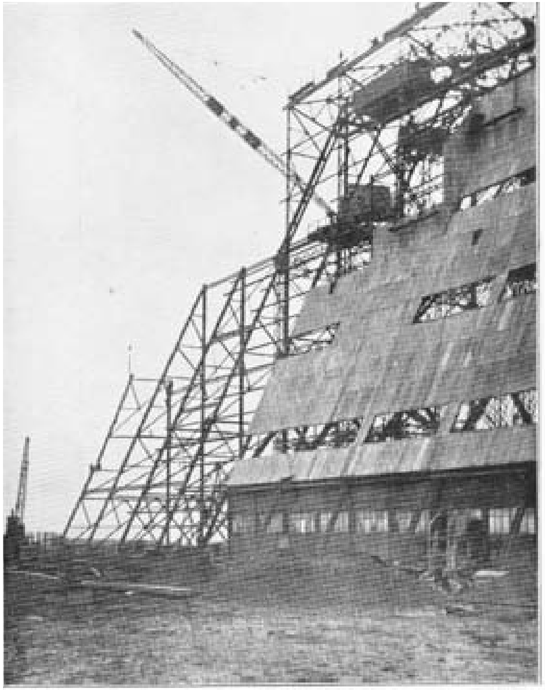


Photo 6. Shed, showing new "A" Frames to extension in course of erection.

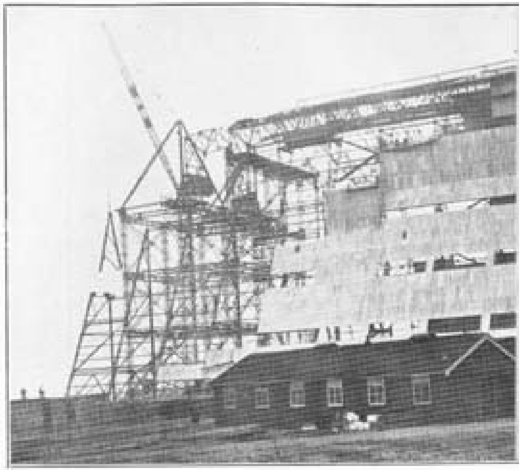


Photo 7. Shed, showing new "A" Frames to extension in course of erection.

CARDINGTON SHED

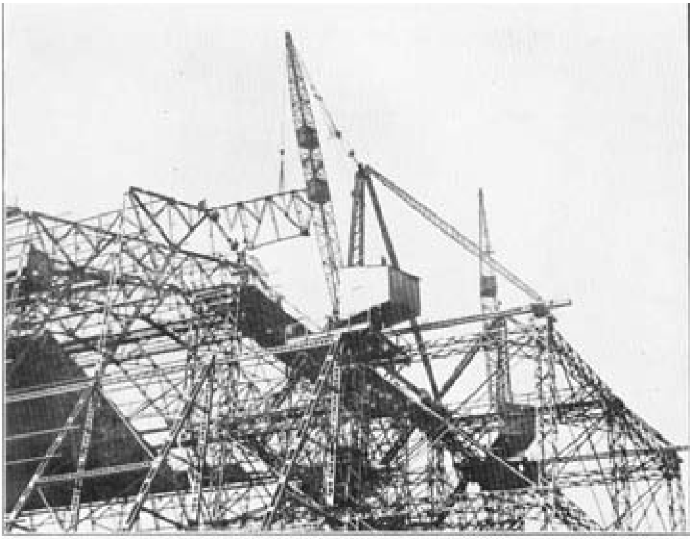


Photo 8. Shed, showing Sections of Roof being hoisted into position.

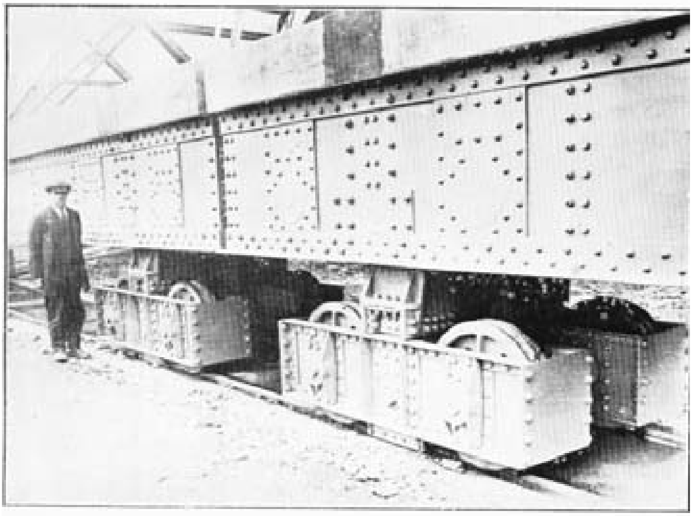


Photo 9. Part of Bogie Carriage to Main Doors.

CARDINGTON ROOF

Photo 10. Cardington Airship Mooring Mast.

CARDINGTON MOORING MAST

CARDINGTON AIRSHIP SHED.

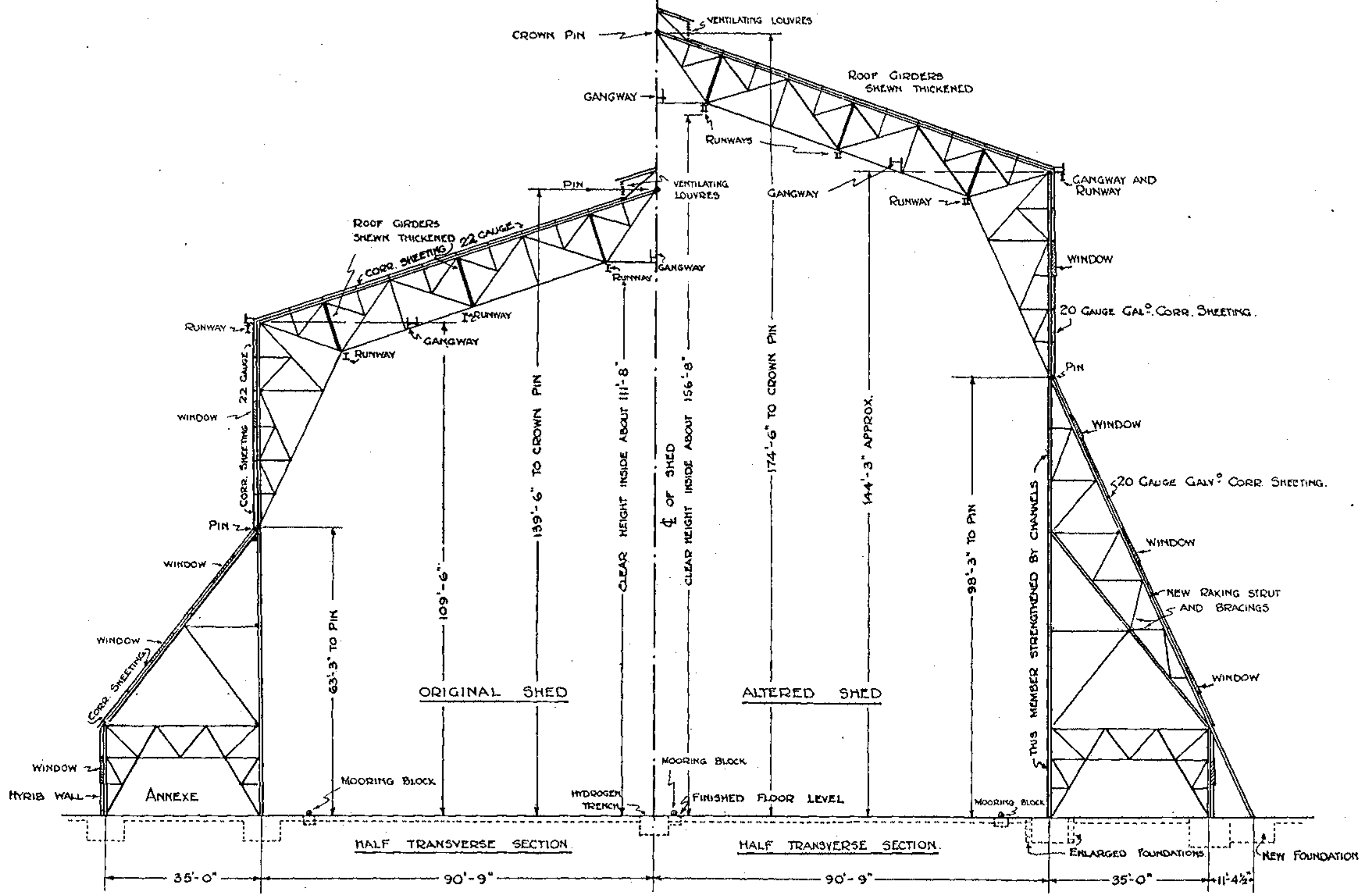
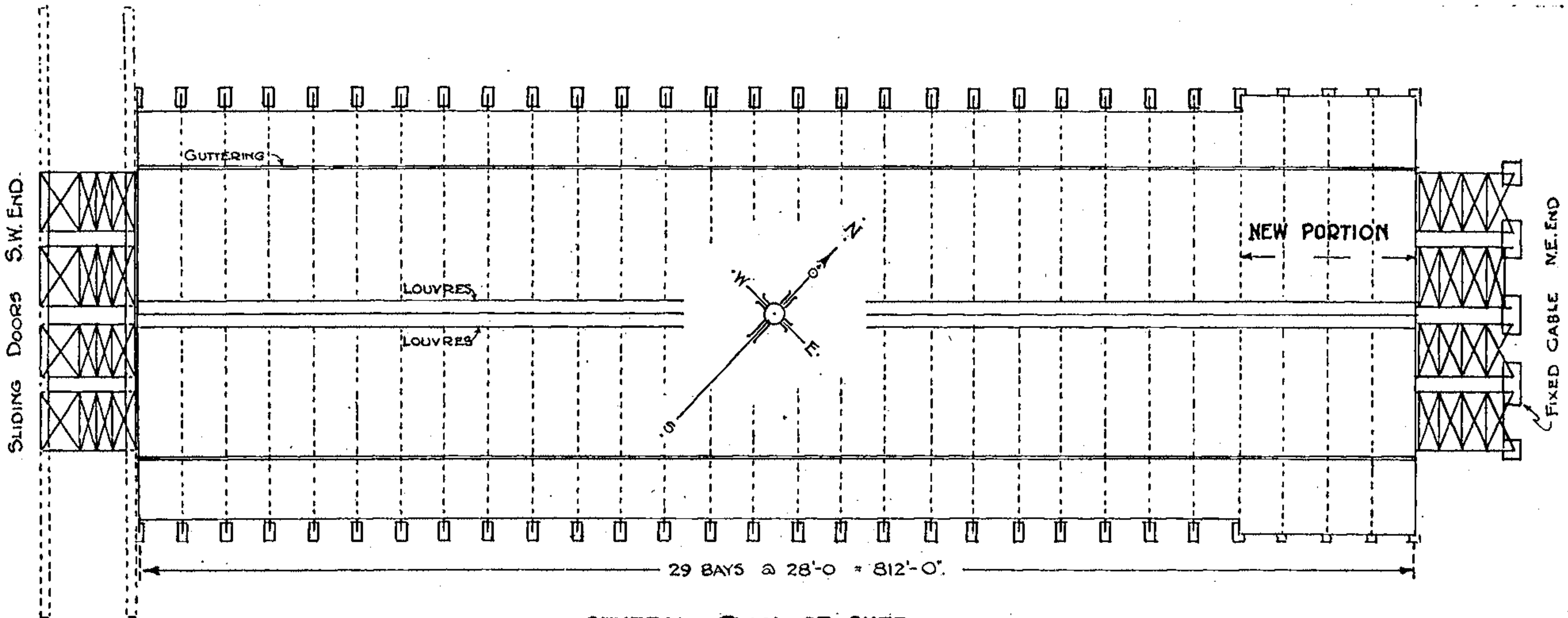


FIG. 1　　FIG. 2

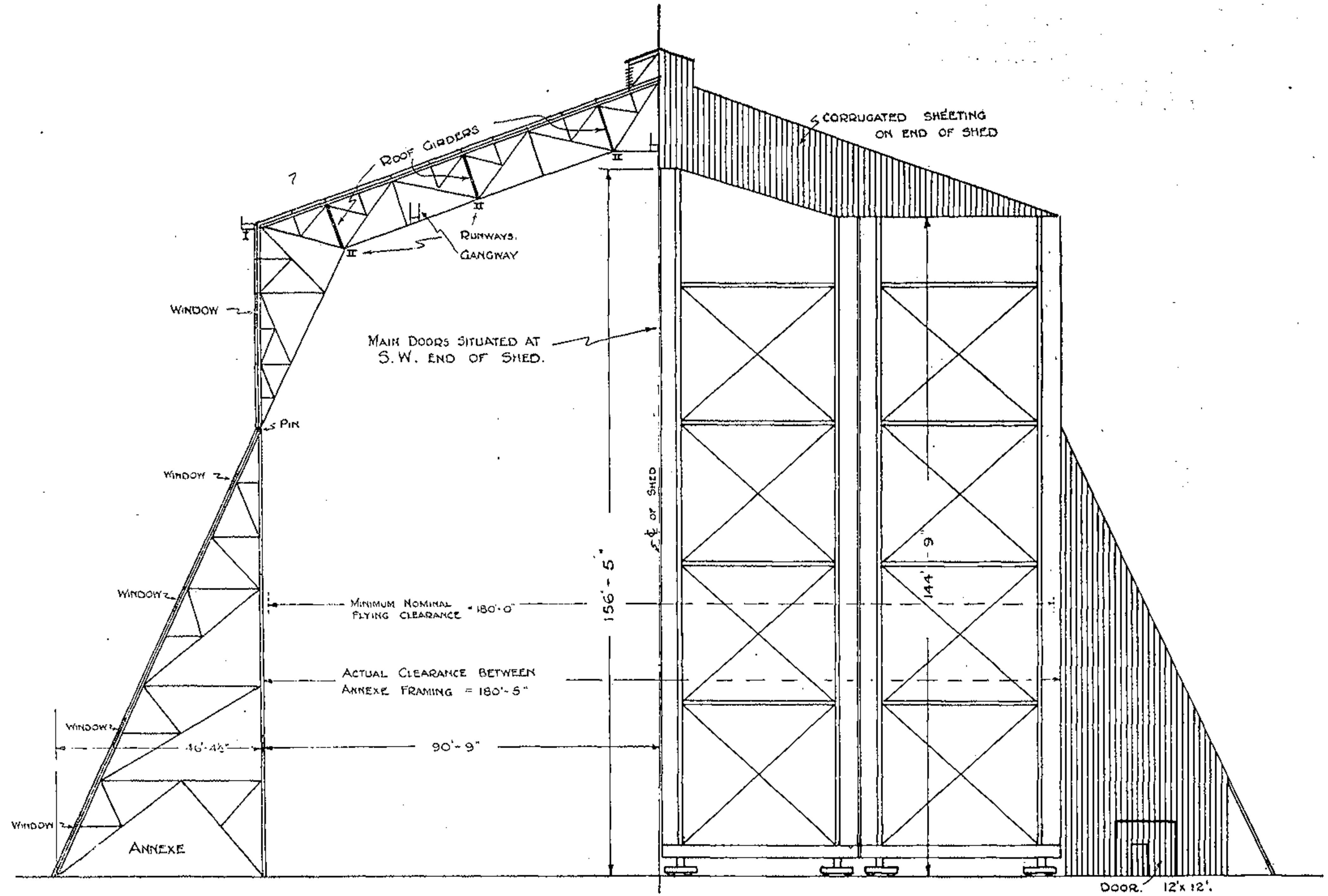
CARDINGTON AIRSHIP SHED.



GENERAL PLAN OF SHED

FIG. 3

CARDINGTON AIRSHIP SHED



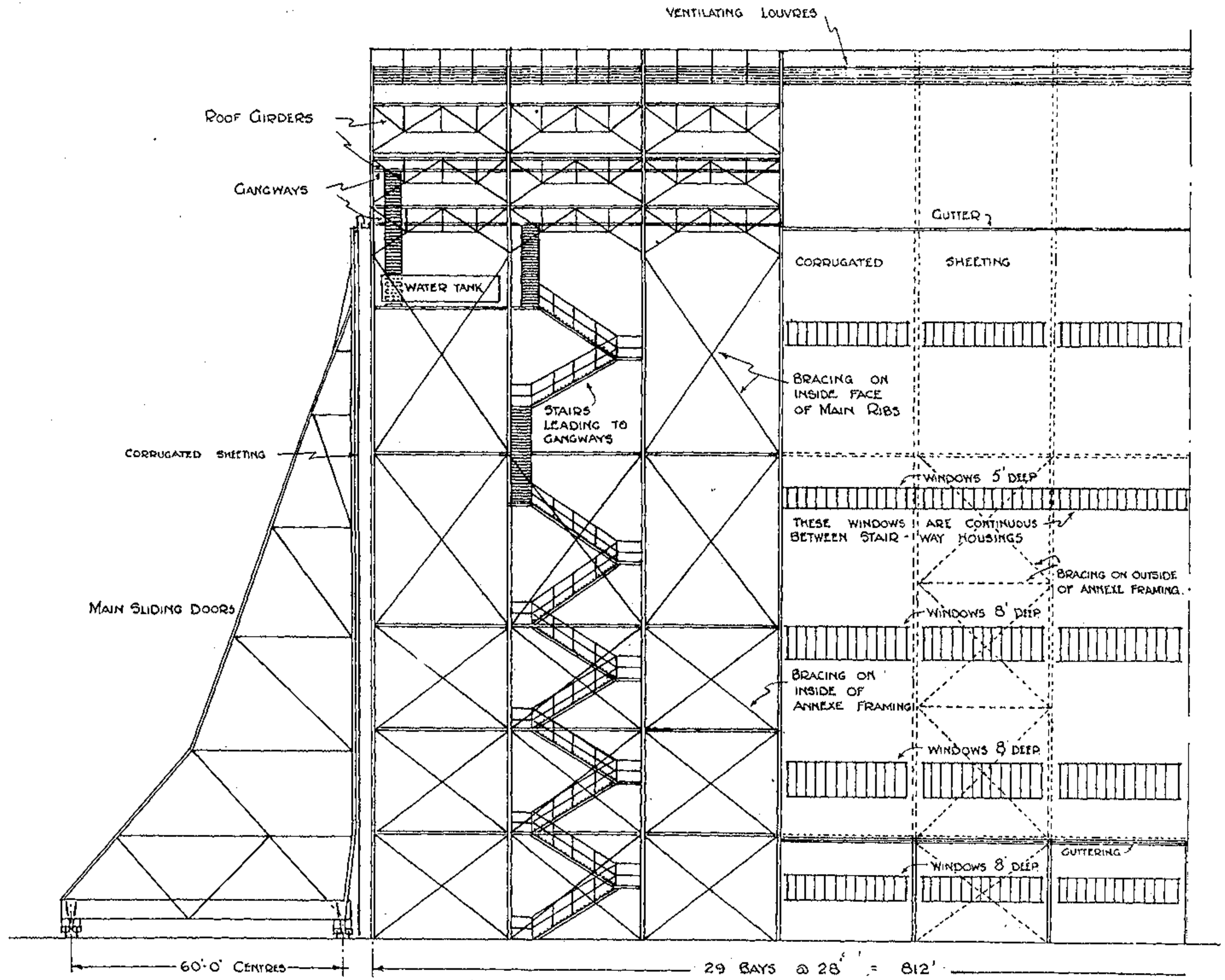
HALF SECTION THROUGH NEW PORTION OF SHED.

FIG. 5

ELEVATION OF MAIN SLIDING DOORS
(TWO OF THE FOUR SECTIONS SHEWN.)

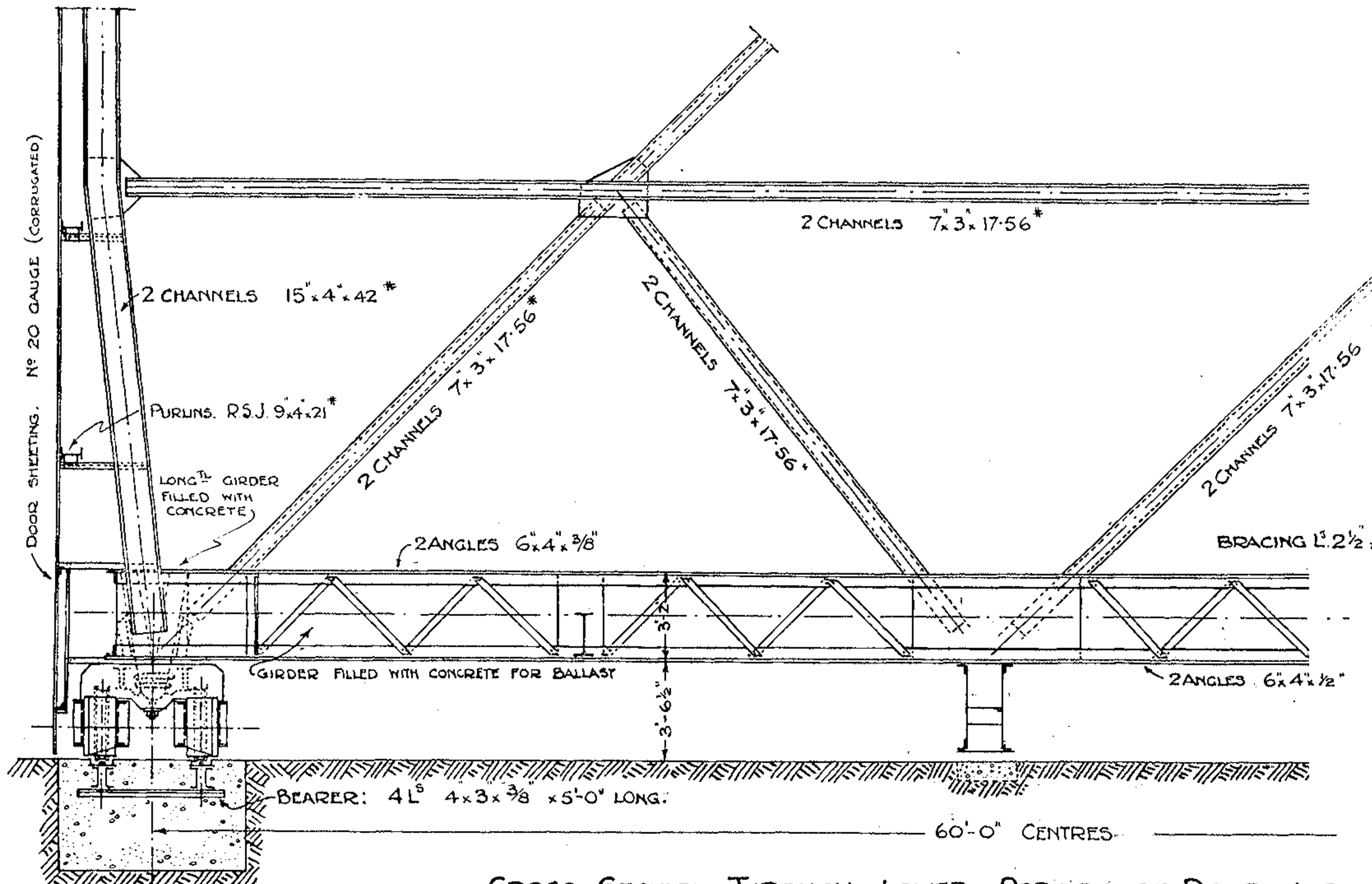
FIG. 6

CARDINGTON AIRSHIP SHED.



PART SECTIONAL ELEVATION OF SHED, SHOWING DOORS. PART OUTSIDE ELEVATION.

FIG. 7



CROSS SECTION THROUGH LOWER PORTION OF DOOR AND

FIG. 8

PICTURE-TELEGRAPHY AND ELECTRICAL VISION.

By COLONEL F. A. ILES, C.B.E., D.S.O., R. of O.

By the aid of the telegraphy of everyday use the thought of one human being reaches the mind of another human being at a distance by the following process. The thought has to be expressed in visible form (generally hand-writing), to be put into code by the telegraphist, to travel along a wire as a series of currents, which announce their presence acoustically to the receiving operator, who de-codes what he hears, and puts the de-code into hand-writing again, when it is ready for the addressee. This is what telegraphy, or "writing at a distance" arrives at, and it is achieved whether the spaced clicks heard by the receiving operator are made on a telegraph sounder by means of changes in line-currents, or made on a telephone-diaphragm, by means of changes in the currents set up in an oscillating circuit as a result of incoming etheric disturbances. In other words, it applies to wireless telegraphy as well as to telegraphy over wires. It is characteristic of this system of conveying messages that it is *indirect*, in that code has to be used.

The transference of pictures to a distance by electrical means is carried out by various methods which fall into two main classes, indirect and direct. Of these, the former is done like the ordinary telegraphy of commerce through the intermediary of code, actually of the same code. The *indirect* methods of picture-transference may therefore fairly be called Picture-Telegraphy, since the medium used is Morse. The *direct* transference of pictures to a distance by electrical means is performed without the intermediary of code and results in the production of fac-similes. As it reproduces the original hand-writing this system is more truly telegraphy, or "writing at a distance" than either ordinary telegraphy or picture-telegraphy by an indirect method, both of which can only produce at the receiving-terminal local interpretations of ideas which were received in code. We will therefore call picture-transference by electrical means picture-telegraphy whether the picture is transferred directly or indirectly. In the latter case it has as good a claim to the title of telegraphy as ordinary telegraphy, and in the former case a better one.

One of the first usages to which an indirect method was put —and this dates back 40 years—was the sending of military sketches. A method of numbering squares having been agreed upon, *e.g.*, letters in one direction and numerals in the other, the sketch was described in a message which could be handed in for transmission as a telegram, *e.g.*, North Point, g8, h1. Road h8, b2. Road, e6, d6, b6, a7. River, b8, c7, d6, d5, c5, b4, a3. Bridge, d5. Wood, and so on. Although adequate for rough black and white work, when no other method of transferring the picture was available, this system had to be improved when it was a question of dealing with photographs. In this case a scale of brightness values was drawn up, ranging from white to black through as many shades as the human eye could be trained to appreciate. A transparent squared paper was laid over the picture to be sent and to each square was allotted a letter of the alphabet corresponding to the mean brightness-value of the portion of the picture it enclosed. The letters were then telegraphed in an agreed order, *e.g.*, 10a, 5b, 6c, might mean "the top row starting from the left has the first 10 squares white, the next 5 squares of the lightest shade, the next 6 squares of the next shade," and so on. A rough picture was then put together at the receiving-terminal to accord with the telegram received. With small enough squares a picture more or less resembling the original was produced. The system was tried out between New York and Chicago as far back as 1910, and improvements were shortly forthcoming. Firstly, the number of brightness-values was increased from 3 in the first trials to 6 or 8. Secondly, a Selenium-cell was made to do the work of gauging the brightness-values, thus eliminating the errors of human eye and judgment. Thirdly, transmission was made automatic and the use of High Speed Telegraphy made possible by causing the Selenium-cell to work a number of electro-magnets, each corresponding to a degree of brightness, and thus to punch holes in a strip. Fourthly, reproduction was made semi-automatic, by means of a special typewriter recording only brightness-values, or even automatic, by making the punched strip reproduce the picture.

While the indirect methods of Picture-Telegraphy cannot compare with the direct methods as regards accurate and clear results, they cannot be lost sight of owing to certain solid advantages they possess. These are :—

(i) The message conveying the details of the picture can be sent and delivered as an ordinary telegram, being dealt with by the G.P.O. in their usual routine.

(ii) The difficulty of arranging for synchronization of sender and receiver in the offices concerned does not arise.

(iii) The necessity and expense of providing or hiring long-distance circuits between the offices concerned does not exist.

(iv) In certain cases direct methods are not possible.

It is probable, therefore, that indirect methods of picture-transference will always have a place to fill, and if, as seems likely, the present efforts to apply high speed telegraphy to wireless are successful, indirect methods of picture-transference may in future receive more attention than at present, owing to the cheapening of long telegrams.

Direct Methods of Picture-Telegraphy.

The introduction of the direct method, that is the eliminating of the Morse Code as a vehicle of picture-transference by wires or wireless, is due to the light-sensitive cell; the most important example of which is the so-called Selenium "cell." By "cell" is commonly understood an arrangement of portions of certain materials in such a way that a difference of electrical pressure is set up in it by chemical means. This difference of electrical pressure is discoverable and available to do work when certain tappable points are connected up outside the cell. The cell is thus a means of producing electro-motive force. This definition covers the primary cell and the secondary cell, and it covers a certain type of light-sensitive cell in which the effect of light is to start chemical action, but it does not cover the class of light-sensitive cell of which the Selenium-cell is the prototype. Such a cell is to be regarded not as a source of electro-motive force but as a variable resistance, whose function it is to affect the current passing through it from an external source of e.m.f. As the Selenium-cell effects changes in current strength of the current that is passing through it, by means of its own varying resistance, and as such variation of resistance is due, not to manipulation of plug or handle, but to changes in the intensity of light falling upon it, it is also in a way a converter. It converts light of varying intensity into electrical currents of varying intensity. There have been several theories to account for the peculiar behaviour of Selenium in changing its electrical resistance under varying degrees of illumination. It is believed by some, though this explanation does not carry one very far, to be due to its being allotropic, and to the existence of different forms of it in the one specimen. In this connection it is not without interest to note that other substances which behave to light as Selenium does, include crystalline sulphur and lamp-black, and that both sulphur and carbon are also allotropic. Whatever the real explanation is, the facts remain. Selenium, belonging to the sulphur group, is obtained in its red amorphous form as one of the by-products in the manufacture of Sulphuric Acid. When it is heated it turns into a black glassy mass. In neither of these states is Selenium a conductor of electricity. On being further heated it crystallizes in grey crystals and becomes a fair conductor of electricity, possessing the remarkable property that its degree of resistance to the passage of a current varies with the degree of illumination to which it is subjected. It does not change its resistance in direct proportion to the light intensity, nor does it respond to a change of light without inertia, and both of these are grave drawbacks to its use as a converter. Also its behaviour is not constant and there is much scrapping of cells. Further its resistance is high. This latter objection to its use mattered formerly very much, but is now, since current amplification by means of valves has arrived, the least of the four evils. A common form of Selenium-cell consists of two metallic electrodes wound spirally and fairly far apart on a piece of slate, on one side of which the space between the wires is filled in with crystalline selenium. It is the function of such a cell in picture-telegraphy to convert optical values into electrical values at the sender, and electrical values into optical values at the receiver. In so doing it replaces the human operator and his code.

Other Forms of Light-Sensitive Cell.

The Alkali-cells, depending upon a different phenomenon, form another important class of light-sensitive cell. The phenomenon in this case is the Hallwachs effect, viz., that if in a vacuum tube with a platinum wire anode and a special large cathode of potassium or other alkali, a high-tension battery is put in circuit in the usual manner and the cathode subjected to light of differing intensity, the changes in the light cause increase or decrease in the number of electrons flowing from the cathode, in other words, a rise or fall of current flowing through the tube. As effects are weaker than with Selenium-cells valve amplification is more necessary in this case, but the Alkali-cell has the advantage, when both electrodes are shielded by earthed metallic rings, of being practically inertialess.

Another class of selenium-cell consists of a platinum electrode and a Selenium electrode in water. A difference of potential is set up by illuminating the selenium electrode. In that it furnishes electromotive force this type is more truly a " cell " in the popular acceptation of the word than the better known Selenium-cell of Bidwell, described above, or that of Siemens. The e.m.f. of this type is, however, so low that the type can only be considered in conjunction with stepping-up by valves. The same can be said of a fourth class of cell, viz. that in which light effects changes in the dielectric constants. Or, if such materials are used in making condensers we can use such a condenser, which changes its capacity according to the intensity of the light to which it is subjected, instead of a light sensitive cell.

The Requirements of Picture Telegraphy.

(i) The picture must be capable of being broken up into small fragments. This applies to all methods of picture-telegraphy, indirect as well as direct. The fragments are generally not larger than 1 sq. millimetre. We will call them the picture-elements. It is easiest when the whole picture is composed of minute parallel lines, so that the picture stands out only by reason of the different shading of these lines throughout their length. Or, the picture may be composed of parallel rows of minute dots, graduated in shade, or even omitted where parts of the picture are white.
Or the picture may consist of a number of areas of different size and shape and differently shaded, thus bringing out the design, as in a photograph. In this case the Relief method (described below) has to be used.

(ii) There must be a means of tracing off the picture, *i.e.*, something which can touch off in succession the whole of the picture elements which go to make up the picture. This tracer-off is either mechanical—a metallic pencil—or optical—a ray of light.

(iii) There must be a means of converting the optical values of the original picture into electrical values. This is usually done by a light-sensitive cell.

(iv) There must be a means of conveying these electrical values to their destination. This may be a line, in which case they travel as current values, or it may be a transmitter of Hertzian waves, in which case they travel as modulations of a carrier-wave.

(v) There must be a means of converting electrical values at the receiving station back into optical values. This is done by a light-sensitive cell.

(vi) There must be a means of building up the picture again element by element.

The Method of Light-Sensitive Cells.

The general principle has already been indicated, viz.: that the picture to be sent must be capable of being broken up into a large number of small parts, and that a light-sensitive cell measures the mean degree of brightness of each picture element and causes changes in the strength of the line-current to correspond with the changes of the brightness-values. These varying current-strengths are either led to line and so to the receiver, where they are utilized for building up a new picture, or they serve the same purpose by being led to the grid of a transmitting-valve.

For requirement (ii), the tracing off of the picture, there are with light-sensitive cells two possibilities :—

(1) In the case of a photographic positive or other picture only the degree of brightness of each picture element due to the light diffused from the picture itself is at our disposal, from whatever source the light originally comes.

(2) In the case of a transparent photograph or other picture, *e.g.*, a film, one can work with far greater light-intensities, since a bright artificial light can be concentrated upon each picture element in turn and allowed to fall upon the light sensitive cell after passing through the picture.

When a choice is possible method (2) is much to be preferred, and in Korn's application of this method (patented in 1902) the photograph at the sending station, as a transparent film, is wrapped upon a glass cylinder, which is capable of movement in the direction of its axis in addition to its rotational movement.

A lamp of bright steady light sends rays through a lens on to a spot on the transparent photograph and thus through the cylinder on to a Selenium-cell within the cylinder. The rotation of the cylinder and its regular lateral motion cause every picture element to be traversed in turn, the spot of light tracing off a series of spirals.

With this direct method of picture-telegraphy, as with all other direct methods, the exact correspondence of the touching off of the picture at the sender in order to break it up and the touching off of the paper at the receiver in order to build up the picture again are of the utmost importance.

There are three methods by which such synchronization is achieved :—

(1) Perfect precision of running at each end, and arrangements for simultaneous starting.

(2) Synchronization control is maintained throughout.

(3) Adjustment takes place at the commencement of the operation and a synchronization correction takes place after every revolution at both sender and receiver.

Of these, method (1) is the least certain ; method (2) is the most exact but needs a special circuit to itself if wires are used, or a special wave-length, if wireless is used ; method (3) is not as accurate as method (2), but more economical, and therefore the most used.

The saving by this method is in expense, an extra circuit for synchronization purposes being unnecessary. The loss is in time, but this is very small. The cylinder at the sender has to pause for an instant at the end of each revolution, it is true, but such stoppage is arranged to take place when the touching off ray reaches the fold of the picture where it is held on to the cylinder, at which point the sending of signals would have to cease momentarily in any case.

When the cylinder at the sender stops, a synchronization current goes out to line. The cylinder at the receiver is set to revolve very slightly faster than that at the sender. It also stops on the completion of each revolution. When the synchronization current arrives it starts again.

The all-important question of synchronization having been arranged for, there is a choice of existing or proposed solutions of the problem of building up the picture at the receiver.

As regards requirement (v), viz.: the reception side :—the first receivers were concerned only with black and white reception, and the matter was comparatively simple, since black or white could be arranged to correspond respectively with current or no current. According as the tracing ray at the sender fell upon a white or black picture element a current was sent to line or not. At the receiver a sheet of paper treated with a solution of potassium iodide was laid upon a zinc plate and a platinum pencil was made to traverse it in the same way as the spot of light was touching off the original picture. The platinum pencil and zinc plate were shunted with a local battery and a resistance, the latter being so adjusted as to permit the local battery to send a current through the platinum pencil and zinc plate when no line-current was arriving. Under these circumstances the paper under the pencil-point was coloured by the passage of the current from the local battery. When line-current arrived the local current at the receiver was checked, no current passed through the platinum pencil and zinc plate, and the pencil ceased to mark the paper. A positive at the sender thus became a negative at the receiver. In this case though selenium was used, the important power it confers of causing graduated signals was not utilized.

Generally, the picture current from the sender is amplified by valves on reception and then flows through the windings of two powerful magnets, between which a small mirror is suspended on the wire of an Einthoven galvanometer. Upon this small mirror impinges a light-ray emanating from a powerful point of light, and is thrown by the mirror into the opening of a sort of photographic camera. According to the strength of the incoming picture-current the mirror is turned more or less out of its position of rest. Thus, owing to varying current-strengths the light-ray from the mirror moves backwards and forwards between the two edges of the opening. In the interior of the camera, opposite the opening, is a light-filter, a glass prism, which, entirely impermeable to light at its base, increases in permeability gradually from opacity to perfect transparency at its apex. Increased current-strength, corresponding to greater light-value of the original picture, causes a greater movement of the mirror. If the differences in transparency of the light-filter are suitably chosen, the latter will permit as much of the light coming from the small mirror to pass as corresponds exactly to the brightness-values of the original. That is, optical values having been converted into electrical values are now changed back into optical values. The rays coming from the light-filter are collected by a lens before passing through a small opening at the end of the camera into a light-proof box, which contains the receiving-cylinder carrying light-sensitive paper. When sending-cylinder and receiving-cylinder move in synchrony a copy of the original picture on the former is now drawn on the latter by the light-ray from the mirror, element by element.

This is how Bélin works, who carried out successful trials of picture telegraphy recently (April, 1926), between Vienna and Paris, with the aid of the Vienna Broadcasting station.

It was, however, Korn in 1906 who first used the reflecting galvanometer for this purpose, and uses it still, although he appears to have replaced the mirror by a small triangular aluminium shutter, which, when no current is passing, throws a complete shadow over the opening to the light-proof box containing the receiving-cylinder. As the current increases the shutter turns more and more, permitting more and more light to enter, up to a maximum when it throws no shadow.

THE RELIEF METHOD.

The Relief Method resembles the method of light-sensitive cells in that it leads up to line-currents corresponding in strength to the varying degrees of brightness touched off. It differs from the method of light-sensitive cells in the means of touching off, viz.: mechanical instead of optical. The Relief Method is thus only a different method of breaking up and sending the picture, and applies to the sender end and not to reception.

Touching off mechanically is based upon the possibility of preparing photographs in relief, such relief corresponding exactly in height at every part of the picture to the degree of brightness of the part. A flat relief is prepared either by using a special silver bromide paper, which swells up in water corresponding to the degree of brightness, being more or less steeped in water, or by utilizing the properties of chrome gelatine, which under the influence of light becomes insoluble in water. When a photograph is printed on a layer of chrome gelatine and then washed, the bright portions of the print remain, while those which are dark are partly or entirely washed away, depending on their degree of darkness. If the chrome gelatine layer is of appreciable thickness it will be washed away, according to the darkness of each portion of the photograph printed on it, to an extent which is appreciable by a mechanical toucher off, *i.e.*, a metal pencil. The photograph is then applied to the sending cylinder and hardened with formalin before use. The sending cylinder is traversed by the metallic pencil in spiral lines, similar to the movement of the sending cylinder under the light-ray of the light-sensitive cell method. By means of a lever the pencil's vertical movements according to the height of the relief increase or decrease the resistance in circuit, so that, corresponding to the brightness of the picture, currents of varying strengths arrive at the receiver.

Reliefs must be extremely accurate, or no great speed can be attained, and that is the chief drawback of the system. As against the light-sensitive cell method it was formerly urged that this drawback was outweighed by the greater currents obtained by mechanical touching off. This is no longer the case, since amplification has come to assist the light-sensitive cell method. Less inertia was also claimed for the Relief method, but this only applies to the use of Selenium-cells, and not of Alkali-cells. In the latter, as already stated, inertia is almost entirely absent and for the use of the former Korn has devised an inertia-compensator. It appears likely, therefore, that the light-sensitive cell method will gain the day over the Relief method. Bélin, however, who abandoned selenium in 1907, has applied the Relief method to wireless and his recent trials between Vienna and Paris were by wireless and the Relief method.

The Telautographic Method.

This is the method of the old copying telegraphs of Bain and Bakewell—metallic pencils are made to describe a series of parallel lines on metal plates at sender and receiver. The pencils are joined by line, and are earthed through their respective plates. The battery at the sender sends a current to line under normal circumstances, and this causes the pencil at the receiver to make a blue line upon paper which has become conductive by treatment with KCN. When the pencil at the sender comes to a spot on the plate which has been written upon with non-conductive ink the circuit is broken and the pencil at the receiver, continuing on its way, ceases to register until the current comes on again. At the conclusion of the operation the paper at the receiver will show a series of fine blue lines parallel to one another and very close together, interrupted in such a way as to show a fac-simile in white of the hand-writing at the sender.

Bain's patent, which covered the foregoing, dates back to 1843. Bain and Bakewell both abandoned the flat plates, on which the pencils work, in favour of revolving cylinders. The hand-writing at the sender was not done on the metallic cylinder but on a thin sheet of tin-foil, which was then wrapped round it. The electrical principle has remained unchanged. Synchronization was achieved by means of a straight line drawn parallel to the writing. If this line appeared broken the speed of the receiving cylinder had to be adjusted so as to make it straight again. Such a method of synchronization was inadequate for quick working and Caselli introduced automatic synchronization, with the aid of which he was able to get up to 900 words an hour, but what spoilt his success in his trials of 1863, was the high capacity in those days of the long lines he used, *e.g.*, from Paris to Marseilles.

Bonelli first increased the number of pencils using five at each end.

If, as Korn thinks, it is possible to use five different high-frequency carrier waves on the same line, then Bonelli's method, using five pairs of pencils, may give Telautography a future by means of wired wireless. Besides electro-chemical reception of the Telautographic method, electro-mechanical reception has been tried with success, but owing to lack of speed, neither of these could give Telautography a permanent place of public utility. This desideratum remained to be supplied by photographic reception.

PHOTOGRAPHIC RECEPTION OF TELAUTOGRAPHY.

Considering that electro-chemical and electro-mechanical receivers give immediately visible results it might well be doubted if photographic receivers, necessitating loss of time in developing and fixing, would prove superior.

The time thus lost has to be gained by extra transmission speed. Even then we have a human element to deal with, in that the telegraph staff have a natural objection to a form of reception producing results not immediately visible. Inasmuch as Telautography can only be brought to practical speeds by photographic reception, the remedies are :—

(1) To reduce the time taken in developing and fixing. This has been done with success.

(2) To give the operator a second and visible picture, not necessarily showing such detail as the photographic picture, but sufficient to assist control.

The speed of reproduction in copying telegraphy is all important, and this for a simple reason. Copying telegraphy cannot afford to be more than a little slower than high speed telegraphy, or running expenses will outweigh the advantages of exact reproduction. While in telegraphy a single letter can be telegraphed by, on an average, five telegraphic signs, a much larger number is necessary per letter in telautography, depending upon the degree of accuracy required. Generally it should be sufficient to reckon 10 to 20 picture lines to each line of hand-writing, and registration is required of every stroke, down to a thickness of $\frac{1}{4}$ mm., *i.e.*, there must be a telegraphic signal every $\frac{1}{4}$ mm. of stroke, passing over letters averaging, say, $2\frac{1}{2}$ mm. broad, and passing over them 10 to 20 times before the letter is complete. Allowing for $\frac{1}{4}$ mm. interval between strokes, it will be necessary to register

$$2\frac{1}{2} \div \frac{1}{4} \times 20 \times \frac{1}{2} = 100 \text{ signs for each letter.}$$

A transmission speed of 1,000 signs a second (or 10 letters a second according to the data of the case just assumed) has been reached by telautography, over wires and with photographic reception, but this must be looked upon as a maximum, not because the apparatus is incapable of higher performances, but because Telautography is primarily required for long-distance working, and the high capacity of long lines prevents a further increase. Against this performance of 10 letters a second by Telautography, high speed telegraphy can do 10 to 20 letters a second, and may well in the near future attain to 30. If we are thus forced to admit that the speed of Telautography must remain inferior to the speed of high speed telegraphy, Telautography can only hold a place in the field by the loss of time it entails being balanced by the advantages of fac-simile reproduction.

All this applies to matter with which ordinary telegraphy can deal. It does not apply to the transmission of portraits or of finger prints for police purposes, or of photographs for newspapers.

Such photographs have to be re-drawn first in black and white. At the receiver they are reproduced as negatives on a photographic film wrapped on a revolving cylinder inside a dark cabinet. A small 6-volt 80 candle-power lamp throws a ray through a lens on to a fine metallic ribbon stretched between the poles of an electro-magnet, and when no line-current arrives the shadow of the ribbon is thrown upon the opening to the cabinet. When line-current arrives the metal ribbon is pulled out of position and the lamp throws its light into the cabinet, *i.e.*, on to the photographic film. For long distance working it is better to produce a negative at the receiver, as just described, but in the laboratory it is just as easy to arrange for the opposite, *i.e.*, for the line-current to cut off the light from the camera, and for no current to admit the light. A positive is thus produced, since the interruption of the line-current means that at the sender the tracer is passing over a line of the picture.

Korn, Jenkins and others use this method of photographic reception, but there is also another method, which is based upon Kerr's discovery that when sulphur di-oxide is used as the dielectric of a condenser and the latter is highly charged, a beam of polarized light passing through the sulphur di-oxide is doubly refracted. It is easy to use this phenomenon for darkening or lighting up the reception film, instead of the electro-mechanical method of pulling aside the obstructing ribbon, and there is also no inertia to reckon with, but all advantages as regards strength of light available for reception lie with the mechanical method.

WIRELESS PICTURE-TELEGRAPHY.

(1) TELAUTOGRAPHIC METHOD.

Even as far back as the days of the Coherer, there were many proposals for wireless to take the place of wires in telautography, since the transmission of black and white (hand-writing and drawings) *i.e.*, of signal or no signal, leaving out all matters of degree or intensity, presented no very great difficulties to wireless. The method of telautographic transmission by wires already described could be modified as follows :—the touching off pencil at the sender to be included in circuit with the source of H.T. and the primary of an induction coil, in circuit with the secondary of which is a spark gap. The pencil would thus permit wave radiation while travelling normally over the picture, and the waves would cease to be radiated whenever the pencil was passing over a place which had been written upon with non-conducting ink. A less primitive method was to govern radiation by means of a relay : but owing to sparking, the cut-out of the relay-arm had to be made comparatively large, and so it was impossible to attain a good speed of transmission. Another disadvantage was the loss of time in bringing the coherer back to its normal state of readiness for reception. As no great speed was attainable, electro-mechanical reproduction satisfied all requirements and photography for this purpose did not need to be considered. Thorne Baker, in 1910, increased the speed by substituting for the coherer a Marconi's magnetic detector, and by introducing a very sensitive ribbon galvanometer, operating a Korn's photographic receiver, as just described under "Telautography."

Up to the war, wireless telautography results continued mostly unsatisfactory, and even when, during the war, the introduction of the valve-amplifier had given very real increases of current at the receiver, the use of the touching off relay at the sender made transmission speed slow.

Towards the end of the war, German G.H.Q. demanded simple wireless telautography sets for transmitting and reproducing sketches made by aeroplane observers, and sets were hurriedly provided both by Korn and by Siemens and Halske with photographic receivers as above, and by Dieckmann with visible reception. All these sets suffered from too slow transmission speed, and, owing to the electro-mechanical relay in the sender, could not get above 60 signs per second, so that in the time permissible, at most 5 minutes, only pictures of the simplest character could be reproduced, and only up to a size of $2\frac{1}{2}'' \times 4''$.

The simplicity of the change from working telautography over wires to working it by wireless does not extend to the arrangements for synchronization. This is a more complicated matter. For synchronization when working over wires all that is necessary is to send a current-impulse in the opposite direction to the line-currents. The nearest analogy with wireless would be to send a synchronization signal on a separate wave length, but this introduces an unwelcome complication. Korn does it as follows :—At the end of each line he has a pause of, say, 1/10th the time of a revolution of the cylinder. During this pause no waves are sent out, and the time serves for the preparation of the synchronization signal ; the circuit at the receiver for the release of the synchronization magnet being automatically interrupted during this time by means of a relay, adjusted to work only when a longer pause comes, and not for the short interruptions of the waves, which occur when the pencil passes over hand-writing, etc. After the pause the first incoming wave of the correct wave-length releases the synchronization-magnet. A delay action relay for this purpose may be either on the hot wire principle, acting when the wire has sufficiently expanded, or it may depend for its action upon a Selenium-cell selected as having the requisite degree of inertia.

We have seen that up to the end of the war wireless telautography was hardly meeting requirements. The first condition for increasing its transmission speed was to get rid of the electro-mechanical touching off relay in the sender. Important as this was for telautography by wires, it was much more so when working by wireless, since the relay in the sender always worked with considerable sparking and on this account could not be got up to more than 100 signals a second. Since the war this fundamental condition of progress has been fulfilled by the valve-relay. The principle of this is well known, viz.: that in the triode valve the current produced between cathode and anode by a suitable high tension supply can be altered within wide limits by quite small changes of the potential of the third electrode, the grid. One is able thus to dispense with the aid of the electro-mechanical relay, and to send out the desired impulses by means of the valve-relay, and this without in any way noticeable sparking when the pencil passes from a conducting spot to a non-conducting spot on the sending cylinder. The earliest and simplest idea was to use the valve itself as a transmitter, and this is still done in laboratory trials where transmission energy is low ; but wireless picture-telegraphy at a distance is obliged to use high power in order that reception may not be unduly affected by extraneous signals and disturbances. It is, therefore, not practicable to go from the telautographic sender direct to the grid of a transmitter valve, but the oscillating potential delivered by the telautographic sender is first applied to the grid of a modulating-valve which controls the transmitter. This is the method which underlies all present wireless telautography transmitters. Korn has modified it to the extent of introducing in the oscillating circuit of the transmitter a capacity, in parallel with the modulating-valve, which alters the oscillation constants according to whether changes of potential are being applied to the grid or not, and thus mistunes the wave, permitting radiation to continue on a different wave-length when no signal is going out.

At the receiver, now that transmission speed is no longer limited by the electro-mechanical relay at the sender, which alone made electro-mechanical or electro-chemical reception adequate, photographic reception is naturally adopted, the method employed being that of the ribbon galvanometer (described above), or of the reflecting galvanometer, or of the Kerr-cell.

As regards amplification at the receiver which must be considerable, especially for great distances, there is the same limitation as regards working over lines: no transformers are permissible. All low frequency amplification must be done by resistance amplifiers. In general, comparing telautography over wires with telautography by wireless, up to the present the same speeds have been obtained by the two methods, for hand-writing, for drawings and for photographs. As the question is economic, greater speed, which reduces expense, is essential. The equality now existing as regards speed is not likely to continue, since the capacity effects of long lines, even though reduced by "loading," will prevent telautography on land line and cable from gaining any material increase of speed, whereas wireless telautography suffers from no similar incapacity.

(2) THE METHOD OF LIGHT-SENSITIVE CELLS AND THE RELIEF METHOD.

Essentially greater difficulties lie in the way of the wireless transmission of pictures by the method of light-sensitive cells and by the relief method. While in the transmission of pictures over wires greater or smaller currents go to line in correct proportion corresponding to the different brightnesses touched off, there is for such transmission by wireless no analogous method possible except that of sending out waves of greater or less energy to correspond with the brightness of the picture elements. The actual sending by wireless of greater or less amounts of energy correctly stepped presents little difficulty, but it is very difficult to receive them. Once outside the laboratory, even over short distances, anomalies appear which have yet to be got rid of. The same thing occurs in broadcasting, where although even over great distances, everything which depends upon frequency, like the tone-sequence and quality, is well reproduced, quite peculiar aberrations occur in tone-strength. Disturbing as these variations may be in broadcasting, in picture transmission, where everything depends on the correct re-production of the degrees of brightness, they are vital. These anomalies, which are not only due to atmospherics and extraneous signals, will have to be thoroughly studied. Apart from this, there is much analogy between the method of light-sensitive cells by wireless and wireless telautography.

It appears to be easiest to produce different potentials by differing degrees of illumination of a Selenium, or other light-sensitive, cell, and to apply these to the grid of a transmitting-valve. The wireless transmitter thus radiates waves of differing energy corresponding in their gradations to the degrees of brightness of the original picture. A sender for the light-sensitive cell method, as used by Korn and already described, is therefore suitable. Similarly at the receiver it is best to work photographically, using the ribbon galvanometer, oscillograph or Kerr-cell, exactly as when working over wires.

For synchronization the same arrangements will serve as when working wireless telautography.

As Korn does in wireless telautography, it is best to interpolate a modulating-valve governing a continuous-wave transmitter, instead of applying the differing potentials provided by means of the light-sensitive cells direct to the grid of a transmitting-valve.

The wireless transmission of pictures by the method of light-sensitive cells may take some such form as that just described, provided the reception difficulties alluded to above can be overcome. This necessary condition has still to be faced, since up to now long distance picture transmission by wireless and light-sensitive cells has been only a partial success. Such success as has been achieved by Marconi's and the Radio Corporation between England and the U.S.A. is possibly to be attributed to :—

(1) A low transmission speed—as evidenced by the use of the lever-arm writer.

(2) Apparently very high power was used.

Hard as people are working in the U.S.A., Germany and France, to make wireless-picture telegraphy by the method of light-sensitive cells a success, it appears likely that wireless telautography will become practical first. It is, however, in the former that the most important prospects of the future lie, not only as regards picture-telegraphy proper but regarding its offspring, electrical vision.

Electrical Vision.

Electrical vision is a special case of picture-telegraphy. What makes picture telegraphy possible is that the optical values of the picture elements, having been changed into current values and conveyed as such to the distant station, are there turned back into optical values, and affect one by one a photographic film upon a revolving cylinder until a picture corresponding to the original has been built up element by element.

From this it is in theory only a step to electrical vision. Break up the image of a desired object placed in front of the apparatus at the sending station into picture elements as before, and reproduce them simultaneously, or practically so, at the receiver, when the impression of the whole object, instead of being made slowly on a prepared film, can be made by diffusion from a screen instantaneously on the eye.

Thus in picture-telegraphy proper the picture produced at the receiving terminal is a permanent one : in electrical vision it is transient.

In picture-telegraphy proper the time of transfer is technically of no importance, and only a factor to be considered from the standpoint of cost. This time has been reduced now so that a picture 5″ × 4″ can be reproduced in from 5 to 7 minutes by more methods than one.

In electrical vision the time of transfer is of essential importance and must not exceed 1/10th of a second. The nature of the picture produced and the time taken in producing it are thus the chief differences between picture-telegraphy proper and electrical vision. They are alike in the methods used and especially in the fact that what they transmit, viz. a picture in the one case and the appearance of persons or objects in the other case, must first be broken up into picture elements for subsequent re-assembly at the receiver.

Electrical vision may be divided into electrical vision proper and the wireless cinema.

The Wireless Cinema, which is a special case of electrical vision, differs from electrical vision proper in that it deals not with objects but with a succession of photographs. As regards the transient images produced by electrical vision, the limit of time of transference permissible is imposed upon us by the retentivity of the retina. Owing to the inertia of the eye any light impression which affects it persists there for about ⅛th of a second. From this it follows :—

(1) That in electrical vision proper the total time available for re-assembling the whole of the picture elements must be less than ⅛th of a second, or the appearance of every portion of the picture will not seem to be simultaneous.

(2) That in the wireless cinema, as in the ordinary cinematograph, pictures must pass before the eye at a minimum rate of, say, 10 per second, in order to produce the necessary impression of persistency.

We must now examine the problems which these conclusions involve. The attempts to solve those arising from (1) date from the discovery that by the use of selenium the lighting of a light at one place could bring about electrically the lighting of another light at a distant station. They have thus lasted fifty years, always approaching, without arriving at a practical solution. Carolus, however, had an electrical vision apparatus working in his laboratory a year-and-a-half ago, while Voss has shown on his electrical vision apparatus moving pictures of about the size of a visiting card. The following are the data upon which the problem of electrical vision must be considered :—

(1) An object or picture to be made visible by electrical means must be capable of being broken up into elements.

(2) These elements must not be larger than 1 sq. mm. For sharpness of detail they should, however, be smaller.

(3) The whole of the elements which go to make up the picture must be capable of re-assembly at the receiver in less than 1/10th of a second.

Taking for instance the size mentioned, viz. that of a visiting card, say $7\frac{1}{2} \times 4$ cm., there would be 3,000 picture elements, and these must be carried and re-assembled in less than 1/10th of a second. Either wires or Hertzian waves can serve as the carriers of the currents created at the sender from picture-elements. In the one case the picture-current, amplified, is sent by the line wire, in the other case this current is used for the modulation of a carrier-wave, as is the microphone current in radio-telephony. A third case is also possible, in which Hertzian waves are conveyed by wires, so that by choice of suitable frequencies, three or more frequencies can use the same line wire without interference, thus reducing materially the number of circuits required.

The number of signals per second which can be sent over telephone circuits up to any distance possible in England without difficulty, *i.e.*, while maintaining the due proportionality of the varying currents, is 1,000, or at the rate of 100 signals per 1/10th of a second.

It is evident, therefore, that from the standpoint of practicability, not of possibility, line transmission for electrical vision need no longer be considered, since to carry the currents of 3,000 picture elements in 1/10th of a second we should have to provide 30 circuits. For the same reason "wired wireless" may be left out of consideration, since even with as many as four high frequency carrier waves using the same line, we should still need eight telephone pairs. If, however, eight long distance circuits were forthcoming, there is no doubt that some of the leading experts could put up an exhibition of electrical vision over wires. There remains only wireless picture-telegraphy, and this we know is capable of transmitting and reproducing as a fixed picture in five minutes pictures even larger than the one taken as an example. The question is then :—Can wireless picture-telegraphy reproduce in 1/10th of a second a picture consisting of 3,000 elements? It is suggested that the answer is an unqualified affirmative, and that for the following reasons:—

(*a*) Bélin has constructed an apparatus which has proved that the eye will take up (and hold for ⅛th of a second) light impressions of a duration down to 1/400,000th of a second. He says that this is true to such a degree as to indicate that the limit has not yet been reached.

This would permit the whole of the 3,000 picture elements to be touched off in succession, and if this were done in 1/10th of a second, still to produce the impression of simultaneous vision of all parts of the picture.

(*b*) Carolus using the Alkali-cell, depending upon the Hallwachs effect, and without inertia, sent recently in trials from Nauen 250,000 picture elements in 5 seconds, or at the rate of 5,000 elements in 1/10th of a second.

There appears therefore, sufficient reason to state that by the use of the light-sensitive cell and by the application of wireless to picture-telegraphy, and in spite of the reception difficulties indicated above, the problem of electrical vision has been solved. There is no doubt that the practical problem of electrical vision will also be solved, since this is primarily a question of lowering the cost of existing solutions.

Whether uses may be found for electrical vision proper, and if so what uses, it is difficult to say. A leading dramatist of the day has introduced in a play of the future a scene in which a telephone conversation is carried on with a person whose image is visible during the conversation. No one would dare to say that this will not come true. Another case of more obvious utility would be the visual broadcasting of theatrical performances, combined with the acoustical broadcasting of to-day. As regards the special case of electrical vision, the wireless cinema, there is more certainty about its having a place to fill when it arrives. Cinematograph films will be broadcast to wireless amateurs in their homes, as musical programmes are now broadcast. In fact, it is in broadcasting that the hope of electrical vision and the wireless cinema lies, for the expense of providing the necessary apparatus can only be met by dividing it amongst the largest possible number of subscribers.

Sources of Information:—

(*a*) "Die Bild Telegraphie," by Gerhard Fuchs, published by Siemens, Berlin.

(*b*) Several articles by Emo Descovich in the "Neue Freie Presse," Vienna.

THE CASE FOR THE HORIZONTAL MULTI-CYLINDER INTERNAL COMBUSTION ENGINE.

By CAPTAIN R. M. H. LEWIS, M.C., R.E.

WHEN faced with the problem of choosing a prime mover of the internal combustion type, the prospective buyer has the choice of a horizontal or a vertical engine.

In the small sizes he can usually find an engine to suit his requirements without much difficulty.

When the larger multi-cylinder type of engine is required the average person who has not studied internal combustion engines very deeply will almost certainly be misled into the popular belief that the vertical multi-cylinder engine is the only possible type to install.

It is very unlikely that he will get any information on the subject of the relative merits of vertical and horizontal multi-cylinder design from the ordinary text books.

This article is, therefore, intended to put the case for the horizontal multi-cylinder engine and to criticise the various claims for superiority put forward on behalf of the vertical multi-cylinder engine.

The vertical engine manufacturer started with the great advantage in the first place that he was following in the footsteps of the manufacturer of the vertical high-speed steam engine.

This type certainly had advantages, which cannot be discussed here, over the old type of slow bulky horizontal steam engine for generating purposes.

It is, however, misleading to take the arguments relating to steam design and apply them to internal combustion design. Temperature problems are entirely different and the necessity of easy and quick overhaul and inspection of valves and piston does not apply to the steam engine.

In addition, for obvious reasons, for marine and transport work the horizontal engine is out of the question.

The advantages claimed for the vertical multi-cylinder I.C. engine are :—

(1) Small space occupied. Inexpensive foundations and buildings.

(2) Good balance and absence of vibration.

(3) Uniformity of torque and small cyclic irregularity.
(4) High speeds suitable for direct coupling to electric generators.
(5) Forced lubrication minimizing the risk of hot bearings.
(6) Less wear on cylinders because owing to their vertical position they have not to support the weight of the pistons.
(7) Low weight per B.H.P.

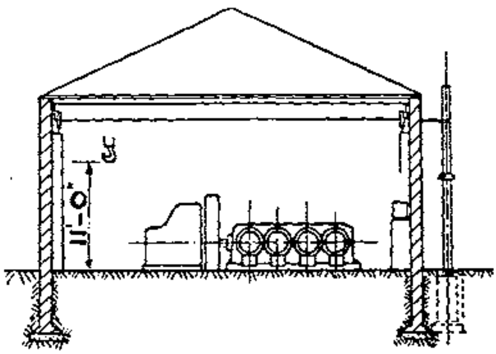


Fig. 1.

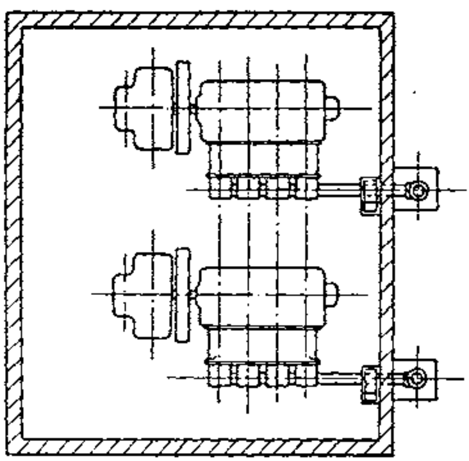


Fig. 2.

To discuss these claims :—

(1) Figs. 1 and 2, reproduced from a pamphlet on the horizontal engine brought out by the Premier Gas Engine Co., show an engine house for two 400 h.p. Premier horizontal engines, and Figs. 3 and 4 show an existing engine house for two open type Diesels of similar output.

In Figs. 3 and 4 the operating platform seems rather unnecessarily elaborate, especially the connecting gangways, which are not usual practice; as the comparison stands, however, the floor space in both engine rooms is the same and the percentage of floor space available for dismantling the horizontals is some 13 per cent. greater than that available for dismantling the verticals.

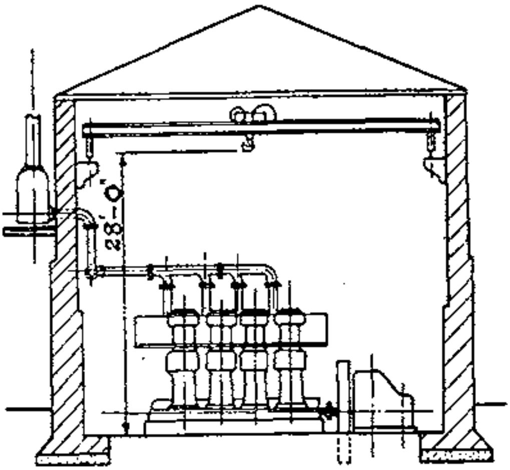


Fig. 3.

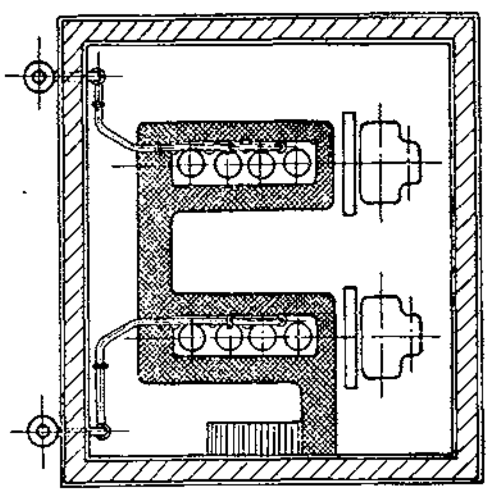


Fig. 4.

As the pistons of the verticals have to be drawn out of the cylinder vertically, the height and, therefore, the cubic capacity of the engine room for the vertical engines must be the greater of the two.

On the other hand, it must be remembered that, especially in military installations and in adding to existing installations, one is not always one's own master as to floor space. The vertical installation could be further compressed if necessary at the expense of ease of dismantling and examination. Also where space is limited the closed type of vertical engine occupies less space than the open type illustrated.

The horizontal installation shown is occupying about the minimum floor space desirable.

The question of foundations is very closely bound up with that of vibration, and here a comparison can be made with the old vertical steam engine. The horizontal engine being a slower speed engine than the vertical will, other things being equal, be the heavier. Therefore, the weight of foundations per b.h.p. must necessarily be heavier, too.

The foundation for the horizontal engine must also, owing to the shape of the engine, be slightly more complicated and of a larger area. It does not appear that in itself this is a very grave disadvantage.

On the other hand, owing to the direction of the thrust, the vibration (if any) produced by a horizontal engine is confined to the surface and localised in the engine room.

The foundation of a large vertical engine may give no trouble at all; but, on the other hand, if there happens to be in the subsoil under the foundation a stratum capable of transmitting vibrations, very serious vibration may be caused, not in the engine room, but transmitted by this stratum to neighbouring buildings.

As an example, the case of one large London power station may be quoted. This station originally installed large vertical power units (steam). No undue vibration was felt in the engine room, but the vibration was transmitted underground to neighbouring dwellings, and so serious was the nuisance resulting that, after spending a large sum of money in unsuccessful attempts to insulate the foundations, the company eventually had to scrap the entire plant and substitute turbines.

(2) Balance in multi-cylinder design, given identical conditions *re* number of cylinders, speed, weight of reciprocating parts and total weight, also the same ratio of length of stroke to connecting rods, is identical in either a horizontal or a vertical engine.

Taking a four cylinder engine, it is easily shown that primary balance as regards reactionary vibration and that caused by the displacement of the centre of gravity due to the piston movement is perfect. The disturbing force of the secondary vibration, due to the angularity of the connecting rod, remains, however, and increases as the square of the speed.

The slower the engine speed, therefore, the less should be this disturbing force.

It would, therefore, appear that the horizontal engine with its slower speed should be, if anything, at a slight advantage over the vertical in this respect.

(3) Uniformity of torque and low cyclic irregularity. These factors depend chiefly on the weight of the flywheel and the number of impulses per revolution. The horizontal engine should, therefore, be at no disadvantage in this respect, and, in fact, a sufficiently good cyclic irregularity can be obtained to drive alternators in parallel, which is the severest test an engine is likely to be called upon to undergo.

(4) High speeds suitable for direct coupling to electric generators. Given good balance there does not appear to be any reason why the horizontal engine should not be run at as high a speed as the vertical. From the point of view of longevity of the engine, however, high speeds are to be avoided, even at the expense of a slightly larger generator. Horizontal engines are run at slower speeds than the vertical type.

(5) Forced lubrication minimizing the risk of hot bearings. There is much to be said for and against forced lubrication, which is very largely, though not universally, used for vertical engines, *e.g.*, many Diesel engines have plain ring oiled main bearings and banjo lubricated big ends.

Forced lubrication has not got the merit of simplicity, and a claim for superior reliability over ring oil and banjo ring lubrication is very open to question.

It is true that forced lubrication allows of higher bearing pressures owing to the greater rate of dissipation of heat, but on the other hand, the crankshaft usually has to be of such diameter for rigidity and absence of whip that high bearing pressures are not necessary. As for the little end bearing no trouble is usually experienced with the ordinary drip feed or splash, although this is the most heavily loaded bearing in any engine.

(6) Less wear on cylinders, because owing to their vertical position they have not to support the weight of the piston.

In a properly lubricated modern engine there is not much evidence to support this contention. In the horizontal engine the pressure of the piston against the cylinder wall is made up of two forces :—

(*a*) The component of the gas pressure transmitted by the connection rod, which acts at right angles to the cylinder axis.

(*b*) The weight of the piston and portion of the connecting rod, which is only some 8 per cent. of (*a*).

In the most common type of vertical engine, *i.e.*, the trunk piston type, the pressure of the piston on the cylinder walls is due to the component of the pressure transmitted by the connecting rod, which acts at right angles to the cylinder axis. This pressure is slightly greater than (*a*) before mentioned, as the connecting rod is now transmitting not only the pressure due to the explosion, but also that due to the weight of the piston.

The nett difference in side pressure due to gas pressure and piston weight in horizontal and vertical design is, therefore, not very material.

There are three other factors which have far more bearing on cylinder wear than the above, and all three favour the horizontal engine.

(*a*) High pressures and, therefore, heavy wear is often caused by gas pressure inside the rings, forcing them out against the cylinder walls, the gas entering at the ring joint.

Fig. 5 shows a cross section of a horizontal engine, from which it will be seen that the ring joints are in the bottom half of the cylinder where the rings are home in their grooves. There is, therefore, little chance of the gas leaking in behind the ring at the joint.

(*b*) Fig. 5 also shows that the lubricating oil tends to flow towards the bottom of the liner, which is taking the side thrust, thus always ensuring a good oil film there and helping to seal the ring joints. This obviously cannot be the case in a vertical cylinder, where the piston ring joints are left either to arrange themselves or spaced equally around the circumference.

(*c*) The cold water coming in round the bottom of the cylinder of the horizontal engine cools the most heavily-loaded portion very effectively, and ensures that the lubricating oil at that portion retains its viscosity.

In the vertical engine the cooling water is hottest near the top of the cylinder, where the temperature conditions are most severe and the gas pressure trying to force its way under the rings is highest.

The question of piston slap in a worn liner must not be overlooked. Piston slap is bound to be detrimental to lubrication. As an illustration of this fact, take two face plates, put a patch of oil on one or both and smash them together—don't try it, however, unless suitably clad.

In the horizontal engine the change from upward to downward pressure on the cylinder walls occurs generally well before dead centre. In the vertical engine the change occurs during the swing over dead centre, *i.e.*, at the moment of maximum pressure.

The slap and, therefore, the tendency to squeeze out the oil film, must obviously be accentuated in the vertical type.

Thus near the top of the stroke of a vertical engine there is a combination of poor lubrication and possible gas pressure behind the rings, demonstrated by the fact that the greatest wear in the vertical engine liner is nearly always found at the top end.

On the question of weight, it is a little dangerous to generalise. On the face of it, given identical conditions of horse power, efficiency, etc., it would appear that the vertical engine with its higher speed must have an advantage in overall weight over the horizontal, if the same factor of safety is employed.

Figures in the possession of the writer for one well-known and reliable make of horizontal engine, however, compare favourably with those of vertical engines with which it is competing.

In addition, these figures show that the larger the engine (and, therefore, the more important the weight factor) the better do the horizontal weights compare with those of the vertical.

So much for the claims of the vertical multi-cylinder engine to superiority over the horizontal.

A few points may now be mentioned in which the horizontal multi-cylinder engine has undisputed advantages over the vertical.

(1) Compare Fig. 6, a vertical engine cylinder head, with Fig. 7, a horizontal engine cylinder head of the same type of engine.

Among the failures in service necessitating the longest stoppages, perhaps the most common in I.C. engines are cracking of castings exposed to the heat of combustion or exhaust. These arise from excessive temperatures and sharp temperature gradients in parts of the casting, and are aggravated by the use of hard or dirty water, which causes non-conducting deposits to be formed on the cooling surfaces, and frequently blocks narrow water passages entirely.

Fig. 6 shows very clearly the constricted nature of the water passages in a typical vertical engine cylinder, and the difficulty of getting at them for cleaning purposes.

Furthermore, the proper circulation of water at very hot portions (*e.g.*, between the fuel and exhaust valves of a Diesel) is difficult to arrange, and the heat has very often a long passage to the water-cooled surfaces.

Moreover, the cooling water for the vertical cylinder head sometimes passes through the cylinder water jacket first, and thus arrives at the hottest portion of the engine nearer the temperature at which it deposits matter in solution.

Fig. 7 shows the simpler nature of the horizontal combustion head, the large and straightforward water spaces and the big inspection and cleaning doors that can be arranged.

It will be noticed that the cooling water enters at the bottom near the hottest portion of the combustion head (*i.e.*, the exhaust valve) and, heated, rises towards the cooler inlet valve and the outlet.

Temperatures, therefore, over the combustion head are more uniform, and the tendency for internal stresses, and, therefore, cracking of the cylinder head, is less.

(2) In the horizontal engine everything is, so to speak, on the ground floor. The attendant is, therefore, more likely to exercise proper supervision of his engine.

(3) A common cause of stoppages is a heated bearing. In a horizontal engine an experienced attendant can always tell by inspection when a bearing is starting to run hot, and take steps to increase the oil supply at once without a shut down.

In the vertical engine the first warning of a hot bearing is usually the engine refusing its load.

(4) A comparison of Figs 8 and 9 and 10 and 11 show two more great advantages in accessibility of the horizontal multi-cylinder engine.

(5) Fig. 12 shows a very good arrangement for partially removing the sludge, which always contaminates the lubricating oil in high compression oil engines.

Such an arrangement is not practicable in the vertical engine.

(6) In a properly designed horizontal engine valve inspection and replacement is quicker and simpler than in the vertical engine—an important matter in high compression engines.

It is hoped that this article will have proved that to the many claims of the vertical multi-cylinder engines the horizontal multi-cylinder engine can make an adequate reply, and add a few claims on its own account.

The subject of first cost is again a dangerous one to generalise on, unless figures for a large number of makes representative of both types of engine are averaged.

On the whole, the horizontal engine is simpler to manufacture, and even combined electrical sets of the horizontal type can compete successfully in first cost with those of the vertical type.

THE DEFENCE OF AOULAI.

By LIEUT. H. B. HARRISON, R.E.

When in April, 1925, Abd el Krim threw off the mask and attacked the French zone he employed the same tactics as had brought him success previously against the Spaniards, namely, the infiltration of bodies of troops between the defensive posts along the frontier, to stir up the country in the rear and eventually to surround and storm the posts in detail.

Aoulai found itself thus surrounded towards the end of April, and successfully repulsed five fierce assaults before being relieved on May 15th. The post appears to have been of the usual rectangular pattern, about twenty yards by fifty yards, with one main gateway, mud brick walls with bastions at the corners.

The siege is of interest as representing the resistance offered by a post not designed to withstand shell fire, when suddenly confronted by an enemy possessing field artillery. The situation as presented to the French captain is one that may quite conceivably have to be faced at any time by those in charge of our many frontier posts, and it is interesting to note the measures adopted at Aoulai and their subsequent results.

The chief lesson of the siege is that, to oppose shell fire, posts must have prepared beforehand a complete trench system, both outside and inside the walls, transforming the position into the strong point of field warfare. Then, given sufficient supplies of water, food, bombs, and ammunition, and in the hands of resolute defenders, a post should be able to hold out until the arrival of the inevitable relief column.

Composition of the Post.—On May 1st the garrison consisted of the following:

Europeans:—1 Captain, 1 Subaltern, 4 N.C.O's and 3 men.
Natives:—38 Senegalese.

There were four machine guns in the post and one light gun, which, however, had previously been damaged and was useless.

The Riffs considered the capture of the post most important for the following reasons:—

(1) Built on the high ground which forms a buttress between the Kelaa-des-Sless and the disaffected zone, the position is an ideal one from which to operate against the neighbouring posts.

(2) It was the gateway to the road to Fez, where were stationed the French Headquarters of that sector, together with important accumulations of stores of all kinds.

From the tactical point of view everything favoured the Riffs. The post had no guns; the outlying works were soon captured; and the post itself was overlooked from four dominating points, at distances of fifty, a hundred and fifty, four hundred, and nine hundred yards from the walls.

The First Attack, May 1st.—The attack opened by rifle fire accompanied by a few shells, one of which wrecked the cookhouse.

At 8 a.m. the lookout signalled the approach of about one hundred Riffs half a mile north of a neighbouring blockhouse, which was being closely invested.

The O.C. post at once ordered his subaltern to proceed with one N.C.O. and 6 men to a ridge about 150 yards S.E. of the post and

(1) Dislodge the snipers firing on the post.
(2) Prevent the advance of the Riffs.
(3) Assist with their fire the garrison of the blockhouse.

Carrying out his mission with complete success, the subaltern succeeded in driving off the enemy snipers, while the N.C.O. surprised several local tribesmen hiding among the olive trees between the post and the blockhouse. The advancing Riffs took cover and opened fire from a ravine some distance away.

About 2 p.m. the subaltern reported small parties of the enemy working round his right flank, and was ordered to withdraw into the post; the withdrawal cost two men wounded.

At 5 p.m. the enemy again tried to approach, but was held off by picked riflemen.

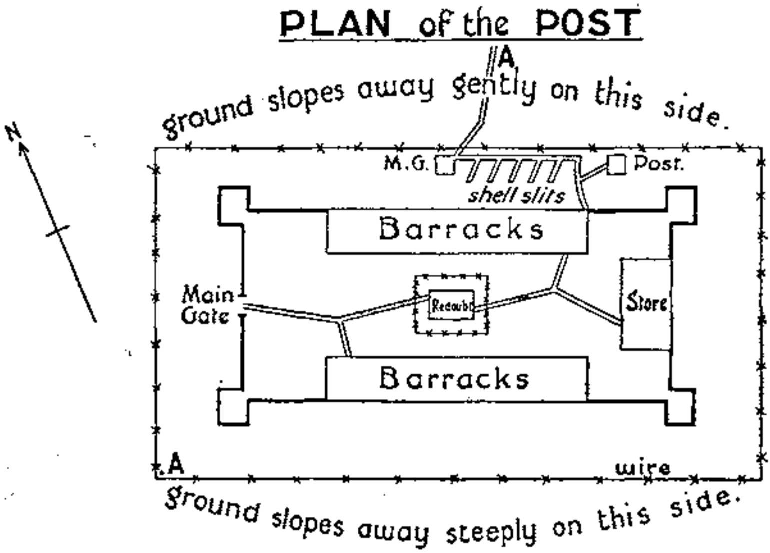
From 8 a.m. till noon every available man had been hard at work digging trenches which, elaborated later, were to save the garrison from the effects of the enemy's shells.

Defensive Works Carried Out.—Up to May 5th the enemy made no actual assault, but snipers hidden in positions around the post kept up an accurate and harassing fire on the men employed on the defensive works.

The works completed up to the 5th were:—

(*a*) Outside the post: 3 look-out posts, 1 covered post, 1 communication trench, 1 m.g. emplacement, 1 line of shell slits, all in the dead ground to the N.E. of the post.
(*b*) Inside the post: 1 redoubt inside the supply store, 2 trenches with overhead cover, 1 central communication trench, 2 dug-outs, 1 barbed wire entanglement round the redoubt, 2 sunken munition dumps, 1 water hole, loopholes in the walls to cope with the enemy snipers.

For the 6th, the O.C. Post ordered a well-earned day of rest, and told off the N.C.O's. to the various defensive sectors for which they were to be responsible.



The water tower was situated at approximately sixty yards northwards from the main gate.
Look-out posts at A A: the third was close by the water tower.

Plan of Defence.—The defence was allotted as follows :—

Main gateway	..	1 Subaltern and	4 men.
Local reserve ..	..	1 N.C.O.	,, 4 ,,
S.E. bastion ..	..	1 ,,	,, 3 ,,
N.E. bastion ..	..	1 ,,	,, 4 ,,
N.W. bastion	..		4 ,,
S.W. sector ..	..	1 ,,	,, 4 ,,
Redoubt ..	..	1 ,,	,, 2 ,, (wounded)
General Reserve	..	1 Captain	,, 6 ,,
Water Tower	..	1 N.C.O.	,, 4 ,,

Every N.C.O. and man had a definite task allotted to him, and strict orders were given that bombs and grenades were only to be thrown when good targets presented themselves.

Accordingly, by the 6th, the post was ready to resist an attack supported by field artillery.

Second Attack, May 6th.—On the 6th, about a thousand Riffs and tribesmen stormed the blockhouse of Ourtzag after a twelve hours' bombardment.

About 2 p.m. on the same day, elated by their success, the Riffs attacked the east face of Aoulai after an accurate bombardment by a 75 mm. field gun. The attack was supported by bombs and grenades, but was driven off with the loss to the defence of three Europeans and four natives wounded.

The enemy contented himself on the 7th with subjecting the post to a severe bombardment from two 75 mm. field guns and one of 6 cm.

During the bombardment the defenders took refuge in the shell slits and trenches, and the moral of the Senegalese was not impaired.

On the 8th, about 300 of the enemy were observed approaching in small groups, and during the night of 8th-9th the post was subjected to severe sniping.

Third Attack, May 9th.—At dawn the Riffs were heard coming down from the village, singing as they advanced, and though hidden by the mist, it was clear that they were in strength.

At 7 a.m., three guns opened a fire which lasted for an hour, at the end of which about 80 riflemen and grenadiers made a determined assault on the east flank, firing and throwing grenades as they advanced, and urged on by the encouraging shouts of a group of about 200 villagers in the background. Being driven off with the loss of five men, they tried to work round further to the north, but were again repulsed and forced to retire to their trenches. The defence suffered only one casualty in this action.

It was at this point that aeroplanes arrived to assist the defenders of the post, and they continued to do so until the post was relieved. They helped by bombing the enemy and by supplying the defenders with water and food, ammunition and medical necessities. The water was supplied by dropping lumps of ice.

While the aeroplanes were overhead the Riffs adopted the tactics of ceasing fire altogether, both guns and rifles, and remaining motionless. This made it difficult for the observers to spot their positions.

Fourth Attack, May 10th.—The water tower was fired on by the Riff guns, and collapsed at the sixth shell. Its garrison of 1 N.C.O. and 4 men retired towards the post, but they were all killed or taken prisoner.

At 9 a.m. the Riffs decided on a supreme effort, and after a heavy bombardment, about 200 of them advanced to the assault, the riflemen firing on the loopholes, while the bombers and grenadiers hurled their missiles into the post. The main gate was the most seriously threatened point and for a time the defenders were forced back, the subaltern being wounded. However, the timely arrival of several bombers of the reserve saved the situation and the enemy was forced back, coming, as he retired, under fire from the machine gun in the S.W. bastion. The defence suffered the following casualties: 3 killed, 5 wounded (including the O.C. Post and the subaltern), 4 missing.

At this point the O.C. Post received a communication from

Headquarters ordering him to evacuate the post by a night sortie, and to retire on Fez, if the enemy's guns were causing him too severe casualties.

This order could not be carried out, firstly because it would have meant abandoning the wounded, and secondly, because the post was being too closely invested.

The moral of the Senegalese still remained high, and on the night of 10th-11th one of them crawled through the wire entanglement and bombed the nearest enemy trenches.

Fifth and Final Attack, May 11th.—Taking advantage of a heavy mist that prevented the aeroplanes from operating, the Riffs attacked again as on the previous day, after a preliminary bombardment by about 20 shells, one of which killed the subaltern.

The attack was launched simultaneously against the west and the east sides of the post, that on the west being carried out by about a hundred villagers, who were at once checked and dispersed by the machine guns on that side. On the east it was a more serious matter, the attack being driven home by about 100 regular Riffs, who succeeded in forcing back the defenders of the main gate. A strong body of the enemy installed themselves close up to the wire entanglement, and despite an accurate fire from the loopholes, began forcing their way through.

At this critical moment an aeroplane came to the rescue, and this, combined with a bombing counter attack by the defenders, forced the enemy to withdraw, leaving 15 casualties on the ground. In this counter attack the last remaining bombs were expended.

This was the last effort of the Riffs, who made no further assault, and contented themselves with bombarding the post.

On the 15th the relief column raised the siege.

Losses of the Defence during the 15 Days Siege.

Europeans: 1 Captain wounded, 1 subaltern killed, 3 N.C.O's wounded, 1 man missing.

Natives: 4 men killed, 6 men missing, 1 N.C.O. and 13 men wounded.

Ammunition Expended by the Defence: S.A.A. 38,000 rounds, bombs 780, grenades 450, Verey Lights 86.

Method of Attacking a Post adopted by the Riffs.—The following sums up the procedure adopted by the Riffs.

The attack consisted of three phases:—

(1) Preliminary Reconnaissance.
(2) Preliminary Bombardment.
(3) The Assault.

(1) *Preliminary Reconnaissance.*—This consisted of the sending of agents to collect all possible information from the local villagers; the posting of observers to watch the actions and habits of the defenders, and the telling off of snipers whose sole objective was the O.C. Post.

(2) *Preliminary Bombardment.*—The length and severity of this phase depended on the importance of the post to be captured and on the resistance offered by the defence.

It usually began at dawn by a sudden fusillade directed against all points of defence, the loopholes being rendered untenable by fixed rifles or picked marksmen.

A badly organised defence might reply to this by the wholesale throwing of bombs and grenades, which is merely a waste and reduces the number available to assist in repulsing the final assault.

The next step in the second phase was the bringing into play of the artillery. The Riffs possessed a number of 75 mms., some bomb-throwers firing at close range, and a type of small gun, 6 cm. which fired at ranges between 600 and 1,000 yards. The average rate of fire adopted by the Riffs was about 6 rounds an hour which increased just before the assault. Under cover of this fire bombers and grenadiers crept up to the post, flung in their missiles and withdrew again.

(3) *The Assault.*—When the enemy thought that the garrison had been sufficiently reduced in numbers by the preliminary bombardment, and that the defenders' bombs were beginning to run short, the assault was launched. Every available man advanced to the attack supported by bombers and grenadiers.

A well organised defence would have reserved its bombs for this moment.

THE ARMY "SECURITY" PROBLEM OF THE NEXT GREAT WAR.

By BREVET MAJOR B. C. DENING, M.C., R.E., *p.s.c.*

The problem of "Security" is one which so largely affects the conduct of war, and one which is so rarely discussed or considered in the every day training of the Army for war to-day, that no apology is called for in bringing forward this subject.

What actually is meant by the term "Security," and in what way does it affect the conduct of war?

"Security" is not easy to define. To many it must appear akin to the term "protection," at rest, on the move, etc., but in reality it is entitled to a broader interpretation. Under the heading of "Security" comes any form of activity intended to "secure" an army against enemy action of any description. It implies rather the prevention of information reaching the enemy, which may enable him to act, than the warding off of the actual enemy himself. The "Security Service" is really the converse of the Intelligence Service, and may, perhaps, be described as Defensive Intelligence. An outline of the organisation and employment of the Security Service in France in the Great War may be helpful in explaining the type of problem coming under the heading of "Security," and in showing the importance of "Security" in war.

It will be remembered that in the years of the war 1915, 1916 and 1917, the British Army was continuously employed in France, either in conjunction with Allies or alone, in offensives against the Germans, designed to break the German front and to introduce a war of movement. These offensives cost many lives and met with only a measure of success for the principal reason that they never in those years came as a complete surprise to the enemy. The enemy was always able to obtain information of an impending or actual attack in time to bring up his reserves and to close any breach made in the line. The fact that it was obvious that we were, in all our operations, giving away information to the enemy which could lead to the neutralisation of those very operations, caused the creation in 1918 of a new branch of the Intelligence Section of the General Staff, known as the "Security" Staff.

The "Security" Staff and its work should not be confused with those of the Contre Espionage and Secret Service branches of the Intelligence Service. There always had been in France, prior to 1918, a staff known as "I (b)," which carried out both

Contre Espionage and Secret Service duties. These duties, however, as the names imply, included respectively only action against suspected persons in allied territories, and action by our agents in enemy territories. The "Security" Service designed in 1918 was intended to cover a different field, to protect our own troops against their own indiscretions. It possessed at no time any great numbers of servants. In fact, its principal personnel consisted, early in 1918, of only 6 officers, a head "Security" Officer at G.H.Q., with subordinate "Security" officers at each of the 5 Army H.Q.'s. In corps and divisions, in fact in any formation, it was hoped that with the watchful activities of the Army "Security" officers to help them, the General Staffs of formations would themselves take in hand the supervision of "Security" measures.

As already mentioned, the duties of the "Security" Service included the taking of all measures necessary to prevent information of any description reaching the enemy. In order to take such measures, it was clearly necessary for the "Security" Staff to possess a very high knowledge of the means by which an Army normally gains information about its opponents. Such means in the last war in France were the Air Force, observation of the enemy from the ground, prisoners and deserters, intercepted telephone and wireless messages, Secret Service and reports in the Press, allied or neutral. It became the task of "Security" officers to see that nothing untoward was exposed to the view of enemy air or ground observers and cameras, that men were given no opportunity of being taken by the enemy prior to important events, that telephones and wireless, etc., were not used carelessly—with possible activities of enemy Secret Service agents and with undesirable reports in the allied or neutral Press, the "Security" officer was not so personally active, for there were already in existence, prior to his creation, respectively the Contre Espionage and Censor Staffs. A glance at the real meaning of the task in front of the "Security" Service will show how immense it was. When it is recollected that every scratch in the ground, whether for a new road, a gun pit, tramway, dump, hospital, trench or even dug-out was plainly discernible upon an air photograph, it can hardly have been easy to devise measures to prevent the enemy "noticing anything" from the air. Similarly any increased work or movement was hard to conceal from accurate and systematic ground observation. And it was difficult to prevent the enemy carrying out a raid on our lines, if he was really determined to gain information, and equally difficult to stop all garrulous telephone and wireless personnel from giving away intelligence.

The following is an example of the type of work carried out by the "Security" Staff in 1918. It was realised quite early in the life of this new service that one means of preventing the enemy from obtaining correct information was by putting him off the scent with false information. Prior to the great Franco-British offensive at Amiens on August 8th, 1918, it was found necessary to move the Canadian Corps of four large divisions down from the Ypres front to take part in the attack. The problem of concealing the transfer of so large a force to the front of intended attack was a real one. The problem was studied by the "Security Staff," and the following measures were taken. First, the move of the Corps was postponed till the last possible moment; and then it took place at times when it would escape the observation both of enemy airmen and local inhabitants of doubtful character. Secondly, no preparations were permitted in the zone of attack. The incoming troops were required to bivouac and to make use of the ground as they found it. Thirdly, to prevent the enemy from noticing the departure of the Canadian Corps from Ypres, some Canadian troops left in the front line contrived to give the enemy a Canadian identification just prior to the appearance of the Canadian Corps at Amiens. As a result of these and other similar measures, the battle of August 8th, 1918, came as a complete surprise to the enemy and led to a victory, which Ludendorff himself admits was the beginning of the end, as far as Germany was concerned.

During 1918, not only the British but also the French and German General Staffs realised the necessity of studying "Security" problems. Prior to the great French counter-attack north of Chateau Thierry on July 18th, 1918, the greatest pains were taken to make the attack a surprise. Before the big German offensives of March 21st, April 9th and May 21st, 1918, there was ample evidence of the efforts the Germans were making to prevent information reaching the Allies.

It may be contended that the work necessary to obtain a surprise is merely one of the normal duties of any General Staff, for *F.S.R.* includes "Surprising the enemy" as one of its eight Principles of War. That argument is perfectly correct and every officer, whatever his employment, probably realises the necessity for surprise. Unfortunately, that is not sufficient. In war, as in manœuvres, everyone is so fully occupied, if not actually so overworked, that no one has time or strength left to quietly consider whether anything is being done that might give information to the enemy, or whether anything is being left undone which might deceive him. The regimental officer will naturally rely upon the Staff to do what is necessary.

The Staff, however, has so many immediate and pressing problems that the question of surprise, at the time rather academic looking, is very liable to be placed in the background and subsequently forgotten altogether. If this was the case in position warfare, how much more is it likely in the harassing life of moving operations.

There is little doubt that a special " Security " Staff is required in future wars to watch over this special subject. This staff could well be small, for one officer per independent formation, such as a Division or Corps in small wars, and Armies in big wars, would suffice. It would be so closely allied to the Intelligence Branch of the General Staff as to be inseparable from it. Yet its officers would require a somewhat different training and outlook from those of the Intelligence Branch proper. The important point to be remembered is that Security officers should *not* be treated merely as extra assistants for ordinary General Staff work, as is very likely to happen under stress, but should be left free to think, to study events and to go about over the whole scene of operations to see that " Security " is not being forgotten.

Is the work of the " Security " officer in the next great war likely to differ from that of 1918? Probably not greatly. As already pointed out, the task of the " Security " Service is one of frustrating the enemy's methods of obtaining Intelligence. Unless sources of Intelligence in the future are likely to be different from those employed in the past, " Security " work cannot alter much. The sources available will be dependent on the type of warfare. Whether warfare in future will differ entirely in type from that of the past is a matter of opinion. If we have stationary warfare, periodically interrupted perhaps, by offensive operations leading to partial movement, there is little reason to suppose that the means of obtaining information, as employed in the last Great War, will change greatly. There will still be aerial observation, the capture of prisoners and documents, the reports of agents, observation from the ground and the various other usual sources of Intelligence. If, as some anticipate, armies are likely to be small and very powerful, possessed of great mobility, it may be that war will not often be stationary, but may revert to the manœuvre type of years gone by, with the difference that armies, and events, will move far more rapidly. If such be the warfare eventually in store for our Army, the task of " Security " officers will again be much the same. The task may be the simpler in that the opposing Intelligence has less time and opportunity to pick up information. Yet it will still be just as necessary to watch over our rapidly moving columns, to see that nothing is done which may give away the intentions of the Commander as it is in the case of stationary entrenched forces. With armies as they are to-day, however, possessed of immense numbers of machine guns, *i.e.*, immense defensive power, and small numbers of tanks, it is fairly safe to assume that for the next few years the stationary type of warfare is likely to prevail.

To perform his duties thoroughly, the " Security " officer requires very great imagination and great knowledge of the every day procedure, staff and regimental, of the force he is serving.

The necessity for "Security" measures in connection with the use of wireless is pretty generally realised and partially provided for in most armies. It is doubtful whether the same can be said of "Security" against information leaking to the enemy by other means. Particularly is the influence of information obtainable by aircraft not sufficiently considered before operations are undertaken.

In 1914 all the armies, British, French and German, advanced mainly by day. By 1918, for the big attacks, all major movements were carried out by night. In training for war to-day, which do we contemplate? Supposing our main columns continue to march at 15 miles a day, by day, is it conceivable that they can escape observation from the air? There is a school of thought in the Army which argues that you cannot ask troops to operate continuously by night without a decisive loss of morale. The writer begs to differ. There were many units in the winter of 1914-1915 in the Ypres Salient which were forced to operate for weeks on end by night, for the reason that the forward zone was under direct enemy observation, and no communication trenches existed. Prior to the big German offensive of 21st March, 1918, there is documentary evidence to show that certain highly trained German Divisions marched for seven successive nights in the advance to the attack, and assaulted with the greatest success on the morning of the 8th day. These and other events of the last Great War go to prove that, where the reason is quite clear to the troops and when adequate arrangements are made for rest by day, continuous night operations are not impossible. But what is the doctrine on this point to-day?

The many points it is necessary to remember in connection with "Security" work were well known to us at the end of the Great War. Many lessons had been learnt by bitter experience. This knowledge is rapidly slipping away from us, and who can be sure that in a new war in a few years' time most of the lessons will not have to be learnt again?

A general recognition of the necessity for "Security" should permeate the Army and particularly all centres of military study. In peace time it should be the duty of someone to study changing methods of obtaining information and the consequent new measures necessary to prevent such information reaching the enemy. "Security" officers at manœuvres could learn a great deal and reports and lectures from such officers would do much to keep this all-important subject before the military eye. As it is, it is very doubtful if the subject receives a second's thought in the busy life of the average officer to-day.

NOTES BY A CHIEF ENGINEER DURING THE GREAT WAR OF 1914-1918 (*continued*).

By BRIGADIER-GENERAL W. BAKER BROWN, C.B.

WORK FOR OR WITH THE Q. STAFF.

The work in connection with quartering formed the larger part of our duties.

As soon as war became imminent the D.F.W., Major-General G. Scott-Moncrieff, at once began the preparation of schemes for hutting additional units, the actual work being under the control of Lt.-Col. B. Armstrong, R.E. On the appointment of Lord Kitchener as Secretary of State, he at once stressed the necessity of preparing for a long war and ordered the schemes of hutting to proceed. Further, Kitchener cut through the War Office routine, sent for Scott-Moncrieff as his principal engineer adviser, and gave him personal instructions not only as regards the policy of hutting but regarding details and sites. As General Scott-Moncrieff has given us his own account of how he carried out these instructions, I need not go into details, but I may mention one point as it had some bearing on our later work. When making out his original scheme the D.F.W. had naturally worked out the cost and estimated that a Battalion of Infantry could be hutted for an expenditure of £12 10s. per head of all ranks. Kitchener thought this was too high, and said the cost should not exceed £5. Scott-Moncrieff was naturally puzzled, and it was some months later that he found out that Kitchener had based his estimate on the amount he had actually spent on hutting about 300 labourers employed on some work on his Kent estate. These, of course, had no officers' or sergeants' messes and no transport. When the first hutments were actually completed and the cost worked out, it was found that the average figure per head was about £15, which, allowing for the increased cost of materials, was very close to the original War Office figure. The cost of the sleeping huts for men only, with lavatory and ablution accommodation, was a little under £5, or very close to Lord Kitchener's figure.

GENERAL DETAILS OF HUTMENTS.

While the general question was being discussed, Col. Armstrong, in concert with the quartering and medical branches, had been preparing typical hutment plans for each class of unit. This involved in practice a complete revision of the barrack synopsis as regards not only the nature of buildings to be provided, but also the scales of accommodation, lighting, water supply and sanitary services. Some details may be usefully referred to here, as they explain some of our difficulties.

First as regards accommodation in sleeping rooms. This is calculated in terms of floor space and cubic space, the usual barrack allowance being 60 sq. feet and 600 cub. feet per head. It was early decided that the ordinary wooden hut without ceiling might be considered as having a cross section equivalent to an average height of 10 feet, so that in practice the cube might be neglected and we could make all our calculations in terms of floor space. It was also settled that with adequate ventilation the floor space might be reduced to 40 feet per man. A further figure has, however, to be kept in mind, and that is the minimum distance between beds, and this was fixed by the medical authorities at 5ft. from centre to centre.

The original huts designed by Col. Armstrong were 60 feet x 20 feet and designed to accommodate 30 men each. This size gives 40ft. floor space but only 4 feet of wall space per bed. The doors were placed at the ends, and there was room in the centre gangway for the two stoves supplied with each hut, and also for tables for meals. With the extended use of dining huts, such tables were not required, and later supplies of huts were designed 60 feet x 15 feet to accommodate 22 men each. These huts were usually sectional. With this width stoves must be placed against the side walls, taking the space of two beds.

The ventilation of huts is important and strict orders were issued that at least one window on each side must always be left open. Later arrangements were made to leave an opening along the whole length of each side just below the eaves. The walls were first unlined, but lining was allowed later and was added to the first built huts.

In the War Office type plans, these huts were arranged in rows with ablution rooms and latrines in blocks between every pair of rows. The number of basins and latrine seats provided was 4 per cent., which proved adequate. The ablution rooms were covered and had concrete floors, and were supplied with shelves on each side fitted with taps and loose basins. The latrines were also covered and with concrete floors.

Another important accessory was the bath-rooms, which usually consisted of 20 showers in one compartment, fitted in sets of five, each shower having hot and cold water supply. Opposite each shower a seat with pegs for clothes was provided for undressing and dressing. Two bath-rooms of this size were provided for each 1,000 men. This type is, however, capable of considerable improvement.

The use of showers was adopted with the idea of providing a complete bath in the shortest possible time, but this advantage was entirely neutralized by placing the dressing accommodation so close to the showers. Assuming each man took 2½ minutes to bathe and 12½ minutes to dress and undress, the most economical arrangement would have been to provide five times as much dressing space as bathing space, and this proportion should always be maintained in designing bathing accommodation. Further, I am not satisfied that the shower system, though much used, is the best possible, especially when separate supplies of hot and cold water are provided. This gave rise to many accidents owing to the incautious use of hot water, and though we tried to render the apparatus fool-proof, none of the methods used proved quite satisfactory. The only safe way is to provide ample storage accommodation for the hot water, with arrangements to mix cold as required in the hot supply tank, so that the temperature at the taps never exceeds 100°F. In the original schemes for hutting, the water supply was based on an allowance of 5 gallons a head, but with the intensive use of baths this had to be increased to 10 gallons.

The arrangements for cooking and feeding for a battalion of infantry consisted of a central cook-house and two dining rooms capable of seating 500 in all at a time. The cooking was done on eight large 6-foot ranges of the ordinary commercial type, supplemented by eight Scotch boilers. The patterns were specially selected of commercial type to ensure ample supply, but the allowance proved unnecessarily liberal, and five ranges and four boilers were found sufficient for a battalion of 1,000 men. The cookhouse was arranged in one building with the ranges in the centre and the sinks and food tables round the walls. This is capable of improvement.

The dining rooms were at first constructed of a standard width of 30 feet, but later sectional huts were designed for a width of 28 feet. This width is convenient for recreation rooms, lecture halls and for similar large buildings.

It struck me as rather wasteful that these large dining rooms were used only for meals, and on my suggestion they were used at other times of the day for lectures, games, or at least for private reading and writing. They can also, in small units, be combined with the recreation establishment, and this was done in the later hutments.

The recreation establishment was, on the whole, a satisfactory design, and calls for no special comment.

The officers' and sergeants' messes were also satisfactory. No special sleeping accommodation was provided for sergeants, but in some cases a complete hut was allotted for this class, and in a few cases bunks were provided in certain huts. Officers' sleeping accommodation was divided into small compartments, each for two junior or one senior officer. These were satisfactory, except as regards heating. No bathrooms were provided for officers, but a boiler was provided in a separate compartment where water could be heated. The reason for this was a War Office ruling that the officers' quarters would not be furnished and officers were to use their camp kit, which includes a portable bath. When they did this they were allowed to draw camp allowance. If, however, fixed baths had been provided, this allowance could not be drawn. This ruling gave rise to some inconvenience, especially in hutments used by the Flying Corps, where a hot bath was considered a medical necessity after a flight of any duration.

The various barrack buildings were all heated by stoves.

The last buildings I propose to refer to were the drying rooms, where men were supposed to dry wet clothes. These were provided on a scale of one room for a company of 250 men, and were well designed, fitted with plenty of rails for hanging clothes and with a special ventilating stove to carry off the moistened air. The drying rooms were not popular, as men were very reluctant to leave their clothes unattended for fear of thefts. Some units started a system of cloak-room tickets, and this met the difficulty, but it involves the addition to the drying room of an ante-room for the use of the attendants in charge, with racks or compartments for dried clothes.

In addition to the preparation of these type plans, the War Office made special arrangements for the supply of huts, stoves and ranges. For these purposes standing contracts were made with all the principal makers of these articles, so that all the Commands had to do was to indent on the War Office, giving the number and destination of the huts, etc., and the War Office then distributed the order so as to equalize work between contractors. This arrangement worked admirably. At first huts were supplied of two widths, 20 feet and 30 feet, and of any length required, but later Armstrong designed sectional huts of 15 feet and 28 feet width, in sections of 10 feet. This width of section is rather large for transport and handling, but otherwise these huts answered well.

In 1916 the above were supplemented by a very light hut made of flat boards, which was very useful for small detachments.

Details of Work Done.

We may now consider some of the work done in connection with quarterings in the Eastern Command.

Barracks. The principal change made in barracks was the reduction of the scale of accommodation per head from 60 feet to 40 feet. This involved some increase in accessory buildings, which presented no difficulty.

In addition, all married families were sent out of barracks and their quarters allotted to single men. For these, additional cooking accommodation was provided and also dining rooms. The difficulties which arose in these buildings are the same as in hired buildings, and are dealt with more fully later. The normal peace occupation of barracks in the Command was about 45,000 men. This was increased by the above methods to about 75,000.

New Hutments. I have already referred to how this group of services was started at the War Office, and the arrangements made to help commands. The hutting in the Eastern Command during 1914 and the early part of 1915 was mainly to provide for the increased garrisons of coast fortresses, and for the special centres for the divisions of the New Armies allotted to the Command. For the coast fortresses, the hutting required was in extension of existing barracks, and as there was plenty of land available and also connections to water and drainage systems, the difficulties met with were mainly matters for local settlement. For the New Armies the schemes were prepared at the War Office, sites selected and Command instructed to carry out the work. The Eastern Command had to provide accommodation for five divisions, and the centres selected were Colchester, Shorncliffe, Halton Park, Seaford and Shoreham. The first two included the barracks at these stations, which provided accommodation in each case for about a brigade of infantry and some details, leaving accommodation to be provided in huts for two brigades of infantry and for other arms. At Colchester the infantry, engineers and Army Service Corps were accommodated in huts on the military ground near the barracks, and the artillery in huts near Ipswich. The work was done by a special contractor on an agency contract, the only contract on this system in our Command. At Shorncliffe, the infantry were in a new hutment at Sandling, and the artillery, engineers and A.S.C. in scattered hutments near the barracks.

At Halton Park the whole of a division, except the artillery (about 15,000 in all,) was in new hutments in the Park on property belonging to the Rothschild family, who kindly gave the use of the house for the G.O.C. of the division. In this case a good water supply was available, but all drainage and most of the roads had to be constructed.

At Seaford the site was on golf links at the back of the town; some water and drainage was available but had to be supplemented. At Shoreham the site was also on golf links, with some water but no drainage. At both these centres the accommodation was for a whole division, less artillery, about 15,000 in all.

At all these centres many of the huts which were started in October, 1914, were occupied in November, 1914, but after about a month's occupation the troops were withdrawn into billets, and the hutments were not occupied again till about May, 1915. I will deal with the reasons for this a little later.

The total accommodation in hutments constructed by the Command up to March, 1915, was about 130,000 of all ranks.

The hutments built by the Central Force during the same period accommodated about 35,000 all ranks. They were built by the Chief Engineers of the three field Armies already referred to, and were based on the same War Office plans. The best known groups were those at Crowborough and Maresfield, which accommodated the greater part of a division.

In addition to these hutments, a system had been instituted under which various official and unofficial bodies who had undertaken to raise battalions, were allowed to provide hutments on a capitation basis, at first fixed at £7 a head and raised later to £12 10s. Soon after I joined, instructions were issued to the Commands to take over these units and their hutments and the Chief Engineers of each Command were required to certify that the money had been properly expended. This was rather difficult. Although the W.O. designs had been issued to these units they had not always been followed, but where the work had been entrusted to an experienced architect or builder, the final price came out about the same as the military rates, or £14 10s. to £15 a head. In other cases the rate varied considerably, one hutment costing £24 a head, and in one case I had to report an unsatisfactory system of lighting. The War Office, however, was not inclined to hold too tightly to the letter of its bond, and eventually all the hutments were taken over. They offered considerable variety of both planning and design. In one camp the sleeping accommodation was provided in large wood huts, each shaped like a church and holding 250 men. In another, where the construction of the huts and their arrangement was distinctly better than the W.O. design, all the cooking was done by steam and there was no arrangement for roasting meat! On the whole, the advantage of using local effort in this way far exceeded the disadvantages, and most of the latter would have been avoided if an engineer officer of the Command had been associated with the local Committee in the first place.

The number of hutments taken over was for 11 battalions in eight localities, or about 12,000 men in all.

In the summer of 1915 we received instructions to prepare hutments for use in the coming winter for various schools and instructional establishments, and for this purpose we used some of the places in the western half of the Command which had been abandoned by the Central Force. Of these I may mention an artillery school at Luton, and the group of signal schools at Haynes Park, Hitchen, Dunstable and Fenny Stratford. We had also a new programme of hutting for the Central Force at Thetford and other places in the

Eastern Counties, and a large demand for extra accommodation for the Canadians at Shorncliffe. So that we had to prepare during the summer of 1915 schemes for the hutting of about 35,000 men. By the end of 1915 the hutting in the Command exceeded 200,000, distributed in 440 different groups. During 1916 the amount of new hutting was much less, but we were kept busy with alterations to suit the varying establishments of units, fitting up camps as convalescent depots with massage establishments, as well as work for the flying units, hospitals and miscellaneous establishments.

The erection of huts was only the beginning of our work. In March, 1915, the roads in the larger hutments were hardly marked out, lining had just been approved for the sleeping huts, while their outsides had to be coated with solignum, and when the troops went into occupation in May, 1915, we found that in most cases the water supply was insufficient, while the drainage arrangements were inadequate. The shortage of water was due to the demand for baths, and some of these had to be closed until we could double the size of the mains. As an instance, at Halton Park, though there was a large water system quite near, the main to the camp was too small to give sufficient head to distribute the water throughout the camp. We calculated we should require a branch 6″ main for a length of 1,700 feet, and our contractors—Messrs. R. McAlpine and Sons—came to the rescue with a suggestion that they had on hand a suitable quantity of 7″ piping, and offered to treat the matter as a rush job. Their estimate was £3,500, which was beyond the limit of our financial powers. With the approval of the M.G.A. I closed with the offer, obtaining W.O. approval in due course. The contractors finished the job in 14 days.

The drainage schemes for the larger hutments were prepared by a civilian engineer, selected by the War Office, and were designed for the bacteriological treatment of sewage with collecting or liquefying tanks, automatic dowsing tank and sprinkler beds. All these designs gave a good deal of trouble, partly because they were in all cases on too small a scale, owing to the under-estimate of the water consumption, and partly because sufficient allowance had not been made for the special conditions of military camps.

All our sewage systems had to stand a very severe test, as not only had they to pass the sanitary experts, but when the effluent ran into a watercourse we had to run the gauntlet of the various Fishery Boards.

In addition to these specially constructed systems of sewage disposal, almost every form of soak pit and irrigation system was tried. Soak pits are seldom satisfactory for a lengthy period, as when the soil is porous there is a risk of fouling the subsoil water, and when the soil is close the pits soon get choked and new ones have to be dug.

A very successful form of disposal for liquid sewage, ablution and cook-house water and urine, was suggested by Lt. Etherington, and first tried at the hutment at Denham, where a sprinkler system put in by a local architect failed to work, as the effluent produced was rejected by the Thames Conservancy authorities. Etherington suggested that the sewage should be well aerated by passing it slowly over the surface of a stretch of turf. He selected a piece of gently sloping ground about 100 feet square, and formed shallow furrows about half a spit deep along the contours. An attendant was detailed to keep the liquid from "ponding" and to shift the movement from one part of the area to another. The result was a satisfactory effluent.

Sites and Roads. I may conclude this section with some remarks on roads, with which I would embody some suggestions on the selection of sites for camps.

In all hutments or camps which are intended for extended occupation, there are three vital necessities which I will name in order of importance—Roads, Water and Drainage. Roads are required, not only for the use of the occupants, but for the use of the contractors forming the camp. Water is also needed for both purposes, while drainage for disposal of foul water is a matter of vital importance to the occupants. On the sites selected for the hutments there was generally some water supply available, but little or no drainage, while the question of roads was hardly considered.

Further, the hutments were designed in large blocks, necessitating the transfer of a large amount of material to the site, so that much of the grass surface round the huts was badly damaged in the process of erecting the huts. A grass surface is very good for a camp which is to be occupied for a short time in fine weather, but once it is cut up it rapidly deteriorates into a sea of mud. In 1914 the newly formed units were put into occupation of the partly finished hutments in November of a particularly wet winter, and having no experience of such conditions were ignorant of how to make the best of things. In most cases, also, the local transport added to the discomfort by driving on the grassy surface, cutting it to ribbons, and then, when one piece was spoilt, driving on to another patch. Had proper unloading points been marked off in the first place in the vicinity of the roads and paths constructed in the camps it should have been possible to use them through the winter.

When selecting a site for a hutment or camp for lengthy occupation, the best positions are likely to be found on the outskirts of towns. In a growing country like England there are always large areas laid out with roads, water, sewage and light, ready for the builder, which make admirable sites for hutments. Situated as they usually are between the town and the country, they get the benefits of both, as the country gives space for training grounds and rifle ranges, while the town gives accommodation for supplies, as well as water and light, and also some facilities for amusement and recreation, which, judiciously used, help the training. It is, of course, important not to crowd too many men on to one area, and in connection with this I evolved a theory that in any locality there is a limit to the number of men who can be "digested," that is, can be provided with water, sewerage and other necessities without overloading the local facilities. The large hutment at Seaford is a case in point. This is a small seaside town, but had sufficient accommodation for a brigade of about 5,000 men in addition to the population. To accommodate a whole division we had to enlarge both the water supply and also the drainage system.

In arranging the details of the hutment for any unit such as a battalion, it is necessary to carefully avoid following the usual barrack practice of arranging the buildings round the four sides of a parade or square. In barracks the parade being metalled forms a convenient means of intercommunication to the various buildings. In a temporary hutment the parades must be left in grass, and this forms an obstacle to communication. In such a case the best arrangement is to lay out the hutment on both sides of a good road, on to which all the buildings requiring special service should front. It is, of course, desirable to avoid main roads, but there are many places in England where existing second class roads could be used for this purpose, avoiding the necessity of entirely constructing new roads. A good layout would be to place the officers' mess, sergeants' mess and transport lines on one side, and the cook-house, recreation room and quartermaster's stores on the other. The officers' huts should be behind their mess, and the men's huts in company groups behind the recreation and dining rooms. Latrines must be placed near the road to facilitate water and drainage connections. The main guard room should be placed on the road at the end from which traffic will usually enter.

I have already stated that we obtained the assistance of the Road Board in making up our roads, and our first efforts were directed to making up one good road fit for motor traffic through each hutment. It was also necessary, to diminish the trouble from *mud*, to provide footpaths to each hut, and a certain amount of subsidiary roads for conservancy purposes and distribution of supplies. In most cases material for this was limited. It was suggested by one of my officers that old tins crushed flat would make very good bottoming for roads, and that the cinders from the cook-house and stoves would make a good surface. Both these articles were at the time accumulating in unsightly heaps, and in many camps special pits were dug to bury the tins out of sight.

Instructions were therefore prepared in the C.E's. office for the preparation of the tins by burning to destroy scraps of food, and by crushing, and for the systematic laying out of roads and paths, and these instructions were embodied in a Command order which included some further points, such as the prohibition of short cuts across grass, the provision and use of scrapers to keep mud out of the huts, and similar details. These orders were called "Instructions for the prevention of mud in hutments," and whenever new units came into the command, copies were issued to all concerned.

The instruction to crush the tins brought at once a series of demands by telephone and letter for rollers to do the crushing. The answer was that if the local supply of rollers was inadequate a very good roller could be made out of a cylinder of concrete, while hand ramming would be effective. We heard no more of this, but the roads and paths in camps increased satisfactorily, and we heard little more of the trouble from mud. In a few camps, especially those on the Essex clay, the mud churned up by the passage of men and horses had become so bad that special measures had to be adopted, wooden walks provided between huts, and horse-watering points removed to the roads.

Hired Buildings. Of all the varied jobs which fell to my lot as Chief Engineer, Eastern Command, the action we took in organizing the accommodation in hired buildings always appears to me as being one of the most effective, not only on account of the large sums of money involved, but on account of the increased comfort and consequently increased efficiency which we were able to give to the troops.

On the outbreak of war it was necessary to make extensive use of hired buildings to accommodate the large number of men called to the colours. In some cases it was possible to adopt the system of billeting, under which the inhabitants are given the responsibility of feeding and housing a certain number of soldiers per household. But this did not meet the requirements, and it was necessary in addition to make use of every form of empty building, public halls, cinemas, schools and empty dwelling houses which could provide cover for troops.

In the peace organisation of our Army the responsibility of providing accommodation is divided between the R.E. and the R.A.S.C. The R.E. are responsible for the provision of all military buildings and for the taking over of any buildings hired on lease, that is for three years or upwards. The R.A.S.C., through the officer in charge of barracks, are responsible for the hiring of buildings for short terms under three years. In the large commands at home the barrack officers report to a District Barrack Officer who reports direct to the Q. branch of the staff, and not to the O.C. R.A.S.C. The object of this arrangement is that while the R.E.

are responsible for the greater part of the accommodation, the barrack officer may supplement this accommodation to a minor extent and as a purely temporary measure.

But on the outbreak of war all hired accommodation is only required temporarily, and there could be no question of long leases. The responsibility of taking up all this new accommodation thus fell on the District Barrack Officer and his assistants. In the military centres the work was fairly well done, as assistance could be obtained from the R.E. in inspecting buildings and adapting them as required. In fact, when the building was a factory or store, considerable R.E. work was necessary, and provision of the accommodation was carried out as an engineer service.

But in the centres where there was no regular military staff, especially places occupied by the divisions of the Central Force, the work of taking over hired buildings was carried out by "Formation Committees" appointed by the troops under *Field Service Regulations*, and additions and alterations were made by the Formation Commander just as he would in a hostile area.

During the winter of 1914-15 all ranks were necessarily somewhat ignorant of the steps to take to maintain these buildings in a habitable condition, and the conditions were aggravated by a short supply of fuel, with the result that the troops supplemented the supply by taking any woodwork they could lay their hands on. The balustrades of staircases fell an early prey, and in some cases these were followed by the wooden porches of houses and other fittings, till in the spring of 1915 some of the places I visited looked as if they had suffered a bombardment. As long as the original units remained in occupation it was possible to bring home such damages to the offenders, but when early in 1915 whole divisions left for the Dardanelles and elsewhere, I began getting requests from my C.R.E.'s for assistance, and I found that in many cases in a single town a mass of over 1,000 claims for damages had been left in the R.E. office, and on enquiring for the Formation Committees I found that they had left with their units! Many of the buildings also were left in an almost uninhabitable condition. The whole question was reported formally and informally to the War Office, and our Major-General of Administration asked for my views on the question. I suggested that the first step seemed to be the appointment of permanent staff officers with the position of A.Q.M.G. covering the whole Command, who could act as permanent staff officers to the Commanding Officers of formations coming to the Command. At the time the Canadian troops were moving into Shorncliffe, and a permanent A.Q.M.G. was appointed to this centre, the right man for the job coming forward in the person of Col. F. H. S. Kincaid (late R.E.). But this suggestion only provided a framework, while we had to deal with a mass of details. The Quartering branch of the War Office worked out a scheme under which most of the well-known firms of House Agents and Surveyors were to be associated with local C.R.E's. for the purposes of investigating and assessing claims, *at a fee of three guineas a day*. This scheme was carried out, but proved quite useless, as our difficulty was not one of assessing claims, for which we had ample technical advice, but in settling whether a claim was reasonable or not, and also in *preventing claims arising in future*. The local firms of house agents were of no help on these points.

In the course of my visits I had been able to hear the views of my officers and to see many of the buildings which had been used by the troops. The points I noted were discussed very fully with Col. Hills and my staff. It was evident that if we were to do better in future we must be able to make a sufficient record of the condition of buildings at the beginning as well as at the end of our tenancy. It would be possible then to assess damages fairly accurately. It was also evident that this work must be done by a permanent organisation independent of the formations occupying the buildings, and in this connection it occurred to me that in the R.E. Lands branch we had an organisation doing almost exactly similar work in connection with damages to land. I therefore proposed to the Major General of Administration the provision of a body of House Valuers to look after accommodation in hired buildings. This was duly passed on to the War Office, and after some discussion was approved, except that the War Office decided that the new valuers should be obtained by an extension of our Lands branch, and we were asked to prepare a scheme accordingly and to say how many additional officers we wanted. While the combination of Lands and House work would have obvious advantages in sparsely occupied areas, there were many details to settle. With this in view the M.G.A. formed what afterwards became a "Command Quartering Committee," composed of the A.Q.M.G. of the Command, the A.Q.M.G. of the Central Force, the C.E. Eastern Command, the District Barrack Officer, with Colonel Hills as Secretary. As soon as we began to discuss the question it was evident that no one branch could undertake all the manifold duties involved, so that we were obliged to use the system of Committees, but formed of representatives of Administrative branches and not drawn from the troops. The whole area of the Command was considered and marked out into Quartering areas, about twenty-eight in number, and it was proposed that in each area there should be a standing Quartering Committee which would replace the Formation Committees and would consist of a representative of the Q. staff as President, the D.O. R.E. and O.i/c Barracks as members, with one of the newly-appointed House Agents as Secretary. These Committees overlapped as regards personnel in some cases, but this was unavoidable, as the areas controlled by individual barrack or engineer officers did not always coincide.

The scheme was duly approved and passed to the War Office with a request that suitable officers might be appointed as Presidents, but a reply was received that, while the scheme might be put into force, Presidents must be found from the senior officers in the Command. This was done and the scheme was worked under this arrangement for some months. It was a great improvement on what had gone before, but it was found that the Presidents having other duties were not in all cases able to give enough time to this special work. The value of the organisation having been proved, on a further application the War Office provided a number of senior officers, about fourteen in all, with the sole duty of looking after quartering. These were distributed to the more important areas, in some cases one officer becoming President of two or even three Committees.

Meanwhile, Col. Hills, as Secretary of the Command Committee, began drafting instructions to the local Committees as to the procedure to be followed in taking up houses. By this time I had seen a good deal of the working of the arrangements in the Command, and had come to a very definite conclusion that the methods adopted were capable of considerable improvement.

The procedure adopted by the old formation Committees up to that time based the taking up of buildings almost entirely on the accommodation required for sleeping; cooking was done in the building in which the men slept, and there was no provision for recreation establishments, lecture rooms or any central headquarters for each unit. When, as often happened, troops were distributed into detachments of 20 to 30 men each, discipline and training suffered, and the labour of distributing food and fuel was much increased. At the same time as each little detachment could not provide a cook, food was badly served. Our instructions to the new Committees thus took the following form :—

(1) To survey the accommodation in empty buildings in each locality and to then decide what class of units and how many could be accommodated in any town, and to divide the town into suitable unit areas.

(2) To set aside all the larger buildings in any unit area as dining and recreation rooms for a company, half battalion or battalion according to size.

(3) To group round these centres, sleeping accommodation in empty houses of any size, allotting certain houses for officers.

(4) To provide, near the central building, cook-houses, latrines and a central bathhouse, and also battalion headquarters, quartermaster's stores, etc., as required.

Under this arrangement, the men of each unit or sub-division of each unit were kept together all day in or near their centre, and only had to go to their sleeping places at night, and the detailed distribution of food and fuel was saved. Instructions were also issued as to the selection and allotment of training grounds and miniature ranges.

The Committees were further told that every important centre in their area should be gradually surveyed on the above lines, so that a scheme for accommodating new units might be got out at short notice, and this instruction proved very useful when the G.O.C. Home Forces changed the position of most of his troops early in 1916.

The number of Valuers appointed to the Command up to the end of 1916 reached a total of 20, making the total number of officers under the Chief Lands Officer up to 40. In many cases, these officers performed lands and house work, so that about 28 in all were more or less employed on work connected with houses. In busy centres each valuer dealt with about 500 houses, and as this was too much for one individual to handle, I authorized local C.R.E.'s to provide a staff for each valuer of one clerk and three or more foremen to prepare detailed schedules, note damages and supervise fittings. At the same time I instructed C.R.E.'s that these foremen might supervise any work on houses ordered by the D.O.R.E. at the request of the Quartering Committee. This resulted in the addition of abour 150 subordinates to our R.E. staff, which was none too many for the work to be handled.

As regards the actual work on individual buildings, Valuers were instructed to prepare a proper schedule of the conditions of the building when first occupied, and instructions were issued as to certain precautions which should be taken to prevent damage. Among these were the following: (1) The ordinary wooden staircases wore out very badly under the tread of heavy boots, so false treads of wood to take the wear were added in all cases. (2) Rifles, if leant against the wall, are liable to damage and themselves damage walls and plaster, so wooden arm racks were supplied. (3) Pegs and shelves must be provided, or men will use gas-fittings or knock nails into walls with damage to paper and plaster. (4) Valuable fittings such as fire-places, chandeliers, or wood carving must be protected.

For bath houses we abandoned the shower system and instructed the Committee to find a building or room with a concrete floor, to fit a water heating system with a few taps for hot and cold water round the sides of the building, and to provide receptacles for washing and pails to carry the water, also seats for dressing with pegs for clothes, in an area quite distinct from the bathing area. For baths it was suggested that the ordinary galvanised iron washing tub would make a good bath, and that one pail of hot water and one pail of cold would be sufficient allowance.

Of course, a new scheme of this sort could not be put into force without some difficulties arising. Many of these were due to the fact already referred to that the District Barrack Officer was responsible for taking over practically all the buildings occupied. Before he could do this he had to decide on a fair rent, and his technical adviser was necessarily the house valuer. The staff of the District Barrack officer had to be strengthened by the addition of assistants with legal training, to prepare and check the necessary agreements.

Although this complication of responsibilities did not result in any trouble at the Headquarters of the Command, it did result in some friction in the outlying stations, which was settled, generally, by the tact and good management of Col. Hills. But on the whole the scheme was an undoubted success, and not only added materially to the efficiency of the troops, but saved the British Taxpayer a very large sum of money.

(To be continued.)

BATTLE HONOURS OF ROYAL ENGINEER UNITS.

ERRATA.

P. 253. Bapaume, 1917. Delete all units of II Corps as Irles is not a Battle Honour

P. 253. The note above Vimy, 1917, should read as follows:—

N.B.—"ARRAS, 1917," COUNTS AS AN EXTRA HONOUR FOR PARTICIPATION IN ANY OF THE BATTLES OF ARRAS, VIZ., VIMY, FIRST SCARPE, SECOND SCARPE, ARLEUX, THIRD SCARPE.

P. 256. In last line, for *C* Corps read *G* Corps.

P. 257. For First Army XII Corps read First Army XIII Co. Corps.

P. 258. Scarpe, 1917 (Second Battle), 23rd-24th April.

Add to XVII Corps—

63rd Field Company.	9th Division	E.
64th ,, ,,	,,	E.
90th ,, ,,	,,	E.

BATTLE HONOURS OF ROYAL ENGINEER UNITS.

N.B. "Ypres, 1917" counts as an extra Honour for participation in any of the Battles from Pilckem to Cambrai, 1917.

PILCKEM, 31st July—2nd August, 1917.

Unit.	Formation.	Remarks.
Second and Fifth Armies.		
20th Army Troops Co.	XIV Corps	E.
42nd ,,	II ,,	,,
133rd ,,	II ,,	,,
134th ,,	XIV ,,	,,
135th ,,	XIV ,,	,,
138th ,,	XIX ,,	,,
141st ,,	XVIII ,,	,,
145th ,,	II ,,	N.E.
146th ,,	XIX ,,	E. No diary.
217th ,,	XVIII ,,	N.E.
235th ,,	II ,,	E.
236th ,,	X ,,	D. No diary.
284th ,,	XVIII ,,	N.E.
288th ,,	XIV ,,	,,
567th (Devon) ,,	X ,,	,,
568th ,,	XIX ,,	,,
573rd (Cornwall) ,,	X ,,	,,
No. 4 Siege Co. R. Monmouth	X ,,	D.
171st Tunnelling Co.	XIX ,,	E.
173rd ,,	XIV ,,	,,
175th ,,	X ,,	,,
177th ,,	II ,,	,,
179th ,,	XVIII ,,	,,
183rd ,,	XIV ,,	,,
184th ,,	XVIII ,,	,,
254th ,,	XIX ,,	,,
255th ,,	XVIII ,,	,, No diary.
1st Can. Tunnelling Co.	X ,,	,,
2nd ,,	II ,,	,,
No. 354 E. & M. Co.		D. No diary.
No. 5 Field Survey Co.		,,
No. 7 Pontoon Park		E.
No. 4 Army Tramway Co.	XVIII Corps.	,,
No. 5. ,,	XIX ,,	,, No diary.
No. 6. ,,	XIV ,,	,, No diary.
No. 9 ,,	II ,,	,, No diary.
X Corps.		
228th Field Co.	41st Divn.	E.
233rd ,,	,,	,,
237th ,,	,,	,,
517th (London) Field Co.	47th Divn.	N.E.
518th ,,	,,	,,
520th ,,	,,	E.
II Corps.		
1st Field Squadron.	1st Cav. Bde.	N.E.
2nd Field Co.	8th Divn.	E.
15th ,,	,,	,,
490th (Home Counties) Field Co.	,,	,,
79th Field Co.	18th Divn.	,,
80th ,,	,,	D.
92nd ,,	,,	N.E.
103rd Field Co.	24th Divn.	E.
104th ,,	,,	,,
129th ,,	,,	,,

PILCKEM, 31ST JULY—2ND AUGUST, 1917.

Unit.	Formation.		Remarks.
II CORPS.			
105th Field Co.	25th Divn.	E.	
106th ,,	,,	,,	
130th ,,	,,	,,	
200th Field Co.	30th Divn.	,,	
201st ,,	,,	,,	
202nd ,,	,,	,,	
XIV CORPS.			
55th Field Co.	Guards Divn.	,,	
75th ,,	,,	,,	
76th ,,	,,	,,	
83rd Field Co.	20th Divn.	,,	
84th ,,	,,	N.E.	
96th ,,	,,	E.	
123rd Field Co.	38th Divn.	,,	
124th ,,	,,	,,	
151st ,,	,,	,,	
XVIII CORPS.			
225th Field Co.	39th Divn.	E.	
227th ,,	,,	,,	
234th ,,	,,	,,	
474th (S. Mid.) Field Co	48th Divn.	,,	
475th ,,	,,	,,	
477th ,,	,,	,,	
400th (Highland) Field Co.	51st Divn.	,,	
401st ,,	,,	,,	
404th ,,	,,	,,	
XIX CORPS.			
73rd Field Co.	15th Divn.	,,	
74th ,,	,,	,,	
91st ,,	,,	,,	
155th Field Co.	16th Divn.	D.	Within area but not employed.
156th ,,	,,	N.E.	
157th ,,	,,	,,	
419th (West Lancs) Field Co.	55th Divn.	E.	
422nd ,,	,,	,,	
423rd ,,	,,	,,	

SIGNALS.

PILCKEM, 31ST JULY—2ND AUGUST, 1917.

Unit.	Formation		Remarks.
Second Army Signal Co.		N.E.	
X Corps. Signal Co.	X Corps	D.	
41st Divl. Signal Co.	41st Divn.	E.	
Fifth Army Signal Co.		N.E.	
B Corps Signal Co.	II Corps	D.	
8th Divl. Signal Co.	8th Divn.	E.	
18th ,,	18th ,,	,,	
24th ,,	24th ,,	,,	
25th ,,	25th ,,	,,	
30th ,,	30th ,,	,,	
J. Corps Signal Co.	XIV Corps	D.	
Guards Divl. Signal Co.	Guards Divn.	E.	
38th ,,	38th ,,	,,	
S. Corps Signal Co.	XVIII Corps	D.	
39th Divl Signal Co.	39th Divn.	E.	
51st ,,	51st ,,	,,	
T. Corps Signal Co.	XIX Corps	D.	
15th Divl. Signal Co.	15th Divn.	E.	
16th ,,	16th ,,	D.	
55th ,,	55th ,,	E.	

LANGEMARCK, 1917. 16TH-18TH AUGUST, 1917.

Unit.	Formation.	Remarks.	
SECOND AND FIFTH ARMIES.			
20th Army Troops Co.	XIV Corps	E.	
42nd ,,	II ,,	N.E.	
133rd ,,	II ,,	D.	
134th ,,	XIV ,,	E.	
135th ,,	XIV ,,	N.E.	
138th ,,	XIX ,,	E.	
141st ,,	XVIII ,,	N.E.	
145th ,,	II ,,	,,	
146th ,,	XIX ,,	E.	No diary.
235th ,,	II ,,	,,	
284th ,,	XVIII ,,	N.E.	
288th ,,	XIV ,,	,,	
568th ,,	XIX ,,	,,	
No. 4 Siege Co. R. Monmouth	X ,,	D.	
171st Tunnelling Co.	XIX ,,	E.	
173rd ,,	XIV ,,	,,	
177th ,,	II ,,	,,	
179th ,,	XVIII ,,	,,	
183rd ,,	XIV ,,	,,	
184th ,,	XVIII ,,	,,	
254th ,,	XIX ,,	,,	
255th ,,	XVIII ,,	,,	No diary.
No. 7 (Horsed) Pontoon Park	XIV ,,	N.E.	
No. 4 Army Tramway Co.	XVIII ,,	E.	
No. 5 ,,	XIX ,,	,,	
No. 6 ,,	XIV ,,	,,	
No. 9 ,,	II ,,	,,	
SECOND ARMY, X CORPS.			
225th Field Co.	39th Divn.	D.	
227th ,,	,,	N.E.	
234th ,,	,,	D.	
FIFTH ARMY, II CORPS.			
1st Field Squadron	1st Cav. Bde.	N.E.	
2nd Field Co.	8th Divn.	E.	
15th ,,	,,	,,	
490th (H.C.) Field Co.	,,	,,	
61st Field Co.	14th Divn.	N.E.	
62nd ,,	,,	,,	
89th ,,	,,	,,	
103rd ,,	24th Divn.	E.	
104th ,,	,,	,,	
129th ,,	,,	,,	
416th (Edinburgh) Fld. Co.	56th Divn.	,,	
512th (London) ,,	,,	,,	
513th ,, ,,	,,	,,	
XIV CORPS.			
55th Field Co.	Guards Divn.	N.E.	
75th ,,	,,	E.	
76th ,,	,,	,,	
83rd Field Co.	20th Divn.	,,	
84th ,,	,,	,,	
96th ,,	,,	,,	
455th (West Riding) Field Co.	29th Divn.	,,	
497th (Kent) Field Co.	,,	,,	
510th (London) ,,	,,	,,	
123rd Field Co.	38th Divn.	,,	
124th ,,	,,	,,	
151st ,,	,,	,,	

LANGEMARCK, 1917, 16TH-18TH AUGUST, 1917.

Unit.	Formation		Remarks.
XVIII CORPS.			
67th Field Co.	11th Divn.	E.	
68th ,,	,,	,,	
86th ,,	,,	,,	
474th (S. Mid.) Field Co.	48th Divn.	,,	
475th ,,	,,	,,	
477th ,,	,,	,,	
XIX CORPS.			
73rd Field Co.	15th Divn.	N.E.	
74th ,,	,,	D.	
91st ,,	,,	N.E.	
155th ,,	16th Divn.	D.	Within area but not employed.
156th ,,	,,	N.E.	
157th ,,	,,	E.	
121st ,,	36th Divn.	,,	
122nd ,,	,,	,,	
150th ,,	,,	,,	
476th (S. Mid.) Field Co.	61st Divn.	D.	
478th ,,	,,	E.	
479th ,,	,,	D.	

SIGNALS.

LANGEMARCK, 1917. 16TH-18TH AUGUST, 1917.

Unit.	Formation.		Remarks.
2nd Army Signal Co.	2nd Army	N.E.	
X Corps Signal Co.	X Corps	D.	
39th Divl. Signal Co.	39th Divn.	,,	
5th Army Signal Co.	5th Army	N.E.	
B. Corps Signal Co.	II Corps	D.	
8th Divl. Signal Co.	8th Divn.	E.	
14th ,,	14th ,,	,,	
24th ,,	24th ,,	,,	
56th ,,	56th ,,	,,	
J. Corps Signal Co.	XIV Corps	D.	
20th Divl. Signal Co.	20th Divn.	E.	
29th ,,	29th ,,	,,	
38th ,,	38th ,,	D.	
S. Corps Signal Co.	XVIII Corps	,,	
11th Divl. Signal Co.	11th Divn.	E.	
48th ,,	48th ,,	,,	
T. Corps Signal Co.	XIX Corps	D.	
15th Divl. Signal Co.	15th Divn.	,,	
16th ,,	16th ,,	E.	
36th ,,	36th ,,	,,	
61st ,,	61st ,,	D.	

MENIN ROAD. 20TH-25TH SEPTEMBER, 1917.

Unit.	Formation		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
1st Field Squadron R.E.	X Corps	E.	
20th Army Troops Co.	XIV Corps	,,	
42nd ,,	I Anzac Corps	,,	
133rd ,,	,,	,,	
134th ,,	XIV Corps	,,	
135th ,,	,,	N.E.	
136th ,,		D.	No diary.
138th ,,	V Corps	E.	

MENIN ROAD. 20TH-25TH SEPTEMBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
141st Army Troops Co.	XVIII Corps	N.E.	
145th ,,	I Anzac Corps	,,	
146th ,,		D.	No diary.
147th ,,		N.E.	
167th ,,	IX Corps	N.E.	
213th ,,		,,	
214th ,,		,,	
216th ,,	IX Corps	,,	
217th ,,	XVIII Corps	,,	
221st ,,	XIV Corps	,,	
235th ,,	I Anzac Corps	,,	
236th ,,	X Corps	D.	No. diary.
284th ,,	XVIII Corps	E.	
285th ,,		D.	No diary.
288th ,,	XIV Corps	N.E.	
290th ,,		,,	
554th ,,	VIII Corps	,,	
567th ,,	X Corps	,,	
568th ,,	V Corps	,,	
573rd ,,		,,	
6th Siege Co. R. Monmouth R.E.	X Corps	E.	
171st Tunnelling Co.	V Corps	,,	
173rd ,,	XIV Corps	,,	
175th ,,	X Corps	,,	No diary.
177th ,,	IX & VIII Corps	D.	
179th ,,	XVIII Corps	E.	
183rd ,,	XIV & XVIII Corps	,,	
250th ,,		D.	
253rd ,,	XVIII Corps	E.	
254th ,,	V Corps	,,	
255th ,,	XVIII Corps	D.	No diary.
1st Can. Tunnelling Co.	X Corps	E.	
2nd ,,	IX Corps	N.E.	
3rd ,,	X Corps	E.	
1st Aus. Tunnelling Co.	IX Corps	D.	No diary.
No. 351 E. & M. Co.		N.E.	
No. 354 ,,		,,	
No. 2 Field Survey Co.		D.	
No. 5 ,,		,,	
No. 2 Pontoon Park		,,	
No. 7 ,,	XIV & XVIII Corps	,,	
No. 4 Army Tramway Co.	XVIII Corps	E.	
No. 5 ,,	V & II Anzac Corps	,,	No diary.
No. 6 ,,	XIV Corps	,,	
No. 8 ,,	IX & VIII Corps	D.	No diary.
No. 9 ,,	X Corps	E.	No diary.
SECOND ARMY.			
IX CORPS.			
81st Field Co.	19th Divn.	E.	
82nd ,,	,,	,,	
94th ,,	,,	,,	
152nd ,,	37th Divn.	N.E.	
153rd ,,	,,	,,	
154th ,,	,,	,,	
X CORPS.			
97th Field Co.	21st Divn.	E.	
98th ,,	,,	N.E.	
126th ,,	,,	,,	

MENIN ROAD. 20TH-25TH SEPTEMBER, 1917.

Unit.	Formation.		Remarks.
SECOND ARMY.			
X CORPS.			
101st Field Co.	23rd Divn.	E.	
102nd ,,	,,	N.E.	
128th ,,	,,	E.	
11th ,,	33rd Divn.	,,	
212th ,,	,,	,,	
222nd ,,	,,	,,	
225th ,,	39th Divn.	,,	
227th ,,	,,	,,	
234th ,,	,,	,,	
228th ,,	41st Divn.	,,	
233rd ,,	,,	,,	
237th ,,	,,	,,	
I ANZAC CORPS.			
1st Aust. Field Co.	1st Aust. Divn.	E.	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
5th ,,	2nd Aust. Divn	,,	
6th ,,	,,	,,	
7th ,,	,,	,,	
4th ,,	4th Aust. Divn.	,,	
12th ,,	,,	,,	
13th ,,	,,	,,	
8th ,,	5th Aust. Divn.	,,	
14th ,,	,,	,,	
15th ,,	,,	,,	
FIFTH ARMY.			
V CORPS.			
56th Field Co.	3rd Divn.	E.	
438th ,,	,,	,,	
529th ,,	,,	,,	
63rd ,,	9th Divn.	,,	
64th ,,	,,	,,	
90th ,,	,,	,,	
419th ,,	55th Divn.	,,	
422nd ,,	,,	,,	
423rd ,,	,,	,,	
467th ,,	59th Divn.	,,	
469th ,,	,,	,,	
470th ,,	,,	,,	
XIV CORPS.			
55th Field Co.	Guards Divn.	N.E.	
75th ,,	,,	,,	
76th ,,	,,	,,	
83rd ,,	20th Divn.	E.	
84th ,,	,,	,,	
96th ,,	,,	,,	
455th ,,	29th Divn.	,,	
497th ,,	,,	,,	
510th ,,	,,	,,	
XVIII CORPS.			
400th Field Co.	51st Divn.	E.	
401st ,,	,,	,,	
404th ,,	,,	,,	
503rd ,,	58th Divn.	,,	
504th ,,	,,	,,	
511th ,,	,,	,,	
67th ,,	11th Divn.	,,	
68th ,,	,,	,,	
86th ,,	,,	,,	

SIGNALS.

MENIN ROAD. 20TH-25TH SEPTEMBER, 1917.

Unit.	Formation.		Remarks.
2nd Army Signal Co.		N.E.	
E Corps Signal Co.	IX Corps	D.	
19th Divl. Signal Co.	,,	E.	
37th ,,	,,	N.E.	
X Corps Signal Co.	X Corps	D.	
23rd Divl. Signal Co.	,,	E.	
33rd ,,	,,	,,	
39th ,,	,,	,,	
41st ,,	,,	,,	
K Corps Signal Co.	I Anzac Corps	D.	
1st Aust. Divl. Signal Co.	,,	E.	
2nd ,,	,,	,,	
4th ,,	,,	,,	
5th ,,	,,	,,	
5th Army Signal Co.		N.E.	
O Corps Signal Co.	V Corps	D.	
3rd Divl. Signal Co.	,,	E.	
9th ,,	,,	,,	
55th ,,	,,	,,	
59th ,,	,,	,,	
J Corps Signal Co.	XIV Corps	D.	
Guards Divl. Signal Co.	,,	E.	
20th ,,	,,	,,	
29th ,,	,,	,,	
S Corps Signal Co.	XVIII Corps	D.	
51st Divl Signal Co.	,,	E.	
58th ,,	,,	,,	
11th ,,	,,	,,	

POLYGON WOOD. 26TH SEPTEMBER—3RD OCTOBER, 1917.

Unit.	Formation		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
1st Field Squadron R.E.	X Corps	E.	
20th Army Troops Co.	XIV Corps	,,	
42nd ,,	I Anzac Corps	,,	
133rd ,,	,,	,,	
134th ,,	XIV Corps	,,	
135th	,,	N.E.	
138th ,,	II Anzac Corps	E.	
141st ,,	XVIII Corps	N.E.	
145th ,,	I Anzac Corps	E.	
146th ,,		D.	No diary.
147th ,,		N.E.	
167th ,,	VIII Corps	,,	
235th ,,	I Anzac Corps	D.	
284th ,,	XVIII Corps	E.	
6th Siege Co R. Monmouth	X Corps	,,	
171st Tunnelling Co	II Anzac Corps	D.	
173rd ,,	XIV Corps	E.	
175th ,,	X Corps	D.	No diary.
179th ,,	XVIII Corps	E.	
183rd ,,	XIV & XVIII Corps	,,	
250th ,,		D.	
253rd ,,	V Corps	E.	
254th ,,	V & II Anzac Corps	,,	
255th ,,	XVIII Corps	D.	No diary.
1st Can. Tunnelling Co.	X Corps	E.	
2nd ,,	IX Corps	,,	
3rd ,,	X Corps	,,	

POLYGON WOOD. 26TH SEPTEMBER—3RD OCTOBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
No. 2 Pontoon Park	X & I Anzac Corps	,,	
No. 7 ,,	XIV & XVIII Corps	,,	
No. 4 Army Tramway Co	XVIII Corps	,,	
No. 5 ,,	V & II Anzac Corps	,,	No diary.
No. 6 ,,	XIV Corps	,,	
No. 8 ,,	IX Corps	,,	No diary.
No. 9 ,,	X Corps	,,	No diary.
SECOND ARMY.			
IX CORPS.			
81st Field Co.	19th Divn.	E.	
82nd ,,	,,	,,	
94th ,,	,,	,,	
152nd ,,	37th Divn.	,,	
153rd ,,	,,	,,	
154th ,,	,,	,,	
X CORPS.			
59th Field Co.	5th Divn.	E.	
491st ,,	,,	,,	
527th ,,	,,	D.	
54th ,,	7th Divn.	E.	
95th ,,	,,	,,	
528th ,,	,,	,,	
97th ,,	21st Divn.	,,	
98th ,,	,,	,,	
126th ,,	,,	,,	
101st ,,	23rd Divn.	N.E.	
102nd ,,	,,	,,	
128th ,,	,,	,,	
11th ,,	33rd Divn.	E.	
212th ,,	,,	,,	
222nd ,,	,,	,,	
225th ,,	39th Divn.	,,	
227th ,,	,,	,,	
234th ,,	,,	,,	
430th ,,	66th Divn.	,,	
431st ,,	,,	,,	
432nd ,,	,,	,,	
I ANZAC CORPS.			
1st Aust. Field Co.	1st Aust Divn.	E.	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
5th ,,	2nd Aust. Divn.	,,	
6th ,,	,,	,,	
7th ,,	,,	,,	
4th ,,	4th Aust. Divn.	,,	
12th ,,	,,	,,	
13th ,,	,,	,,	
8th ,,	5th Aust. Divn.	,,	
14th ,,	,,	,,	
15th ,,	,,	,,	
II ANZAC CORPS.			
9th Aust. Field Co	3rd Aust. Divn.	E.	
10th ,,	,,	,,	
11th ,,	,,	,,	
1st N.Z. Field Co.	N.Z. Divn.	,,	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
4th ,,	,,	,,	

POLYGON WOOD. 26TH SEPTEMBER—3RD OCTOBER, 1917.

Unit.	Formation.		Remarks.
FIFTH ARMY. V CORPS.			
56th Field Co.	3rd Divn.	E.	
438th ,,	,,	,,	
529th ,,	,,	,,	
467th ,,	59th Divn.	,,	
469th ,,	,,	,,	
470th ,,	,,	,,	
XIV CORPS.			
9th Field Co.	4th Divn.	E.	
406th ,,	,,	,,	
526th ,,	,,	,,	
83rd ,,	20th Divn.	,,	
84th ,,	,,	,,	
96th ,,	,,	,,	
455th ,,	29th Divn.	,,	
497th ,,	,,	,,	
510th ,,	,,	,,	
XVIII CORPS.			
67th Field Co.	11th Divn.	E.	
68th ,,	,,	,,	
86th ,,	,,	,,	
474th ,,	48th Divn.	,,	
475th ,,	,,	,,	
477th ,,	,,	,,	
503rd ,,	58th Divn.	,,	
504th ,,	,,	,,	
511th ,,	,,	N.E.	
79th ,,	18th Divn.	E.	
80th ,,	,,	D.	
92nd ,,	,,	E.	

SIGNALS.

POLYGON WOOD. 26TH SEPTEMBER to 3RD OCTOBER, 1917.

Unit.	Formation.		Remarks.
2nd Army Signal Co.		N.E.	
E Corps Signal Co.	IX Corps	D.	
19th Divl. Signal Co.	,,	E.	
37th ,,	,,	,,	
X Corps Signal Co.	X Corps	D.	
5th Divl. Signal Co.	,,	E.	
7th ,,	,,	,,	
21st ,,	,,	,,	
23rd ,,	,,	N.E.	
33rd ,,	,,	E.	
39th ,,	,,	,,	
K Corps Signal Co.	I Anzac Corps	D.	
1st Aust. Divl. Signal Co.	,,	E.	
2nd ,,	,,	,,	
4th ,,	,,	,,	
5th ,,	,,	,,	
Y Corps Signal Co.	II Anzac Corps	D.	
3rd Aust. Divl Signal Co.	,,	E.	
N.Z. ,,	,,	,,	
5th Army Signal Co.		N.E.	
O Corps Signal Co.	V Corps	D.	
3rd Divl. Signal Co.	,,	E.	
59th ,,	,,	,,	
J Corps Signal Co.	XIV Corps	D.	
4th Divl. Signal Co.	,,	E.	
20th ,,	,,	,,	
29th ,,	,,	,,	
S Corps Signal Co.	XVIII Corps	D.	
11th Divl. Signal Co.	,,	E.	
48th ,,	,,	,,	
58th ,,	,,	,,	

BROODSEINDE. 4TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
1st Field Squadron R.E.	X Corps	E.	
20th Army Troops Co.	XIV Corps	,,	
42nd ,,	I Anzac Corps	N.E.	
133rd ,,	,,	E.	
134th ,,	XIV Corps	,,	
138th ,,	II Anzac Corps	,,	
141st ,,	XVIII Corps	D.	
235th ,,	I Anzac Corps	N.E.	
283rd ,,	IX Corps	,,	
284th ,,	XVIII Corps	E.	
6th Siege Co. R. Monmouth	X Corps	,,	
171st Tunnelling Co.	II Anzac Corps	,,	
173rd ,,	XIV Corps	,,	
175th ,,	X Corps	D.	No diary.
179th ,,	XVIII Corps	E.	
183rd ,,	XIV & XVIII Corps	,,	
250th ,,		,,	
253rd ,,		,,	
254th ,,	II Anzac Corps	,,	
255th ,,	XVIII Corps	D.	No diary.
1st Can. Tunnelling Co.	X Corps	E.	
2nd ,,	IX Corps	,,	
3rd ,,	X Corps	,,	
No. 2 Pontoon Park		,,	
No. 7 ,,	XIV & XVIII Corps	,,	
No. 4 Army Tramway Co.	XVIII Corps	,,	
No. 5 ,,	II Anzac Corps	,,	No diary.
No. 6 ,,	XIV Corps	,,	
No. 8 ,,	IX Corps	,,	No diary.
No. 9 ,,	X Corps	,,	No diary.
SECOND ARMY.			
IX CORPS.			
81st Field Co.	19th Divn.	E.	
82nd ,,	,,	D.	
94th ,,	,,	N.E.	
152nd ,,	37th Divn.	E.	
153rd ,,	,,	,,	
154th ,,	,,	,,	
X CORPS.			
59th Field Co.	5th Divn.	E.	
491st ,,	,,	,,	
527th ,,	,,	D.	
54th ,,	7th Divn.	E.	
95th ,,	,,	,,	
528th ,,	,,	,,	
97th ,,	21st Divn.	,,	
98th ,,	,,	,,	
126th ,,	,,	,,	
11th ,,	33rd Divn.	,,	
212th ,,	,,	,,	
222nd ,,	,,	,,	
430th ,,	66th Divn.	,,	
431st ,,	,,	,,	
432nd ,,	,,	,,	
I ANZAC CORPS.			
1st Aust. Field Co.	1st Aust. Divn.	E.	
2nd ,,	,,	,,	
3rd ,,	,,	,,	

BROODSEINDE, 4TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
I ANZAC CORPS.			
5th Aust. Field Co.	2nd Aust. Divn.	E.	
6th ,,	,,	,,	
7th ,,	,,	,,	
4th ,,	4th Aust. Divn.	N.E.	
12th ,,	,,	D.	Within area.
13th ,,	,,	E.	
II ANZAC CORPS.			
9th Aust. Field Co.	3rd Aust. Divn.	E.	
10th ,,	,,	,,	
11th ,,	,,	,,	
1st N.Z. Field Co.	N.Z. Divn.	,,	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
4th ,,	,,	,,	
57th Field Co.	49th Divn.	,,	
456th ,,	,,	,,	
458th ,,	,,	N.E.	
FIFTH ARMY.			
XIV CORPS.			
9th Field Co.	4th Divn.	E.	
406th ,,	,,	,,	
526th ,,	,,	,,	
455th ,,	29th Divn.	,,	
497th ,,	,,	,,	
510th ,,	,,	,,	
XVIII CORPS.			
67th Field Co.	11th Divn.	E.	
68th ,,	,,	,,	
86th ,,	,,	,,	
79th ,,	18th Divn.	,,	
80th ,,	,,	D.	Within area.
92nd ,,	,,	E.	
474th ,,	48th Divn.	,,	
475th ,,	,,	,,	
477th ,,	,,	,,	

SIGNALS.

BROODSEINDE. 4TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
Second Army Signal Co.		N.E.	
E. Corps Signal Co.	IX Corps	D.	
19th Divl. Signal Co.	,,	,,	
37th ,,	,,	E.	
X Corps Signal Co.	X Corps	D.	
5th Divl. Signal Co.	,,	E.	
7th ,,	,,	,,	
21st ,,	,,	,,	
33rd ,,	,,	N.E.	
K. Corps Signal Co.	I Anzac Corps	D.	
1st Aust. Divl. Signal Co.	,,	E.	
2nd ,,	,,	,,	
4th ,,	,,	N.E.	
Y Corps Signal Co.	II Anzac Corps	D.	
3rd Aust. Divl. Signal Co.	,,	E.	
N.Z. Divl. Signal Co.	,,	,,	
Fifth Army Signal Co.		N.E.	
J. Corps Signal Co.	XIV Corps	D.	
4th Divl. Signal Co.	,,	E.	
29th ,,	,,	,,	
S. Corps Signal Co.	XVIII Corps	D.	
11th Divl. Signal Co.	,,	E.	
48th ,,	,,	,,	

POELCAPPELLE. 9TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
1st Field Squadron	1st Cav. Divn.	D.	
20th Army Troops Co.	XIV Corps	E.	
42nd ,,	I Anzac Corps	N.E.	
133rd ,,	,,	E.	
134th ,,	XIV Corps	,,	
138th ,,	II Anzac Corps	,,	
145th ,,	I Anzac Corps	,,	
146th ,,	XVIII Corps	D.	
235th ,,	I Anzac Corps	N.E.	
283rd ,,	IX Corps	E.	
284th ,,	XVIII Corps	,,	
No. 6 Siege Co. R. Monmouth	X Corps	,,	
171st Tunnelling Co.	II Anzac Corps	,,	
173rd ,,	XIV Corps	,,	
175th ,,	X Corps	D.	No Diary
179th ,,	XVIII Corps	E.	
183rd ,,	XIV & XVIII Corps	,,	
250th ,,		,,	
253rd ,,		,,	
254th ,,	II Anzac Corps	,,	
255th ,,	XVIII Corps	D.	No diary.
1st Can. Tunnelling Co.	X Corps	E.	
2nd ,,	IX Corps	,,	
3rd ,,	X Corps	,,	
No. 2 Pontoon Park		,,	
No. 7 ,,	XIV & XVIII	,,	
No. 4 Army Tramway Co.	XVIII Corps	,,	
No. 5 ,,	II Anzac Corps	,,	
No. 6 ,,	XIV Corps	,,	
No. 8 ,,	IX Corps	,,	
No. 9 ,,	X Corps	,,	
SECOND ARMY.			
IX CORPS.			
81st Field Co.	19th Divn.	E.	
82nd ,,	,,	,,	
94th ,,	,,	N.E.	
152nd ,,	37th Divn.	E.	
153rd ,,	,,	,,	
154th ,,	,,	,,	
X CORPS.			
59th Field Co.	5th Divn.	E.	
491st ,,	,,	N.E.	
527th ,,	,,	E.	
54th ,,	7th Divn.	D.	
95th ,,	,,	E.	
528th ,,	,,	,,	
61st ,,	14th Divn.	D.	
62nd ,,	,,	,,	
89th ,,	,,	E.	
97th ,,	21st Divn.	D.	
98th ,,	,,	E.	
126th ,,	,,	,,	
I ANZAC CORPS.			
1st Aust. Field Co.	1st Aust. Divn.	D.	Within area.
2nd ,,	,,	E.	
3rd ,,	,,	,,	
5th ,,	2nd Aust. Divn.	,,	
6th ,,	,,	,,	

POELCAPPELLE. 9TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
I ANZAC CORPS.			
7th Aust. Field Co.	2nd Aust. Divn.	E.	
4th ,,	4th Aust. Divn.	N.E.	
12th ,,	,,	E.	
13th ,,	,,	,,	
8th ,,	5th Aust. Divn.	,,	
14th ,,	,,	,,	
15th ,,	,,	,,	
II ANZAC CORPS.			
57th Field Co.	49th Divn.	E.	
456th ,,	,,	,,	
458th ,,	,,	,,	
430th ,,	66th Divn.	,,	
431st ,,	,,	,,	
432nd ,,	,,	,,	
9th Aust. Field Co.	3rd Aust. Divn.	,,	
10th ,,	,,	,,	
11th ,,	,,	,,	
1st N.Z. Field Co.	N.Z. Divn.	,,	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
4th ,,	,,	,,	
FIFTH ARMY.			
XIV CORPS.			
55th Field Co.	Guards Divn.	E.	
75th ,,	,,	,,	
76th ,,	,,	,,	
9th ,,	4th Divn.	,,	
406th ,,	,,	,,	
526th ,,	,,	,,	
455th ,,	29th Divn.	,,	
497th ,,	,,	,,	
510th ,,	,,	,,	
207th ,,	34th Divn.	,,	
208th ,,	,,	,,	
209th ,,	,,	,,	
XVIII CORPS.			
63rd Field Co.	9th Divn.	E.	
64th ,,	,,	,,	
90th ,,	,,	D.	Within area.
67th ,,	11th Divn.	E.	
68th ,,	,,	,,	
86th ,,	,,	,,	
79th ,,	18th Divn.	,,	
80th ,,	,,	,,	
92nd ,,	,,	,,	
474th ,,	48th Divn.	,,	
475th ,,	,,	,,	
477th ,,	,,	,,	
247th ,,	63rd Divn.	,,	
248th ,,	,,	,,	
249th ,,	,,	,,	

SIGNALS.

POELCAPPELLE. 9TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
2nd Army Signal Co.		N.E.	
E. Corps Signal Co.	IX Corps	D.	
19th Divl. Signal Co.	,,	E.	
37th ,,	,,	,,	

SIGNALS.

POELCAPPELLE. 9TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
X Corps Signal Co.	X Corps	D.	
5th Divl Signal Co	,,	E.	
7th ,,	,,	,,	
K. Corps Signal Co.	I Anzac Corps	D.	
1st Aust. Divl. Signal Co.	,,	E.	
2nd ,,	,,	,,	
Y Corps Signal Co.	II Anzac Corps	D.	
49th Divl. Signal Co.	,,	E.	
66th ,,	,,	,,	
5th Army Signal Co.		N.E.	
J. Corps Signal Co.	XIV Corps	D.	
Guards Divl. Signal Co.	,,	E.	
4th ,,	,,	,,	
29th ,,	,,	,,	
S. Corps Signal Co.	XVIII Corps	D.	
11th Divl. Signal Co.	,,	E.	
48th ,,	,,	,,	

PASSCHENDAELE (1ST BATTLE). 12TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
20th Army Troops Co.	XIV Corps	E.	
42nd ,,	I Anzac Corps	N.E.	
133rd ,,	,,	E.	
134th ,,	XIV Corps	,,	
138th ,,	II Anzac Corps	,,	
145th ,,	I Anzac Corps	,,	
146th ,,	XVIII Corps	D.	
235th ,,	I Anzac Corps	,,	
283rd ,,	IX Corps	E.	
284th ,,	XVIII Corps	,,	
No. 6 Siege Co. R. Monmouth	X Corps	,,	
171st Tunnelling Co.	II Anzac Corps	,,	
173rd ,,	XIV Corps	,,	
175th ,,	X Corps	D.	No diary.
179th ,,	XVIII Corps	E.	
183rd ,,	XIV & XVIII Corps	,,	
250th ,,		,,	
253rd ,,		,,	
254th ,,	II Anzac Corps	,,	
255th ,,	XVIII Corps	D.	No diary.
1st Can. Tunnelling Co.	X Corps	E.	
2nd ,,	IX Corps	,,	
3rd ,,	X Corps	,,	
2nd Pontoon Park		,,	
7th ,,	XIV & XVIII Corps	,,	
No. 4 Army Tramway Co.	XVIII Corps	,,	
No. 5 ,,	II Anzac Corps	,,	
No. 6 ,,	XIV Corps	,,	
No. 8 ,,	IX Corps	,,	
No. 9 ,,	X Corps	,,	

PASSCHENDAELE (1st BATTLE). 12th October, 1917.

Unit.	Formation.		Remarks.
Second Army.			
IX Corps.			
81st Field Co.	19th Divn.	E.	
82nd ,,	,,	,,	
94th ,,	,,	N.E.	
152nd ,,	37th Divn.	E.	
153rd ,,	,,	,,	
154th ,,	,,	,,	
X Corps.			
59th Field Co.	5th Divn.	E.	
491st ,,	,,	,,	
527th ,,	,,	,,	
54th ,,	7th Divn.	,,	
95th ,,	,,	,,	
526th ,,	,,	,,	
61st ,,	14th Divn.	,,	
62nd ,,	,,	D.	
89th ,,	,,	E.	
101st ,,	23rd Divn.	,,	
102nd ,,	,,	,,	
128th ,,	,,	,,	
I Anzac Corps.			
1st Aust. Field Co.	1st Aust. Divn.	E.	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
5th ,,	2nd Aust. Divn.	,,	
6th ,,	,,	,,	
7th ,,	,,	,,	
4th ,,	4th Aust. Divn.	,,	
12th ,,	,,	,,	
13th ,,	,,	,,	
8th ,,	5th Aust. Divn.	,,	
14th ,,	,,	,,	
15th ,,	,,	,,	
II Anzac Corps.			
57th Field Co.	49th Divn.	E.	
456th ,,	,,	,,	
458th ,,	,,	,,	
430th ,,	66th Divn.	,,	
431st ,,	,,	,,	
432nd ,,	,,	,,	
9th Aust. Field Co.	3rd Aust. Divn.	,,	
10th ,,	,,	,,	
11th ,,	,,	,,	
1st N.Z. Field Co.	N.Z. Divn.	,,	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
4th ,,	,,	,,	
Fifth Army.			
XIV Corps.			
55th Field Co.	Guards Divn.	D.	Within area but not employed.
75th ,,	,,	,,	Within area but not employed.
76th ,,	,,	,,	Within area but not employed.
9th ,,	4th Divn.	E.	
406th ,,	,,	,,	
526th ,,	,,	D.	

PASSCHENDAELE (1ST BATTLE). 12TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
XIV CORPS.			
207th Field Co.	34th Divn.	D.	
208th ,,	,,	E.	
209th ,,	,,	D.	
77th ,,	17th Divn.	E.	
78th ,,	,,	,,	
93rd ,,	,,	,,	
XVIII CORPS.			
63rd Field Co.	9th Divn.	E.	
64th ,,	,,	,,	
90th ,,	,,	,,	
67th ,,	11th Divn.	,,	
68th ,,	,,	,,	
86th ,,	,,	N.E.	
79th ,,	18th Divn.	E.	
80th ,,	,,	,,	
92nd ,,	,,	,,	
247th ,,	63rd Divn.	,,	
248th ,,	,,	,,	
249th ,,	,,	,,	

SIGNALS.

PASSCHENDAELE (1ST BATTLE). 12TH OCTOBER, 1917.

Unit.	Formation.		Remarks.
2nd Army Signal Co.		N.E.	
E Corps Signal Co.	IX Corps	D.	
19th Divl. Signal Co.	,,	E.	
37th ,,	,,	,,	
X Corps Signal Co.	X Corps.	D.	
14th Divl. Signal Co.	,,	E.	
23rd ,,	,,	,,	
K Corps Signal Co.	I Anzac Corps	D.	
4th Aust. Divl. Signal Co.	,,	E.	
5th ,,	,,	,,	
Y Corps Signal Co.	II Anzac Corps	D.	
3rd Aust. Divl. Signal Co.	,,	E.	
N.Z. Divl. Signal Co.	,,	,,	
5th Army Signal Co.		N.E.	
J Corps Signal Co.	XIV Corps	D.	
Guards Divl. Signal Co.	,,	E.	
4th ,,	,,	,,	
17th ,,	,,	,,	
S Corps Signal Co.	XVIII Corps	D.	
9th Divl. Signal Co.	,,	E.	
18th ,,	,,	,,	

PASSCHENDAELE (SECOND BATTLE). 26TH OCTOBER-10TH NOVEMBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
20th Army Troops Co.	XIV & XIX Corps	E.	
42nd ,,	I Anzac Corps	,,	
133rd ,,	,,	,,	
134th ,,	XIV Corps	,,	
135th ,,	XIX Corps	,,	
136th ,,		D.	No diary.
138th ,,	Canadian Corps	E.	
141st ,,	XVIII & II Corps	N.E.	
145th ,,	I Anzac Corps	E.	
146th ,,	XVIII Corps	,,	

PASSCHENDAELE (2ND BATTLE). 26TH OCTOBER-10TH NOVEMBER, 1917.

Unit.	Formation.		Remarks.
2ND AND 5TH ARMIES.			
ARMY TROOPS.			
147th Army Troops Co.		N.E.	
213th ,,		,,	
214th ,,		,,	
216th ,,		,,	
217th ,,	XVIII Corps	,,	
221st ,,	II Corps	,,	
235th ,,	I Anzac Corps	E.	
236th ,,		D.	No diary.
283rd ,,	IX Corps	E.	
284th ,,	XVIII & II Corps	,,	
285th ,,		D.	No diary.
288th ,,	XIV & XIX Corps	N.E.	
567th ,,	X Corps	,,	
568th ,,		,,	
573rd ,,		,,	
2nd Can. Army Troops Co.	Canadian Corps	D.	
4th ,,	,,	E.	
5th ,,	,,	,,	
No. 6. Siege Co. R. Monmouth	X Corps	,,	
171st Tunnelling Co.	Canadian Corps	,,	
173rd ,,	XIV & XIX Corps	,,	
175th ,,	X Corps	D.	No diary.
179th ,,	XVIII & II Corps	E.	
183rd ,,	XIV & XIX Corps	,,	
250th ,,		D.	
253rd ,,	XIV & XIX Corps	E.	
254th ,,	Canadian Corps	,,	
255th ,,	XVIII & II Corps	,,	No diary.
1st Can. Tunnelling Co.	X Corps	,,	
2nd ,,	IX Corps	D.	
3rd ,,	X Corps	E.	
1st Aust. Tunnelling Co.		D.	No diary.
351st E. & M. Co.		N.E.	
354th ,,		D.	
2nd Field Survey Co.		,,	No diary.
5th ,,		,,	
No. 2 Pontoon Park	Can. & I Anzac Corps	E.	
No. 6 ,,	II Corps	D.	
No. 7 ,,	II & XIX Corps	E.	
No. 4 Army Tramway Co	XVIII & II Corps	,,	
No. 5 ,,		D.	No diary.
No. 6 ,,	XIV & XIX Corps	E.	
No. 8 ,,	IX Corps	,,	No diary.
No. 9 ,,	X Corps	,,	No diary.
SECOND ARMY.			
IX CORPS.			
81st Field Co.	19th Divn.	E.	
82nd ,,	,,	,,	
94th ,,	,,	,,	
152nd ,,	37th Divn.	,,	
153rd ,,	,,	,,	
154th ,,	,,	,,	

PASSCHENDAELE (2ND BATTLE). 26TH OCTOBER-10TH NOVEMBER, 1917.

Unit.	Formation		Remarks.
X CORPS.			
59th Field Co.	5th Divn.	E.	
491st ,,	,,	,,	
527th ,,	,,	,,	
54th ,,	7th Divn.	,,	
95th ,,	,,	,,	
528th ,,	,,	,,	
61st ,,	14th Divn.	,,	
62nd ,,	,,	,,	
89th ,,	,,	,,	
97th ,,	21st Divn.	,,	
98th ,,	,,	,,	
126th ,,	,,	,,	
101st ,,	23rd Divn.	N.E.	
102nd ,,	,,	,,	
128th ,,	,,	,,	
225th ,,	39th Divn.	E.	
227th ,,	,,	,,	
234th ,,	,,	,,	
I ANZAC CORPS.			
1st Aust. Field Co.	1st Aust. Divn.	E.	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
5th ,,	2nd Aust. Divn.	,,	
6th ,,	,,	,,	
7th ,,	,,	,,	
8th ,,	5th Aust. Divn.	,,	
14th ,,	,,	,,	
15th ,,	,,	,,	
CANADIAN CORPS.			
1st Can. Field Co.	1st Can. Divn.	E.	
2nd ,,	,,	,,	
3rd ,,	,,	,,	
4th ,,	2nd Can. Divn.	,,	
5th ,,	,,	,,	
6th ,,	,,	,,	
7th ,,	3rd Can. Divn.	,,	
8th ,,	,,	,,	
9th ,,	,,	,,	
10th ,,	4th Can. Divn.	,,	
11th ,,	,,	,,	
12th ,,	,,	,,	
FIFTH ARMY. (Passed to 2ND ARMY, 1st November, 1917).			
XVIII CORPS (relieved by II CORPS, 2nd November, 1917).			
79th Field Co.	18th Divn.	E.	
80th ,,	,,	,,	
92nd ,,	,,	,,	
206th ,,	32nd Divn.	D.	
218th ,,	,,	E.	
219th ,,	,,	,,	
503rd ,,	58th Divn.	,,	
504th ,,	,,	,,	
511th ,,	,,	,,	
247th ,,	63rd Divn.	,,	
248th ,,	,,	,,	
249th ,,	,,	,,	
II CORPS.			
23rd Field Co.	1st Divn.	E.	
26th ,,	,,	,,	
409th ,,	,,	,,	
5th ,,	2nd Divn.	,,	
226th ,,	,,	,,	
483rd ,,	,,	,,	

PASSCHENDAELE (2ND BATTLE). 26TH OCTOBER-10TH NOVEMBER, 1917.

Unit.	Formation.	Remarks.
XIV CORPS (relieved by XIX CORPS, 29th October, 1917).		
203rd Field Co.	35th Divn.	E.
204th ,,	,,	,,
205th ,,	,,	,,
7th ,,	50th Divn.	,,
446th ,,	,,	,,
447th ,,	,,	,,
421st ,,	57th Divn.	,,
502nd ,,	,,	,,
505th ,,	,,	,,
XIX CORPS.		
77th Field Co.	17th Divn.	E.
80th ,,	,,	,,
92nd ,,	,,	,,

SIGNALS.

PASSCHENDAELE (2ND BATTLE) 26TH OCTOBER-10TH NOVEMBER, 1917.

Unit.	Formation.	Remarks.
Second Army Signal Co.		N.E.
B. Corps Signal Co.	II Corps.	D.
1st Divl. Signal Co.	,,	E.
58th ,,	,,	,,
63rd ,,	,,	,,
E. Corps Signal Co.	IX Corps	D.
19th Divl. Signal Co.	,,	E.
37th ,,	,,	,,
X Corps Signal Co.	X Corps	D.
5th Divl. Signal Co.	,,	E.
7th ,,	,,	,,
14th ,,	,,	N.E.
21st ,,	,,	E.
23rd ,,	,,	N.E.
39th ,,	,,	E.
Can. Corps Signal Co.	Canadian Corps	D.
1st Can. Divl. Signal Co.	,,	E.
2nd ,,	,,	,,
3rd ,,	,,	,,
4th ,,	,,	,,
K. Corps Signal Co.	I Anzac Corps	D.
1st Aust. Divl. Signal Co.	,,	E.
2nd ,,	,,	,,
5th ,,	,,	,,
Fifth Army Signal Co.		N.E.
J. Corps Signal Co.	XIV Corps	D.
35th Divl. Signal Co.	,,	E.
50th ,,	,,	,,
57th ,,	,,	,,
S. Corps Signal Co.	XVIII Corps	D.
T. Corps Signal Co.	XIX Corps	,,
17th Divl. Signal Co.	,,	E.
18th ,, ,,	,,	,,

CAMBRAI 1917. 20TH NOVEMBER—3RD DECEMBER, 1917.

Unit.	Formation.	Remarks.
THIRD ARMY.		
ARMY TROOPS.		
A. Special (Cyl.) Co.	Special Brigade	N.E.
G. ,,	,,	E.
P. ,,	,,	,,
Q. ,,	,,	D.

CAMBRAI, 1917. 20TH NOVEMBER—3RD DECEMBER, 1917.

Unit.	Formation.		Remarks.
THIRD ARMY.			
ARMY TROOPS.			
No. 1 Special (Mortar) Co.	Special Brigade	E.	
No. 3 ,,	,,	N.E.	
142nd Army Troops Co.	IV Corps	E.	
147th ,,	V Corps	,,	
149th ,,	IV Corps	D.	
232nd ,,	III Corps	E.	
238th ,,	VII Corps	N.E.	
239th ,,	III Corps	E.	
280th ,,		N.E.	
281st ,,	VII Corps	,,	
559th ,,	V Corps	E.	
565th ,,	IV Corps	,,	
574th ,,	III & VII Corps	,,	No diary.
577th ,,	IV Corps	,,	No diary.
No. 2 Siege Co. R. Anglesey	IV Corps	,,	
178th Tunnelling Co.	III & VII Corps	,,	
180th ,,	VII Corps	D.	
181st ,,	III Corps	E.	
252nd ,,	V Corps	,,	
1st Aust. ,,	IV Corps	D.	
N.Z. ,,	IV Corps	,,	
No. 352 E. & M. Co.		,,	No diary.
No. 353 ,,		,,	No diary.
No. 3 R.E. Workshop		,,	No diary.
No. 3. Field survey Co.		,,	No diary.
No. 3 Pontoon Park (Horsed)	III & IV Corps	E.	
No. 8 Pontoon Park (M.T.)	,,	,,	
No. 1 Army Tramway Co.		D.	
No. 3 ,,	III Corps	E.	
CAVALRY CORPS.			
1st Field Squadron	1st Cav. Divn.	E.	
2nd ,,	2nd ,,	,,	
3rd ,,	3rd ,,	N.E.	
4th ,,	4th ,,	E.	
5th ,,	5th ,,	,,	
II, IV, V AND VII CORPS.			
55th Field Co.	Guards Divn.	E.	
75th ,,	,,	,,	
76th ,,	,,	,,	
5th ,,	2nd Divn.	,,	
226th ,,	,,	,,	
483rd ,,	,,	,,	
56th ,,	3rd Divn.	N.E.	
438th ,,	,,	,,	
529th ,,	,,	,,	
12th ,,	6th Divn.	E.	
459th ,,	,,	,,	
509th ,,	,,	,,	
69th ,,	12th Divn.	,,	
70th ,,	,,	,,	
87th ,,	,,	,,	
83rd ,,	20th Divn.	,,	
84th ,,	,,	,,	
96th ,,	,,	,,	
97th ,,	21st Divn.	N.E.	
98th ,,	,,	,,	
126th ,,	,,	,,	
455th ,,	29th Divn.	,,	
497th ,,	,,	,,	
510th ,,	,,	,,	

CAMBRAI, 1917. 20TH NOVEMBER—3RD DECEMBER, 1917.

Unit.	Formation.	Remarks.
II, IV, V AND VII CORPS.		
121st Field Co.	36th Divn.	E.
122nd ,,	,,	,,
150th ,,	,,	,,
224th ,,	40th Divn.	,,
229th ,,	,,	,,
231st ,,	,,	,,
517th ,,	47th Divn.	,,
518th ,,	,,	,,
520th ,,	,,	,,
400th ,,	51st Divn.	,,
401st ,,	,,	,,
404th ,,	,,	,,
419th ,,	55th Divn.	,,
422nd ,,	,,	,,
423rd ,,	,,	,,
416th ,,	56th Divn.	,,
512th ,,	,,	,,
513th ,,	,,	,,
467th ,,	59th Divn.	,,
469th ,,	,,	,,
470th ,,	,,	,,
476th ,,	61st Divn.	,,
478th ,,	,,	,,
479th ,,	,,	,,
457th ,,	62nd Divn.	,,
460th ,,	,,	,,
461st ,,	,,	,,

SIGNALS.

CAMBRAI 1917. 20TH NOVEMBER—3RD DECEMBER, 1917.

Unit.	Formation.	Remarks.
Third Army Signal Co.		D.
Cavalry Corps. Signal Sqn.	Cav. Corps	E.
1st Signal Sqn.	1st Cav. Divn.	,,
2nd ,,	2nd ,,	,,
4th ,,	4th ,,	,,
5th ,,	5th ,,	,,
C. Corps Signal Co	III Corps	D.
D. ,,	IV Corps	,,
O. ,,	V Corps	,,
G. ,,	VII Corps	,,
Guards Divl Signal Co.		E.
2nd ,,		,,
3rd ,,		D.
6th ,,		E.
12th ,,		,,
20th ,,		,,
21st ,,		,,
29th ,,		,,
36th ,,		,,
40th ,,		,,
47th ,,		,,
51st ,,		,,
55th ,,		,,
56th ,,		,,
59th ,,		,,
61st ,,		,,
62nd ,,		,,

HYDRO-ELECTRIC DEVELOPMENT IN FRANCE.

By CAPTAIN D. FITZJ. FITZMAURICE. R.E.

The utilisation of water-power, "Houille Blanche," or "white coal," was more or less forced on France by the shortage of black coal during the Great War. This is not to say that no considerable exploitation of her water-power resources had been undertaken previous to 1914; on the contrary, France claims the credit for some of the earliest experimental and practical work in this direction.

In 1827, Fourneyron invented his Pressure Turbine which was to oust the old waterwheel, and to be the forerunner of the Francis Turbine of the present day. In the sixties, Aristide Bergés to whom the name of "Houille Blanche" is due, was installing water-power stations for the paper industry in the Dauphiné Alps, and many other pioneers soon followed in his footsteps. In 1870 the curved buckets of the Cascade wheel, the prototype of the present day Pelton, were first employed. It was not, however, till the eighties that, as a result of electrical developments, it became possible to transmit power to a distance, with the natural corollary that the utilization of water-power situate at a considerable distance from centres of Industry became an economic commercial possibility. The earlier turbines had been more or less direct-coupled to the machines they served, gearing, belts and shafting, and even the endless cable soon reaching their economic limit. In the nineties, however, 3-phase high-tension current was being transmitted over distances up to 100 miles.

In 1899, the first really important Hydro-electric power station in France was completed at Champ-sur-le-Drac (Isére), with an installed capacity of 10,000 h.p. under a head of 118 ft. As might be expected, the Alpine Region, the Dauphiné and Savoie, was the cradle of the hydro-electric movement in France. 1900 saw the foundation of the *Institut Electro-Technique* in the University town of Grenoble, where in 1901 the *Syndicat des Forces Hydrauliques* was formed, while in 1902, this town held the first *Congrés de la Houille Blanche.*

In 1903, the *Ministère de l'Agriculture,* in conjunction with the *Ministère des Travaux Publics,* inaugurated the *Service d'Etudes des Grandes Forces Hydrauliques,* whose researches into the availability of power in the various river basins are published periodically by the *Imprimerie Nationale.* It is the function of this Service to obtain and collate full information as to the characteristics of river basins, with a view to their ultimate development for power purposes. This includes the making of accurate surveys of the valleys and the plotting of periodical profiles of the watercourses; geological investigations; the compilation of rainfall and discharge statistics; the time of floods and their duration and the observation of the nature and quantity of matters carried by the streams in suspension.

By 1914, about $1\frac{1}{2}$ millions of h.p. had been harnessed in the whole of France. The Great War, with its abnormal demands on the factories, and the coal famine existing on the continent from 1916 onwards, gave a great impulse to the development of water-power, with the result that the amount of installed h.p. now reaches $2\frac{1}{2}$ millions, of which some $1\frac{3}{4}$ millions are in the Alpine region. (*)

In 1925 the third *Congrès de la Houille Blanche* was held in Grenoble, the town that has fostered water-power in France since its earliest infancy, and where the mountains and rivers that gave it its early importance as a military stronghold now provide it with the power for its industries.

Geographical Distribution of Water-Power in France.

The most important, and by far the most numerous works are to be found in the Alpine region, where some 70% of the total of installed h.p. in the whole country is located.

The region of the Pyrenees is the next in order of importance, with about 20% of the total; the largest individual station being that of Eget (35,000 h.p.), on the river Neste, a tributary of the Garonne.

The *Massif Central* supplies the majority of the remainder. The natural heads available here are small, and have almost invariably to be increased by the construction of dams, artificial lakes being thus formed to increase the storage. The most recently opened station in this region is at Eguzon on the river Creuze (75,000 h.p.), where a barrage 200 ft. high and 840 ft. long has been built: the power is to be utilised for the electrification of the Paris-Orleans railway system, and to supply light and power to Paris.

General Considerations.

While the undertakings for these installations can be grouped broadly as "high head" and "low head" works, using respectively the Pelton wheel and the Francis turbine as prime movers, no two schemes are quite alike, the variations being due *inter alia* to the discharge characteristics of the streams to be harnessed, the general configuration of the ground, and the choice of the most suitable site for the power station itself.

The determination of the discharge characteristic of the stream is the all-important factor on which the project for the utilisation

* "La Houille Blanche" V. Sylvestre, 1925.

of the water must be based; and the variability of the discharge is one of the inherent difficulties in the economic utilisation of water-power. While the mountain torrent fed by glaciers will give its maximum discharge in the summer months due to the melting of ice and snows, and its minimum discharge in winter when its sources are more or less ice-bound; with streams in the plains, fed only by rains and occasional snow, the reverse will be the case. The variation in discharge will also be largely affected by the slope and permeability of the surface strata of the basin, the rise of floods being much more rapid where the majority of the rainfall runs off direct down steep slopes to the watercourses, than where the latter are fed largely by percolation.

The discharge regulation can be improved by the construction of dams and storage reservoirs, but such works are very costly, and other means of regulation are sought where possible. Manifestly in the case of a river of the plains fed by both winter rains and the summer discharge of a glacial tributary, a considerable natural improvement is effected in the discharge regulation. Such a situation occurs, for example, at the confluence of the Drac and the Romanche, close to Grenoble, where a low-head power station was completed in 1921. Further, it is sometimes possible to connect electrically two or more stations working under different seasonal discharge conditions, in order to be in a position to deliver a more or less constant output to the network; while in some cases a natural lake has been tapped as a reservoir to supplement the low water discharge of a river. A case in point is the power station of Le Baton (Isére), where the surplus river water at maximum discharge is pumped back to refill the lake.

As in most river works, the quantity of sand or silt brought down in suspension is of the utmost importance. Not only must arrangements be made for excluding it as far as possible from the turbines, where it is likely to cause erosion of the runners and guide-passages, but the danger of silting-up of reservoirs has also to be considered.

The quantity of granitic sand brought down by the Alpine torrents is large, and the full head behind a dam cannot always be relied on for this reason; the bottom of the reservoir being considered as a depository for sand accumulations. Special residuum lodges can also be provided at the upstream end of the reservoir, where the velocity of the incoming water must be sufficiently checked to make further transport of the sand or silt impossible.

The tendency of a reservoir to silt up and its effect in clarifying the waters feeding it, are well illustrated by the Lake of Geneva. The Rhone, at its entrance to the lake, is very turbid indeed, but the turbidity ceases a very short way from the upstream end of the lake, and at Geneva a clear Rhone flows out, only however, to be fouled a little further on by the blue grey waters of the Arve flowing in from the direction of Chamonix and the great glaciers of the Mont Blanc range. The foreshore at the upstream end of the lake is steadily advancing under the continuous action of the silt-deposit.

Nature of the Works.

The works required on the Civil Engineering side of a project for the utilisation of water-power may be roughly grouped as:

(1) The Intake works, and Head-race or Approach channel;
(2) The Power House;
(3) The Tail-race Works;

and in addition, any temporary works which may be necessary to facilitate access to, and transport of men and material to, the works.

Where large storage works are necessary these will often form one of the most important and costly items in the project. For this reason they are avoided wherever possible, and sites chosen for development where a sufficiently continuous flow or natural storage facilities are available.

Typical Developments are:

(*a*). A natural cascade diverted into a water chamber hollowed in the rock, and thence piped down either above or below ground to the turbines or Pelton wheels. (Fig. 1).

(*b*). A high level lake, natural or artificial, tapped by tunnel or canal, and the water then led some distance, maybe, to a neighbouring gorge where a good fall is obtainable by pipe line to a low-level power station. (Fig. 2).

(*c*). A deep and narrow river gorge closed by a masonry or concrete dam, usually built arch-shaped in plan; the water being piped to the power-station situated near the foot of the dam. (Fig. 3).

(*d*). A steady-flowing river of the plains, harnessed by a low barrage, carrying movable weirs above the fixed crest for passing the flood waters; the power station being sited either in the river bed itself at the barrage, or being reached by an approach canal, advantage being taken of a further fall in the river bed to get a low level for the tail-race discharge. (Figs. 4 and 5).

High-Head Works.

Type (*a*). This type of development lends itself particularly to the case where a high head is available and only a small quantity of water. This development is, therefore, commonest in the Alpine Region proper. By a high head is meant 500 ft. or over, and for such heads the Pelton wheel is generally preferred as prime-mover, on account of its high economical speed as compared with the Francis turbine.

The Pelton wheel, as is well known, consists essentially of a disc mounted on a horizontal spindle and carrying a number of buckets (about 20) bolted to its periphery, the wheel being rotated by the impulse of a high velocity jet playing on the buckets, tangentially to the wheel.

The buckets are designed:

(i) To receive the jet with the minimum of shock, or loss of energy.

(ii) To change the direction of the jet through nearly 180 degrees (with the stipulation that the oncoming bucket shall be cleared by the water thrown off), and to throw the water off "dead," *i.e.*, to convert its available momentum into an impulsive force tangential to the wheel.

To achieve the above, the buckets normally take the form of the open bivalve (Fig. 6), with a sharp central ridge to divide the jet, and external edges splayed slightly outwards from the plane of the disc. A lip is usually removed, as shewn, to avoid the splashing (and consequent loss of energy) that would be caused by the deflection of some of the water radially inwards towards the centre of the wheel, by the lip, if allowed to remain. The central ridge is curved back in the plane of the wheel so as to meet the incoming jet at right angles. The convex back of the bucket is strengthened by ribs as necessary.

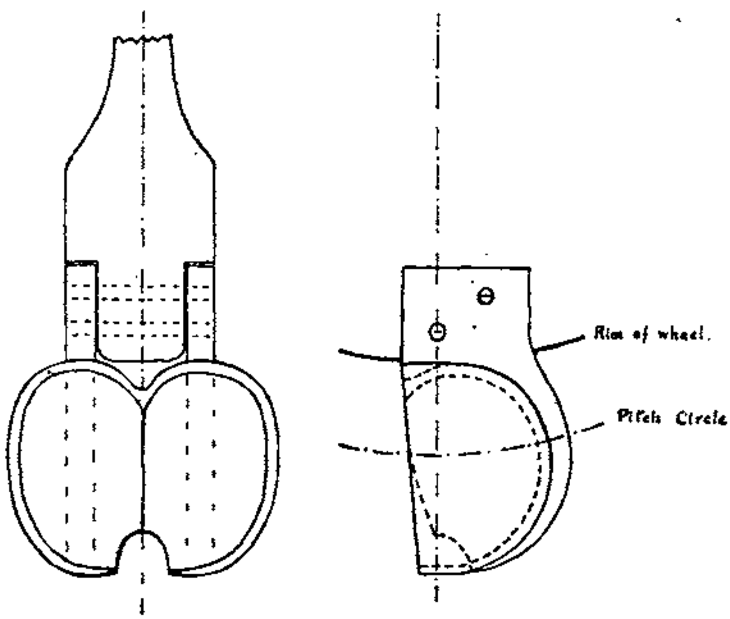


FIG. 6.

Bucket of Pelton Wheel.

As a rough rule, 1 inch of jet diameter is given to every foot of wheel diameter; and the bucket width is made about four times the jet diameter; while the length of the bucket measured along a radius of the wheel should be sufficient to ensure that no part of the jet escapes unused. The most efficient bucket speed is about ·46 times the jet velocity.

The jet is usually of the needle valve type, controlled by a hydraulic relay regulator operated by a centrifugal governor. To obviate the disastrous effect of water hammer under the great pressures employed, either a relief valve is fitted at the lower end of the pipe line, or a deflecting nozzle is employed cutting off the supply to the buckets without altering the flow in the pipe line. The pipe line velocity must be kept down to avoid heavy friction losses, and in practice seldom exceeds 15 to 20 ft.-sec. The water thus arrives under great pressure at the nozzle, where its pressure energy is converted into kinetic.

If D and V are the diameter and the velocity in the pipe line, and d and v are the diameter and velocity at the nozzle, then for continuity of flow,

$$\frac{\pi . D^2 . V}{4} = \frac{\pi . d^2 . v}{4}$$

or

$$\frac{D^2}{d^2} = \frac{v}{V}$$

Also, $v = \cdot985\ \sqrt{2gh}$, where h is the effective head at nozzle.

h = H (total head) — H′ (pipe line losses).

The pipe line must be designed to keep H′ down within economical limits.

If Q be the quantity of water available in cusecs, the theoretical

power obtainable $= \frac{62\cdot5 . Qh}{550}$ H.P.

With a well-designed Pelton wheel at full load, an efficiency of 85% may be expected; while with a well-designed needle valve nozzle the part load efficiency can be maintained at a remarkably high figure, governing being almost entirely on quantity, the nozzle velocity remaining nearly constant.

According to Gibson, "*Hydraulics and its Applications*," 1920, the Pelton wheel is by far the most suitable hydraulic prime mover for high heads, for powers in single units up to 2,000 b.h.p.

Two wheels are often mounted side by side on a single shaft, while two or three jets may be employed on a single wheel.

The Chute du Baton.

A typical high head Pelton wheel installation is the small power station at the Chute du Baton on a tributary of the Romanche, near Grenoble. The scheme was designed and executed by M. Ch-A. Keller, and incidentally employs the highest head utilised in France, viz.: 3,444 ft., and as such is deserving of description. The 6,600 h.p. is developed in two equal units, Pelton wheels, one of 8 ft. 6 in. diameter and 500 revs./min., and the other of 11 ft. 3 in. diameter and 375 revs./min. To each of the Peltons is coupled a 2,500 KVA alternator at 3,000/4,350 volts at 50 cycles. The pressure is transformed up to 26,000 volts for transmission. The intake works are at an altitude of 5,773 ft. The stream is here canalised, and the water is taken from the bed, so that a supply may be assured when the stream is covered with ice and snow. The water rushes into an underground tunnel, whence it is discharged into an underground settlement chamber, which can be flushed out when necessary, via a gallery specially constructed for this purpose; it then runs into a reservoir tunnel some 3,600 ft. long and 240 sq. ft. in section. The tunnel ends in a thick stopping wall, containing the inlet to the pipe line and an automatic throttle valve, which closes if the pipe line velocity exceeds the safe limit.

The twin pipe line itself is 5,133 ft. long and weighs over 400 tons. The upper half is constructed of riveted steel sections of thickness increasing from 3/16ths of an inch at the top, to nearly 1 inch at a depth of 1,650 ft. The lower half is of welded steel pipes of thickness varying from ⅝ths of an inch to 1 1/16th inch at the bottom depth of over 3,400 ft. The diameter of each of the pipes is, for the upper half, 23½ inches, and for the lower half 17¼ inches. The diameter at entry to the needle valve is 9¾ inches, while the jet diameter is only about 2½ inches.

Governing is by the usual hydraulic relay regulator, and in addition if the wheel tends to run away, the spent water fails to clear the backs of the oncoming buckets, thus forming an automatic brake on the wheel.

The pipe line is buried 6 ft. below the surface of the ground to avoid freezing, the upper half by trenching, and the lower half by tunnelling, owing to the steepness of the slope—some 61 degrees.

An aerial ropeway was constructed to transport the pipes up the mountain side, the pipes being held in a cradle suspended by tackles from the travelling carriage, and capable of being lowered or raised at will. This ropeway has been left in position for maintenance purposes and to provide a ready means of communication from the valley to the headworks. The pipes forming the lower half of the pipe line were placed in position by hauling them one by one to the top of the tunnel, and lowering them down it.

The tunnel has a further object, namely the protection of the lower part of the pipe-line from the falls of rock that occur sufficiently frequently on the steep part of the mountain side. With this object also, the power station itself is hollowed out of the rock.

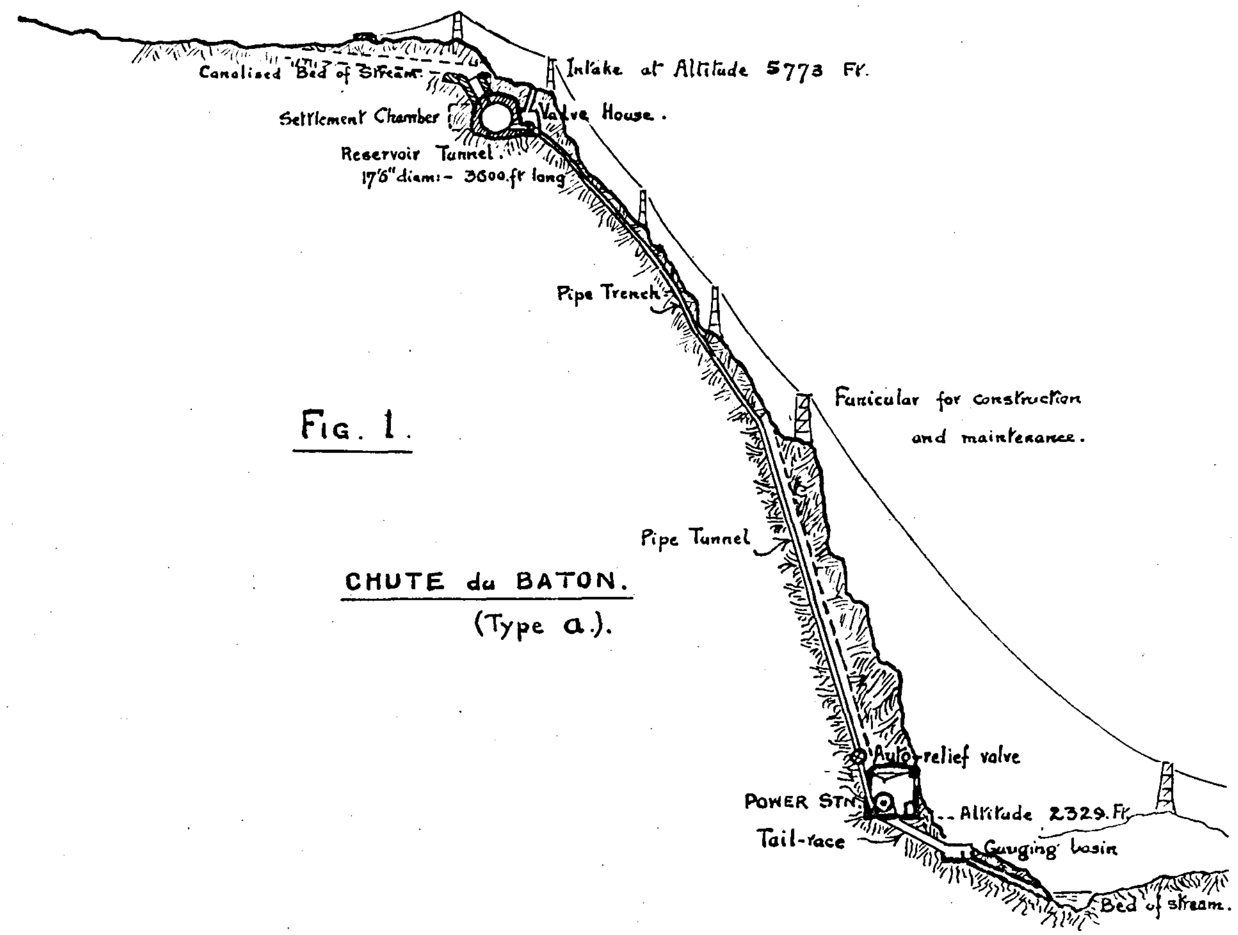


FIG. 1.

CHUTE du BATON.
(Type a.).

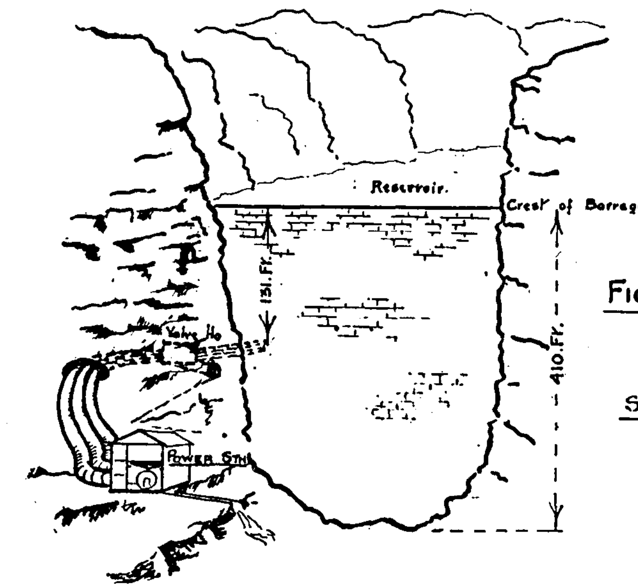


FIG. 3.

Type C.

SAUTET PROJECT. HAUT-DRAC.

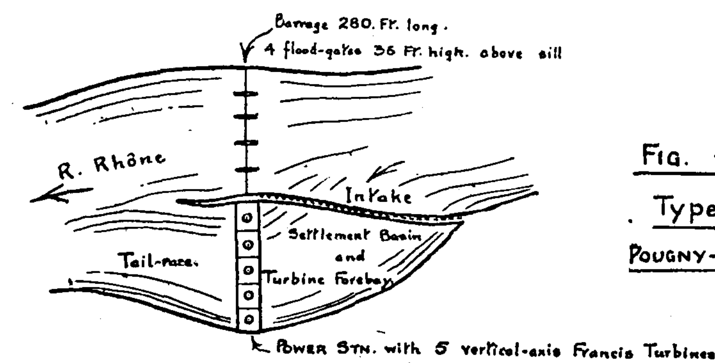


FIG. 4.

Type d.

POUGNY-CHANCY.

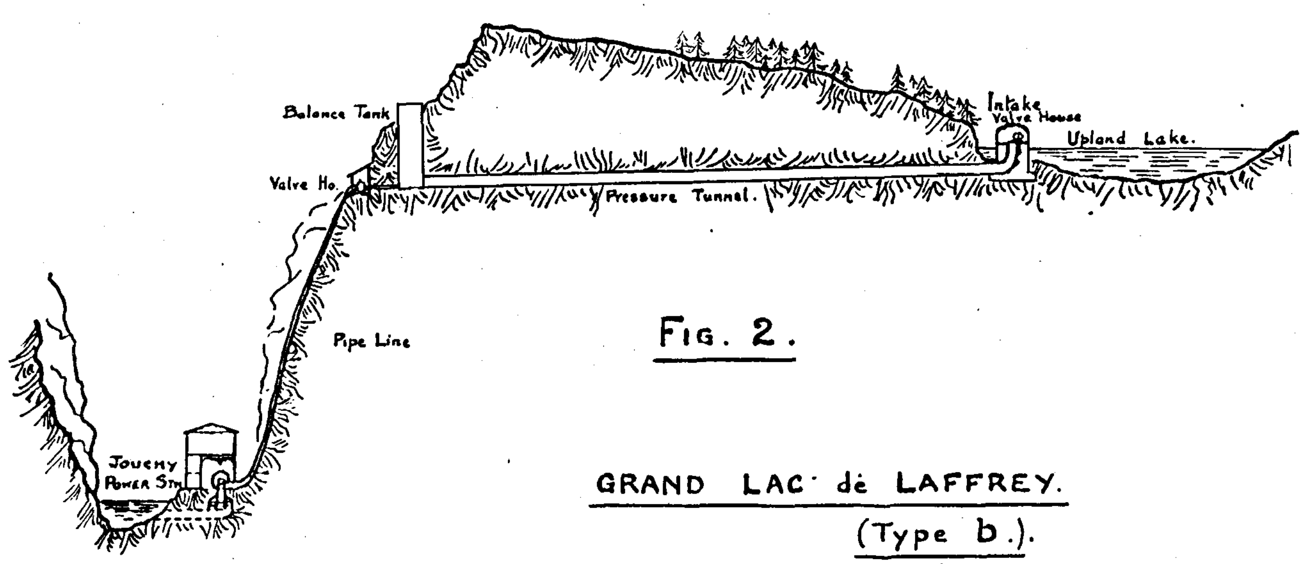


FIG. 2.

GRAND LAC dè LAFFREY.
(Type b.).

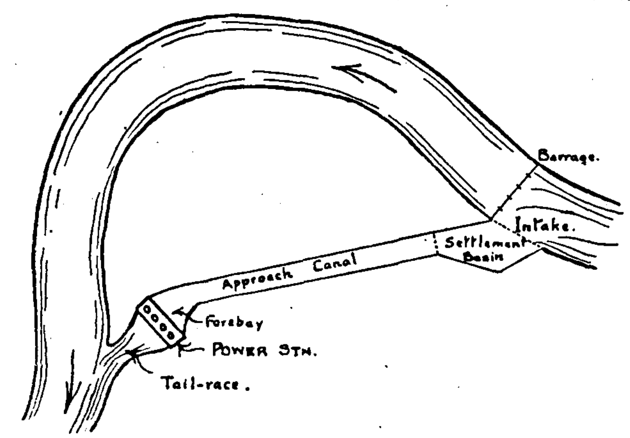


FIG. 5.

Alternative to Type d.

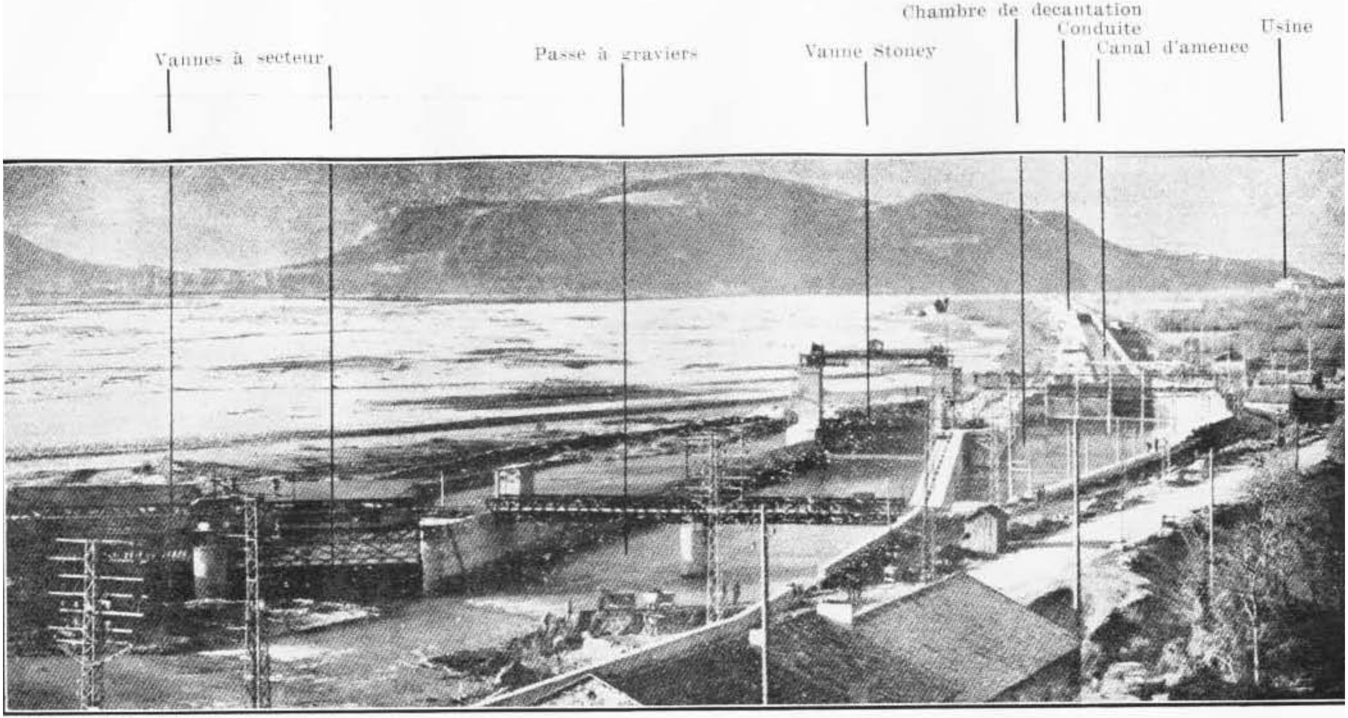


Fig. 7. Vue Générale de L'installation Hydro-Électrique Drac-Romanche.

VUE GENERALE DE L'INSTALLATION

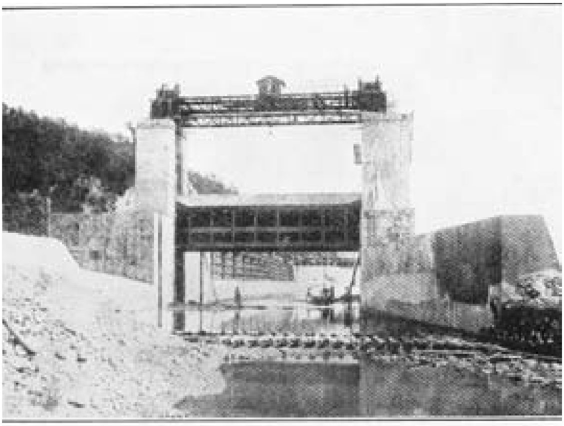


Fig. 8.
Prise d'eau, passe à graviers et vanne Stony. — Vue de l'aval.

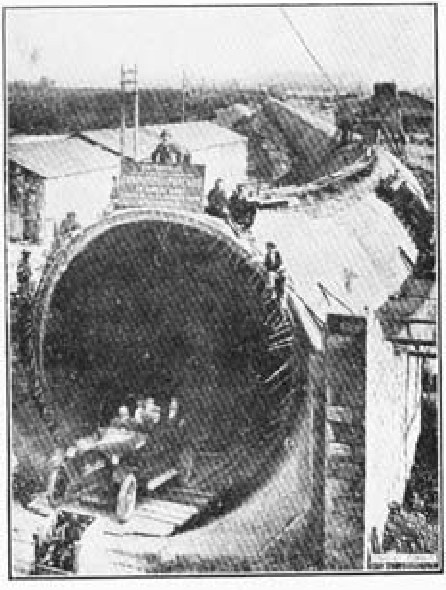
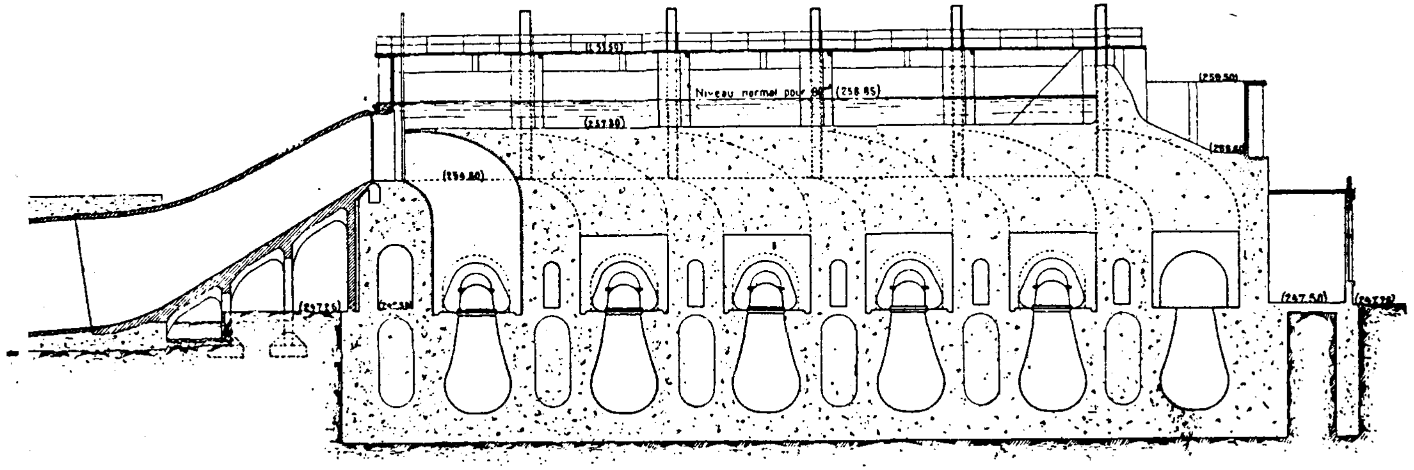


Fig. 9.
Conduite de Drac-Romanche
Diamètre : 6m00 — Longueur : 1600m.

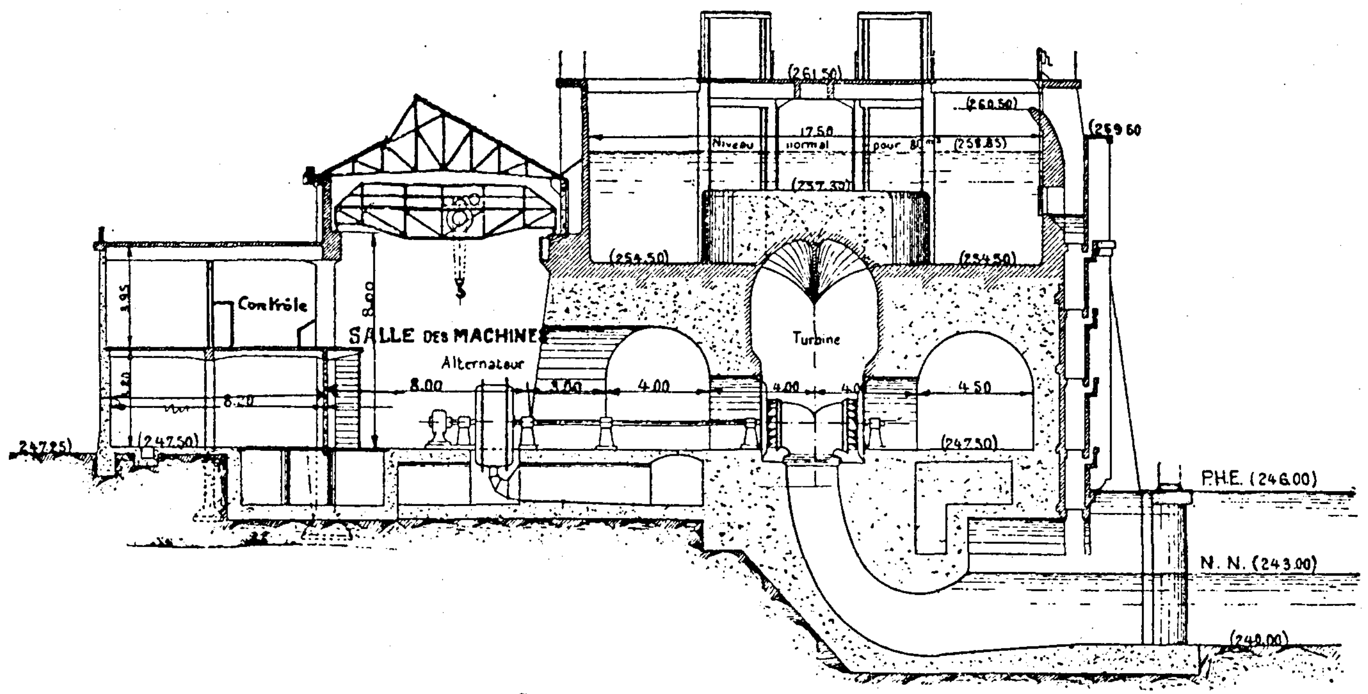
PRISE DE L'EAU

FIG 10.

DRAC-ROMANCHE POWER-STATION



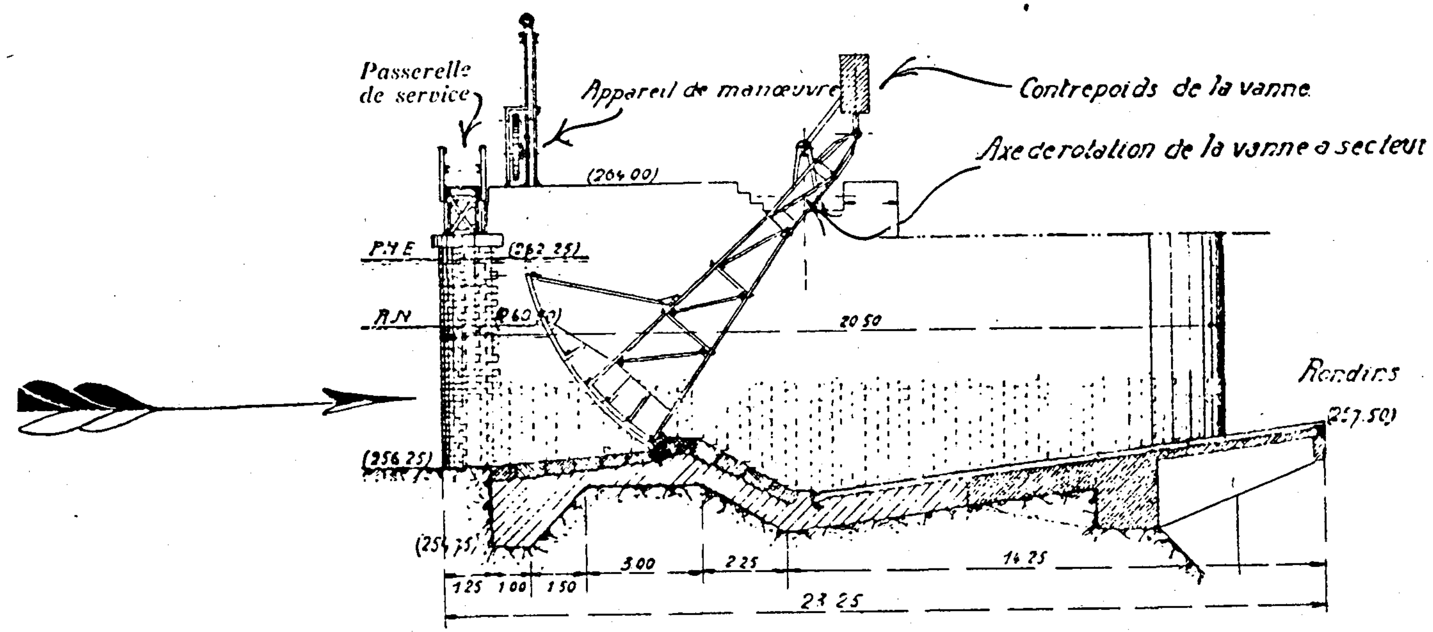
— Coupe longitudinale sur l'axe des turbines. —



Coupe transversale sur l'axe d'une turbine.

FIG. 11.

SECTOR GATE



Coupe longitudinale d'une vanne à secteur.

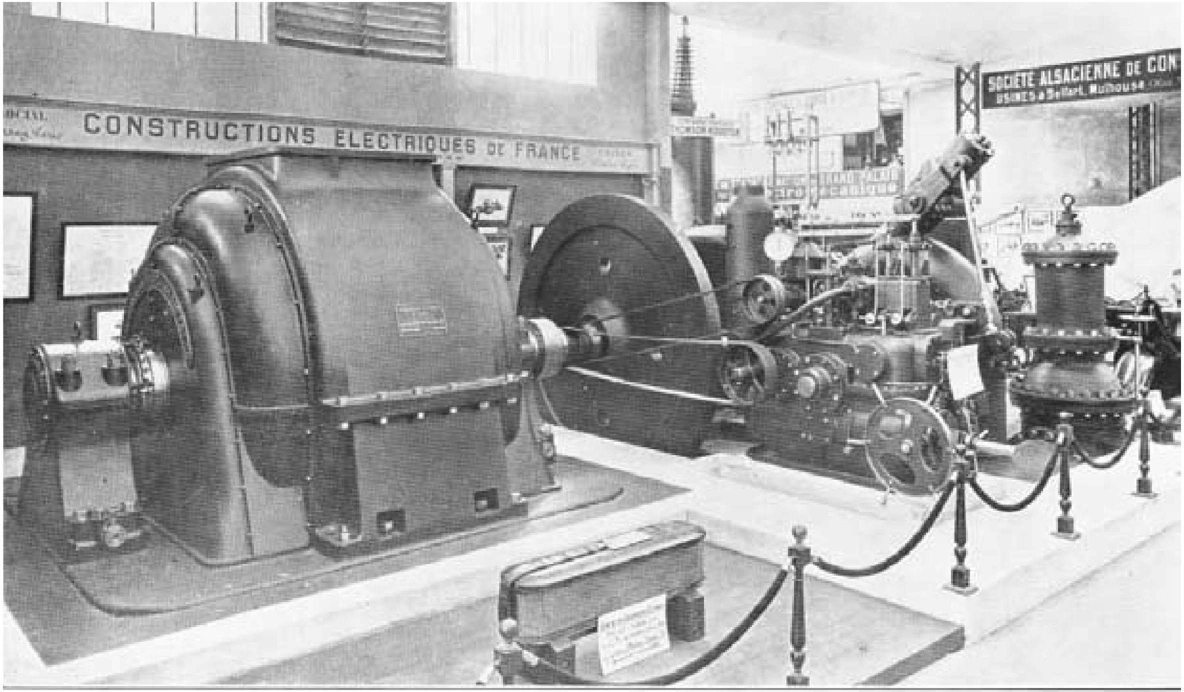


Fig. 12.

Grenoble Hydro - Electric Exhibition. Pelton-Wheel Unit, with Hydraulic Regulator.

PELTON-WHEEL UNIT

For safety, it is not placed directly at the foot of the pipe line, but a short way to one side. The pipe line tunnel is continued, however, after the pipes have turned off towards the power house, so that, in case of rupture, the water would be discharged clear of all buildings., Hydraulically operated pressure relief valves are placed at the foot of the pipe line. The only pipes entering the power station are actual connections to the needle valves of the two Pelton wheels. The tail race consists of twin channels leading to a gauging basin, whence a reinforced concrete conduit returns the water under low pressure to the bed of the stream. Fig. 1 shews the general arrangement of the works.

Type (*b*).

This type of development is suitable for high and medium heads, and is common in the region of the Pyrenees, where the existence of numerous high level lakes provides a solution of the problem of discharge regulation. It is also met with in the Alpine region. The constructional costs are, in general, greater per h.p. than in type (*a*). The pressure tunnel shewn in Fig. 2 may be replaced by an open channel approximately following the contours of the hillside, with the necessary slope to give the required discharge ; or a tunnel following the hydraulic gradient and ending in a water chamber with ample overflow weirs, may be constructed, as in the Eget scheme already mentioned. Here some 5½ miles of tunnel aqueduct have been constructed, bringing the waters from two systems of lakes to the head of the pipe line, whence a fall of over 2,400 ft. is obtained to the power station at Eget.

Type (*c*).—Where the natural slope of a watercourse is small, and the stream is confined between steep rocky banks, a comparatively small dam provides both a medium head and a considerable reservoir of water. The " Barrage reservoir " so formed is a type of development that is common in the region of the Massif Central. The dam is usually arch-shaped in plan, this type being particularly suited to short spans across narrow gorges with good rock abutments. The intake is by concrete lined tunnel from well behind the barrage. The tunnel ends in a solid obturating wall, beyond which is the valve-house, reached by an inclined gallery from the face of the rock, downstream of the barrage. The inlet level is generally some distance above the bottom level of the reservoir, on account of silt deposit. Thus, though the full head given by the barrage is available, the full storage cannot be utilised. From the valve house the water is led by pipe line to the power station, sited near the foot of the barrage at sufficient elevation to give a good tail race discharge. A part or the whole of the barrage may be used as a spillway to pass the flood waters.

Type (d). Low head works.—Heads from 2 ft. up to about 100 ft. are classified as low heads, those from 100 ft. to 500 ft. as medium heads, and those above 500 ft. as high heads.

A high head, though as a rule economical, is by no means an essential to a satisfactory scheme. Where a large quantity of water is available continuously, large powers may be obtained with quite small heads. This means, however, an increase in the size of the turbines, the power station, and the head and tail race works. For example, in the Shannon scheme for the electrification of the whole of the Irish Free State a head of 100 ft. only is available, yet the discharge of the river is calculated to be sufficient to supply power to every dairy churn and chaff cutter in the country. Similarly, the spring tidal range in the Severn estuary is only some 42 ft., yet the day will doubtless come when this head will be economically turned to account to supply England and Wales with electric power.

Low head works do not, in general, admit of so much variation constructionally as the other types. They usually involve: a low barrage, or dam across the stream; the intake works, including trash-racks, settlement basin, head race canal and penstock forebay; the power station; and the tail race canal. The disposition and relative importance of these works depends on the conditions at the site.

Where the natural slope of the river bed is considerable, the necessary fall may be obtained with quite short head and tail race canals; while the fall around a long loop can often be utilised by cutting across the neck. (Fig. 5).

It is, however, frequently desirable to increase the natural head, and at the same time improve the discharge regulation, by constructing a low barrage across the stream. Where the barrage can be founded on rock it is usually constructed of masonry or concrete, otherwise an earthen dam with core wall is built. Timber crib dams are not common in France, but for very low heads with shingle river beds, barrages of gabions are largely employed, with a carefully constructed masonry or concrete spillway at one end. Above the fixed crest of the barrage the head can be further raised by a number of movable gates, which are automatically overturned in case of heavy floods.

A case in point is the barrage directly below the confluence of the Drac and the Romanche (Drac Romanche power station at Pont-de-Claix, near Grenoble), illustrated in Figures 7 to 11. The intake is on the right bank of the stream. The water passes first into a large gravel sluice closed at the downstream end by a Stoney lifting gate weighing 50 tons. Here the heavy gravels are deposited and can be sluiced clear to return to the river bed by a rapid hoisting of the Stoney gate. In the side of this gravel-sluicing basin are twelve orifices, protected by vertical trash-racks, through which the water passes to the settlement basin proper. This can be cleaned out periodically by dredging. A short open channel leads from this basin to the reinforced concrete pressure conduit which claims to be the largest of its kind in the world, being nearly 20 ft. in diameter, and a mile long. The working head of water at the lower end is 50 ft. and here the conduit rises steeply with an increasing section to discharge the water into the open turbine forebay, which acts as a balance tank to protect the conduit and the turbines from the effects of water hammer. For this elevated forebay a considerable concrete structure was necessary, and alongside it is built the machine hall. The five turbines are of the back-to-back horizontal axis Francis type, with draught tube, developing 3,000 h.p. at 300 revs. per minute. An emplacement exists for the installation of a sixth turbine. Regulation is by compensated oil pressure servo-motor, operated by a centrifugal governor. The alternators and their exciters are mounted on the long horizontal turbine shaft, and an elevated control platform overlooks the machine hall. Three phase current at 5,500 volts and 50 cycles is delivered to the outside transforming station, whence it is fed at 26,000 volts by overhead line to the steelworks of MM. Bouchayer et Viallet (4,500 KVA.), and to the town of Grenoble for lighting. Underground cables at 5,500 volts feed the paper mills at Pont-de-Claix (1,500 KVA.), and the liquid chlorine factory (4,500 KVA.). The installation was completed in 1921, under the supervision of M. Pierre Ducrest, to whom the author is indebted for the permission to reproduce the illustrations referring to this work and the above particulars. The clear width of the flood gate openings is here, as elsewhere, laid down by the *Ministére des Travaux Publics.* To the left of the gravel sluicing basin are four sector gates, each of width 52 ft. 6 ins., and retaining a head of 10 ft. of water. These gates are carefully balanced so that they can each be raised by one man, with the aid of the winch.

The Economics of Water Power.

The commercial possibilities of water power depend mainly on the comparative costs of water power and any other kind of power that may be available for the area under consideration. With the increasing complexity of the coal problem, the future potentialities of water power become more and more assured. It is impossible to give any figures of general application as to the costs of water power, individual cases differing so widely. In general, however, large-scale developments are more economical per h.p. than small-scale ; and high head than low head schemes. The general tendency is towards the use of larger units for the prime movers, but in France little progress appears to have been made in this direction. Similarly, though in general it is more economical to harness the flow of a river with the minimum number of power stations, utilising the available fall in as large "slices" as possible, yet the first cost of the high head works involved when the natural slope of the river bed is small, the difficulty of raising capital and the fact that demands for power grow only gradually, have resulted in France in the installation of a large number of comparatively small power stations along the length of a river, the tail race waters of one discharging directly into the headworks of its downstream neighbour.

The costs of water power are almost entirely capital costs, namely, interest, sinking fund, depreciation, etc., The annual working costs are comparatively low.

Gibson (*Hydro-electric Engineering, Vol.* 1), gives the average constructional costs per installed turbine h.p. (exclusive of water-rights, land, transmission and distribution), on a pre-war basis, as

Canada	£14.2
Sweden	£11.7
Scotland..	£25

and states that the average costs for Canada and Sweden range from £27 for installations of less than 200 h.p. to £6.8 for an installation of 20,000 h.p.

The projectors of the Shannon scheme for the Irish Free State calculated the cost of production at ¼d. per unit.

The cost to the consumer is, of course, considerably increased by the cost of long-distance transmission.

In France constructional costs tend to be lower than in England on account of the lower basic wage rates and the lower cost of living, while in the Alpine region there is the further factor of the steady influx of Italian labour.

In conclusion, it may be noted that France stands second only to the North American continent for aggregate of hydro-electric horse-power installed, and in view of the numerous works actually under construction and projected, it would appear that she is making a determined bid for the leading place.

MORE ABOUT OURSELVES.

By "PRAEFECTUS FABRUM."

"Oh, wad some Power the giftie gie us,
To see oursel's as others see us!"

Burns.

The poet's aspiration has never been fulfilled and never will be, but though we lack the gift in question we can have the next best thing to it. We can ask ourselves what are the qualities which others require of us, and how we can attain them.

In the interesting and thoughtful article which appeared in the last number of this Journal under the title of "Ourselves," the writer does, in fact, ask this question in another form. He says that we Sappers now and then discuss "that most interesting of all subjects—Ourselves—what we are, why we are what we are, whether we are what we ought to be, and if not, why not." In his lecture on "Engineers and the Army," General Thuillier spent some time in expounding why we are what we are, but the far more important question is whether we are what we ought to be.

What ought Royal Engineer Officers to be? For what purposes are they maintained by the State? Surely for no other purpose than to organise and superintend the engineering services required by the army *in war*. The Corps of Royal Engineers is not maintained in order to provide a soul-satisfying career for keen and ambitious young men. Do not those who dispute on the subject of the employment of our officers sometimes forget that service to the country in whatever line the country wants us is the real and high calling of every one of us? And the line in which she wants Royal Engineers is for the assistance they can give the rest of the army in war—nothing else.

It is unfortunate that the typical career described by Major Kerrich does not contain any war experience whatever. It no doubt happens sometimes that an officer goes through the whole of his service without being employed in war, but surely it cannot for any soldier be called typical.

He says that his typical specimen presents points of interest, "even if he has failed to strike out a line for himself, like the two officers who are now respectively Governor of Queensland and Permanent Under Secretary for the Colonies." Typical soldiers of any branch of the Army are not expected to strike out lines of that kind for themselves. Exceptional cases occur, of course, in every branch. An artillery officer became the first High Commissioner in Egypt, the cavalry can at this moment shew a Chancellor of the Exchequer and a Governor General of Canada. Another is a banker and was a member of the Coal Commission. But the system of training adopted for cavalry officers does not aim at fitting them for positions of this sort, and the training of engineer officers, though it does aim at producing a versatility which will render them adaptable to any work that confronts them, is nevertheless directed primarily at fitting them for their task in war. The question of specialism is one that puzzles a good many officers. It is undoubtedly, as Major Kerrich says, a relative term. On what all-round efficiency means he is not equally clear. He rightly shows that the military engineer cannot hope to become a specialist in the terms that would be understood in the civil engineering world. Nor is such a degree of specialism necessary. He does not, however, apply the same test to the definition given of the average all-round officer. Are not "first-class engineer and first-class soldier" also relative terms? What did the speaker whom he quotes mean by them? Did he mean that he should be as highly skilled in engineering as the best civil engineers of the day, and in soldiering as the most eminent and experienced soldiers? Obviously not; we all have a tendency to speak in superlatives, especially when decoyed into speaking in public. It is a little unkind to take a phrase without its context and hang an essay on it. Probably the speaker really meant "a thoroughly good engineer and a thoroughly good soldier."

Major Kerrich would have us abandon the idea that the average R.E. officer should be an all-round engineer. His reason is that this ideal is so high as to be discouraging. It certainly is if we tack on the qualifying epithet of "first-class" to it, and mean by it that he is to be practically a specialist in every branch of engineering. We are brought back to the necessity for defining what we mean by "first-class," and by "specialism."

The requirement for a regular military engineer, whose function, as I have said before, is to serve his country by organising and superintending the engineering services required by the army in war, is quite different from that of a civil engineer, whose aim in life is to make a competence—a fortune if possible—by the practice of civil engineering in peace. Modern developments force the latter to be a specialist, but the army does not require more than a few of its *regular* officers to be specialists. When it requires real specialists it can get them from civil life, but it requires from the majority of its regular engineers the capacity for dealing promptly and efficiently with the numerous minor engineering problems which arise in war, most of which are of a fairly simple nature. Above all, it requires from them the ability to improvise, to make the best use of limited, and often not very suitable, local resources. This requires a high standard of engineering training and a considerable all-round experience, both of which are incompatible with real specialism.

There is much similarity between the army's need of engineers and the ordinary citizen's need of doctors. Our everyday doctor is a "general practitioner." He can deal with the common colds, the children's whooping cough, measles etc., also with smallpox, typhoid, and all the normal everyday diseases, he can superintend the confinement of our wives and can also set broken limbs, treat wounds and accidents and perform minor surgical operations. But many cases arise when our general practitioner advises his patients to call in a specialist. The specialist may be required to diagnose obscure symptoms, to effect a special treatment, or to carry out an operation. The general practitioner does not pretend to be "first-class" at every branch of the medical and surgical arts, nor does the existence of numerous lines of specialism in the slightest degree lessen the necessity for "general practitioners." To divide the whole medical profession into specialists only and abolish the general practitioner would be most embarassing for the ordinary citizen, who when he had a pain would not know whether to send for his heart specialist or his stomach specialist. It would be more embarrassing still for the military commander when he wanted a bridge to find that his only engineer officer was a tunnel specialist. Or when he required a pumped water supply, to be told that the C.R.E. was only a construction specialist.

Major Kerrich proposes the adoption of the ideal of a "First-class Constructional (or Railway, Survey, or E. and M.) Engineer and First-class Soldier," instead of "First-class Engineer, etc." In other words he proposes a complete system of specialism. He bases this proposal on statistics of the peace employment of the officers of the Corps. But engineers are trained for war duties primarily, peace duties are quite secondary. Moreover statistics are notoriously dangerous things to quote from. It is said that they can be made to prove anything. From the table quoted by Major Kerrich it appears that—omitting the officers under instruction—the specialists, *i.e.*, E. and M., Railway and Survey officers, number 132 out of a total of 872, or 15 per cent. Those employed on "Works" are 302 out of 872, or 35 per cent. There is, however, no division at all between those employed on Works and those on Staff, Units, Military Schools and Miscellaneous. All these officers are interchangeable, even in peace.

Many of those now employed on Works and other duties have during their career in peace and war been employed (or will be), on Railway and Surveys, and the duties of Works officers often include E. and M. work of many kinds.

Railway operation may be specialism, but Railway Construction is not; it is just ordinary engineering like any other. Every R.E. officer must be capable of carrying out surveys of the sites, often in undeveloped and tropical countries, of the engineering works, roads, etc., which he is going to construct. The mechanical and electrical requirements of the army in the theatre of war are getting greater every year. For the military engineer the various branches of engineering cannot be kept separate. A single job may embrace several of them, and all officers must be capable of interchange freely between the various kinds of work, according to whatever is the dominant need of the moment and the place. There is no parallel with civil life, and officers considering the question of their careers require to remember that they are soldiers, not merely engineers, and that they must look at the question from the point of view of what the army needs of them, and not only of what will best satisfy their personal tastes or ambitions. If the army mainly wants "general practitioners" their training should as far as practicable prepare them for this end. It is in no way an impossible ideal. If doctors can reach it so can engineers. Great numbers of military engineers have reached it in the past, and if it be said that engineering is more technical to-day than it was, it can also be said that the standard reached by the training of our young officers is higher.

RAISING WATER FROM DEEP WELLS.

By MAJOR R. CHALMERS BLACK, R.E. (T.A.).

In the interesting Professional Note in the March issue of the Journal, details are given of a proposed method of pumping from deep wells, using a P.E. lorry to supply the power. Two sizes of pump are dealt with, of which the smaller is certainly within the capacity of the standard P.E. lorry. The larger (5½") pump would however, seem to call for more power than is ordinarily available from a P.E. lorry.

Assuming the usual efficiency (say 84%), the pump motor would take 330 amperes with 110 volts at the motor terminals. Allowing a 5-volt drop in the cable, the required output of dynamo and engine would be 38 kw. and 60 b.h.p. respectively. The pump water horse power is 22.7, showing an apparent efficiency of 57%, which includes all losses in pipes, valves and strainer. Whilst this efficiency can doubtless be attained on the test bed, it is doubtful if 50% would be exceeded in ordinary work from day to day. At 50% efficiency, the motor h.p. would be 45, equivalent to, say, 43 kw. and 68 b.h.p. at the dynamo and engine.

It is understood that the 'acceptance' figures for the P.E. lorry are 24 kw. and 50 b.h.p., from which it would appear that the 5½" pump would seriously overload the generating plant. The use of two P.E. lorries connected in parallel (or in series with a 220 volt motor) would seem to be impracticable on account of the peculiar field circuits employed on these lorries. It is for consideration however, whether an electrically driven pump is justified for use in the field and whether equally good results may not be attained at much less cost by driving the pump by means of a directly coupled petrol engine, the whole set being slung in the well as in the case of the motor driven pump. Certain difficulties present themselves in connection with operating an I.C. engine in such a position, but these difficulties are by no means insuperable. A suitable type of engine for this purpose would be that fitted to the 25 cwt. Morris lorry. This engine, which developes 35 b.h.p. at 2,000 r.p.m., measures about 2' 0" in length, over all, and, when coupled to the pump, the whole set should not exceed 3' 6" in length.

A special casting bolted to the flywheel casing would carry the pump casing, and totally enclose the coupling, which would conveniently be of the fabric disc type, connecting the engine clutch studs to a spider keyed to the pump shaft. A coil and distributer in place of the magneto would facilitate starting. A bye-pass on the rising main would furnish cooling water. The coupled set would be built into a cage or framing which would also carry the starter battery, the roof of the cage forming a platform from which the engine could be turned by hand, by means of a chain drive from the engine to the starting handle on the platform. Ordinarily the engine would be started by means of the self starter. As the drop in volts in the starter cable, if carried to the surface, would be prohibitive, some form of remote control for the starter switch would be essential. Probably a rope or wire from the switch to the well head would be all that would be necessary.

It is agreed that the duty would be a fairly arduous one for the engine, but as the cost of the engine (about £70 or £80) is moderate, and as it is made in quantity, frequent renewal would be less costly than the capital charges involved in having a P.E. lorry standing by driving an electrical pump. The weight of the engine-driven pump would be less than that of an electrical pump, whilst the consumption of petrol and oil would be at least 40% less.

The diameter of the well will, in general, restrict the choice to a 4-cylinder engine, which in turn will limit the power to something like 40 to 50 h.p. at 2,000 r.p.m. There are of course, 4-cylinder engines made capable of developing over 100 b.h.p., but this power is given off at 3,000 or 4,000 r.p.m.

If special circumstances make it necessary to use over 50 or 60 h.p. in a well of small diameter, the use of an engine of the radial type would be worth considering. An eleven-cylinder engine of this type having a bore and stroke of 80 x 125 mm. should develop over 100 b.h.p. when run at 2,000 r.p.m., the extreme diameter over the cylinder heads not exceeding 3′ 6″.

This type of engine has been developed considerably, chiefly as an air cooled unit, for aeroplane work, but, doubtless, a water cooled set could be built mainly from standard engine parts, and which would provide the maximum power within the limitations of space. It is probable, however, that the type of engine fitted to the 30-cwt. subsidy lorry would provide sufficient power for the very large majority of wells. It is, of course, most desirable to use an engine of which large supplies are available and which can be readily adapted for use with the minimum of alteration and special parts.

Placing the motor, of whatever kind, at the water level introduces certain complications, and as inspection is difficult, the plant is likely to suffer from neglect. For this reason, the bore-hole type of centrifugal pump, in which the power is transmitted to the pump by means of shafting passing down through the rising main, would seem to merit serious consideration as a pump for semi-portable use in the field. An interesting form, made by Messrs. Mirrlees, Watson and Co., Ltd., Glasgow, has shaft bearings of rubber, lubricated by the water in the rising main.

This type of pump, suitably modified for use in the field, would seem to be preferable in all respects to any form of pump having the driving motor at, or near, water level.

THE RELATION BETWEEN DECKING AND ROADBEARERS IN MILITARY BRIDGES.

By CAPT. H. A. BAKER, M.C., R.E.

Judging by the information obtainable from the various military text books this is a subject that has not received the consideration it deserves. It is, however, one of great importance to the military engineer when designing bridges for heavy military loads.

In civilian practice there are certain rules which lay down a definite relationship between the stringers and the flooring for highway bridges for various classes of load. In designing military bridges the problem is closely analogous to that of the civilian bridge if an R.S.J. bridge is compared to the span between the cross girders of a girder bridge. There are to be found in certain text books tables giving the spacing of joists and the thickness of decking for various classes of load. These allow for a concentrated wheel load with or without the addition of a distributed load on the remainder of the bridge. Unfortunately, these tables are worked out for different classes of loading, and although useful for comparison do not give the actual figures required.

Military bridges are almost invariably designed for single line traffic, and the problem, therefore, has to be worked out for a single axle load in various positions.

It is laid down that bridges for mechanical transport should be 10′ wide between wheelguides, and that not less than 8′ is required for infantry in fours. A 3-ton lorry with a wheel track of 6′ 7″ can thus wander 3′ 5″ from either wheelguide. This brings up the problem of the number of roadbearers and the thickness of decking required. If, in a particular case, the number of roadbearers required to resist the Maximum Bending Moment were calculated in the usual way, it might be found that perhaps 4 or 5 were required. Considering the arrangement of these, if only two were placed under each wheel, the decking would have to be very thick to distribute the load sufficiently evenly to both roadbearers with the lorry in the most eccentric position.

In practice it will usually be found necessary to increase the number of roadbearers found by calculation, and to provide decking stiff enough to ensure that no roadbearer is overstressed under the worst conditions.

There is an alternative when material is scarce, which consists in cutting down the width of the roadway to, say, 8′, and grouping the roadbearers directly under the wheels. In this case the decking can be quite small provided it is strong enough to carry Infantry in fours, horses, etc., which may come between the roadbearers. It is desirable to provide a footwalk alongside, so that individuals can cross the bridge while wheel traffic is on it. It will be necessary to provide very strong wheelguides, and to arrange them at the approaches so that vehicles cannot get on the wrong part of the bridge. The disadvantage of this method is that traffic is slowed up considerably in crossing the bridge, which is not desirable.

Let us take an example, and investigate the ways in which roadbearers and decking may fail.

Suppose by calculation for Mff. it is found that two R.S.J.'s are required to support each wheel of a vehicle.

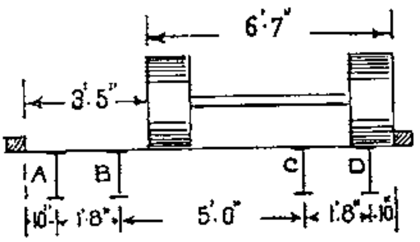


FIG. 1.

Referring to Fig. 1, the R.S.J.'s might be arranged as shown. With the vehicle in this position what are the proportions of load borne by the joists and what is the Maximum Bending Moment and shear in the decking? It will be quite evident from an inspection of the figure that joist D is bearing a large proportion of the load. If it is only capable of taking half a wheel-load, it will be considerably overstressed. The decking is also subjected to a large bending moment in distributing the load to the joists. It is clear that this arrangement is unsuitable unless the joists are strong enough to carry the proportion of the load that comes on them in this position of the load, or the decking is stiff enough to distribute nearly half a wheel-load to joists A and C. To effect this the decking would have to be so thick as to be quite impracticable.

The decking may also fail by Bending Moment in the position shown in Fig. 2, or shear in the position shown in Fig. 3.

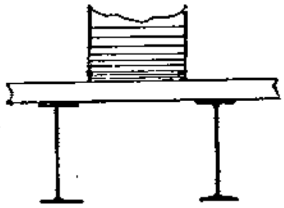


FIG. 2.

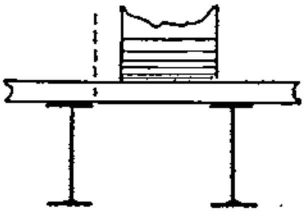


FIG. 3.

The calculation of the actual percentage of wheel-load borne by any one joist is of a complicated nature, depending on deflections, and is quite impracticable in the field. The object of this paper is to deduce from calculations and practical tests some standard methods of arranging roadbearers which will be useful as a guide in designing bridges for military loads.

It is proposed, therefore, to work through one example by calculation to show the method in which the table on page 484 has been compiled. The references in the table to practical tests refer to tests carried out at Christchurch and Chatham, and the figures will be seen to bear out the theory fairly well. The differences are due to the following causes:—

1. Firmly fixed ribands tend to distribute the load through the decking.

2. Timber is an unreliable material and the Modulus of Elasticity varies considerably in each piece. The figure chosen is an average one.

3. Although a timber beam may begin to shear along the grain this may not cause immediate failure; this is due to the fact that timber is an unhomogeneous material; its strength in shear along the grain is much less than in shear across the grain. The effect is that, although it may begin to split at the ends where shear is greatest, this does not reduce the section to resist vertical shear. It does reduce the resistance to bending, but the point of maximum shear does not coincide with the point of maximum bending moment except in the case of a cantilever. Hence, if the split does not go too far, the beam may still be able to support the load if it has been correctly designed for Bending Moment. It will thus be seen that, provided the figures for vertical shear and for bending are not exceeded, the beam will probably be safe enough for this class of work. Experience is valuable in such cases and in applying theory to practical design it must be used to aid the designer. If a piece of decking does crack badly it can easily be replaced.

Example.—Calculate the maximum percentage of a wheel-load borne by any one joist and the Bending Moment and Shear in the decking for conditions shown in Fig. 4.

It will be evident that the maximum percentage borne by one joist will occur in the position shown in Fig. 4. The example is, therefore, worked out for this position of the load. The arrangement shown is that chosen for the old stock spans of 21′ 6″ and 30′. No

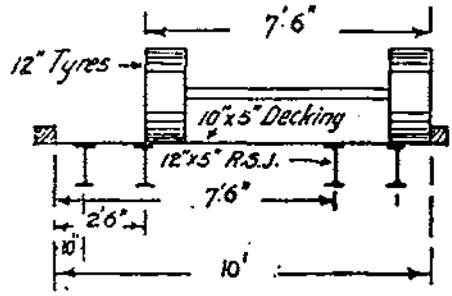


FIG. 4.

practical figures are available for this case, but the example with 5 joists is too complicated to include here. The results are, however, shown in the table. The calculation is worked out in more or less general terms as in Fig. 5 and the figures for a particular case inserted afterwards.

This arrangement will bring maximum stress into the joist S.

The following data are known in addition to those shown on Fig. 5.

Span of joists	$=a$
Modulus of Elasticity for joists	$=E_1$
,, ,, for decking ..	$=E$
Moment of Inertia joists	$=I_1$
,, ,, decking..	$=I$

The only departure from a general case is that, to save endless figures, it is assumed that the axle is in the position shown against one wheelguide and that l_1 is less than b, which is less than l_2 and that $b+c$ is greater than l_3.

Now if P, Q, R, S, are the reactions of the respective R. S. J., and δ_1, δ_2, δ_3, δ_4 the deflections at these points as loaded in Fig. 5.

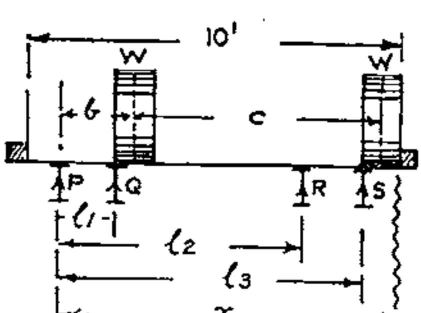


FIG. 5.

Then from Statics.

$$P + Q + R + S = 2W \quad \ldots\ldots (1)$$

$$Ql_1 + Rl_2 + Sl_3 = W(2b + c) \quad \ldots\ldots (2)$$

Then the B.M. in the decking at any point x measured from $P = Mx = -\frac{EId^2y}{dx^2}$

and hence $\frac{-EId^2y}{dx^2} = Px + Q(x-l_1) + R(x-l_2) + S(x-l_3) - W(x-b) - W(x-b-c) \ldots (3)$

The terms in brackets are to be neglected when negative and integration is to be made with respect to $(x - l_1)$; $(x - l_2)$, etc.

Then integrating both sides of equation (3) we get

$$\frac{-EIdy}{dx} = \frac{Px^2}{2} + \frac{Q}{2}(x-l_1)^2 + \frac{R}{2}(x-l_2)^2 + \frac{S}{2}(x-l_3)^2 - \frac{W}{2}(x-b)^2 - \frac{W}{2}(x-b-c)^2 + A$$

and

$$-EIy = \frac{Px^3}{6} + \frac{Q}{6}(x-l_1)^3 + \frac{R}{6}(x-l_2)^3 + \frac{S}{6}(x-l_3)^3 - \frac{W}{6}(x-b)^3 - \frac{W}{6}(x-b-c)^3 + Ax + B \quad (4)$$

Now the deflection of a joist length a under a load P at the centre is $\frac{a^3}{48E_1I_1}P = d_1$

Therefore $-EId_1 = \frac{-a^3EIP}{48E_1I_1} = B$ (substituting $x = 0$ in (4)) ....(5)

Similarly $-EId_2 = \frac{-a^3EIQ}{48E_1I_1} = \frac{Pl_1^3}{6} + Al_1 + B$ (substituting $x = l_1$ in (4)) (6)

and $-EId_3 = \frac{-a^3EIR}{48E_1I_1} = \frac{Pl_2^3}{6} + \frac{Q}{6}(l_2-l_1)^3 - \frac{W}{6}(l_2-b)^3 + Al_2 + B$ (7)

and $-EId_4 = \frac{-a^3EIS}{48E_1I_1} = \frac{Pl_3^3}{6} + \frac{Q}{6}(l_3-l_1)^3 + \frac{R}{6}(l_3-l_2)^3 - \frac{W}{6}(l_3-b)^3 + Al_3 + B$ (8)

For simplicity write $\frac{a^3EI}{48E_1I_1} = F$

Then substituting in (6) for B we get $FQ + \frac{Pl_1^3}{6} + Al_1 - FP = 0$

whence $A = \frac{P}{l_1}(F - \frac{l_1^3}{6}) - \frac{FQ}{l_1}$ ....(9)

Substituting for A and B in (7) and (8) we get

For (7) $FR + \frac{Pl_2^3}{6} + \frac{Q}{6}(l_2-l_1)^3 - \frac{W}{6}(l_2-b)^3 + \frac{Pl_2}{l_1}(F - \frac{l_1^3}{6}) - \frac{Fl_2}{l_1}Q - FP = 0$

and collecting terms

$$FR + P\left\{\frac{l_2^3}{6} + \frac{l_2}{l_1}(F - \frac{l_1^3}{6}) - F\right\} + Q\left\{\frac{(l_2-l_1)^3}{6} - \frac{Fl_2}{l_1}\right\} - \frac{W}{6}(l_2-b)^3 = 0$$

For simplicity write $\left\{\frac{l_2^3}{6} + \frac{l_2}{l_1}(F - \frac{l_1^3}{6}) - F\right\} = V$

$$\frac{(l_2 - l_1)^3}{6} - \frac{Fl_2}{l_1} = X$$

$$\frac{(l_2 - b)^3}{6} = Y$$

Then $FR + VP + XQ - YW = 0$ ....(10)
and for (8)

$$FS + P\left\{\frac{l_3^3}{6} + \frac{l_3}{l_1}(F - \frac{l_1^3}{6}) - F\right\} + Q\left\{\frac{(l_3-l_1)^3}{6} - F\frac{l_3}{l_1}\right\} + \frac{R}{6}(l_3-l_2)^3 - \frac{W}{6}(l_3-b)^3 = 0$$

For simplicity write
$$\left\{\frac{l_3^3}{6}+\frac{l_3}{l_1}(F-\frac{l_1^3}{6})-F\right\}=Z$$
$$\frac{(l_3-l_1)^3}{6}-\frac{Fl_3}{l_1}=H$$
$$\frac{(l_3-l_2)^3}{6}=K$$
$$\frac{(l_3-b)^3}{6}=M$$

Then $FS+ZP+HQ+KR-MW=0$ ....(11)

Now from (1) $P=2W-Q-R-S$

and from (2) $Q=\frac{W(2b+c)}{l_1}-\frac{Rl_2}{l_1}-\frac{Sl_3}{l_1}$ ....(12)

Hence $P=W(2-\frac{(2b+c)}{l_1})+R(\frac{l_2}{l_1}-1)+S(\frac{l_3}{l_1}-1)$ ....(13)

Substitute for P and Q in (10) and (11). (10) becomes

$$FR+VW(2-\frac{2b+c}{l_1})+VR(\frac{l_2}{l_1}-1)+VS(\frac{l_3}{l_1}-1)+XW\frac{(2b+c)}{l_1}-\frac{XRl_2}{l_1}-\frac{XSl_3}{l_1}-YW=0$$

$$\text{or } R\left\{F+V(\frac{l_2}{l_1}-1)-\frac{Xl_2}{l_1}\right\}+S\left\{V(\frac{l_3}{l_1}-1)-\frac{Xl_3}{l_1}\right\}+W\left\{V(2-\frac{2b+c}{l_1})+X\frac{2b+c}{l_1}-Y\right\}=0$$

Writing
$$F+V(\frac{l_2}{l_1}-1)-\frac{Xl_2}{l_1}=\alpha$$
$$V(\frac{l_3}{l_1}-1)-\frac{Xl_3}{l_1}=\beta$$
$$V(2-\frac{2b+c}{l_1})+X\frac{2b+c}{l_1}-Y=\Delta$$

This becomes $\alpha R+\beta S+\Delta W=0$ ....(14)

(11) becomes

$$FS+2W(2-\frac{2b+c}{l_1})+ZR(\frac{l_2}{l_1}-1)+ZS(\frac{l_3}{l_1}-1)+HW\frac{2b+c}{l_1}-\frac{HRl_2}{l_1}-\frac{HSl_3}{l_1}+KR-MW=0$$

$$\text{or } R\left\{Z(\frac{l_2}{l_1}-1)-\frac{Hl_2}{l_1}+K\right\}+S\left\{F+Z(\frac{l_3}{l_1}-1)-\frac{Hl_3}{l_1}\right\}+W\left\{Z(2-\frac{2b+c}{l_1})+H\frac{2b+c}{l_1}-M\right\}=0$$

Writing
$$\left\{Z(\frac{l_2}{l_1}-1)-\frac{Hl_2}{l_1}+K\right\}=\theta$$
$$F+Z(\frac{l_3}{l_1}-1)-\frac{Hl_3}{l_1}=\phi$$
$$Z(2-\frac{2b+c}{l_1})+H\frac{2b+c}{l_1}-M=\rho$$

This becomes $\theta R+\phi S+\rho W=0$ ....(15)

Solving (14) and (15) for R
$$R(\alpha\phi-\theta\beta)+W(\Delta\phi-\rho\beta)=0$$

or $$R=-\frac{(\Delta\phi-\rho\beta)}{\alpha\phi-\theta\beta}W \quad\text{.......................(16)}$$

and solving for S

$$S = -\frac{(\Delta\theta - \rho\alpha)}{\beta\theta - \alpha\varphi}W \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

and P and Q can be found by substitution in (1) and (2).

The particular case under consideration can now be taken. It is not proposed to show the working as it is too laborious. It is merely a matter of substituting figures for the various symbols taken. The arrangements are as in Fig. 4. The decking is 10″ x 5″ and the R. S. J's are 12″ x 5″.

The various data then become.

$a = 21' = 252''$
$I_1 = 220.115$ Ins.^{4}
$E_1 = 13400$ In. tons units.
$I = 104.17$ Ins.^{4}
$E = 811$ In. tons units.
$l_1 = 20$ in.
$l_2 = 80$ in.
$l_3 = 100$ in.
$b = 26$ in.
$c = 78$ in.

By substitution in the above formula

$P = 20.8\%$ W
$Q = 48.7\%$ W
$R = 51.3\%$ W
$S = 79.2\%$ W

For the purpose of finding the maximum percentage of wheel-load to be borne by the joist S with varying spans, decking and joists, but for the same arrangement of joists and the same wheel-track, the formula can be reduced to

$$S = \frac{52F^2 + 0.4831 \times 10^6F + 986.8 \times 10^6}{68F^2 + 0.6187 \times 10^6F + 880 \times 10^6} \times W$$

The value of F being $\dfrac{a^3EI}{48E_1I_1}$

Bending Moments in Decking.

The Maximum Bending Moment in the decking can now be determined by substituting for P, Q, R, and S, in equation (3) for Bending Moment previously found. Shear can be written down at once, P, Q, R, and S being known.

The results so obtained are shown in the graph.

From this it will be seen that *Mff* is 8.33 W, and the Maximum Shear is 0.305 W for the wheel in this position.

Assuming these are the maximum figures arising from this consideration, the Bending Moment and Shear in the decking when a wheel is directly between two joists should now be calculated (Fig. 6).

This is determined as follows.

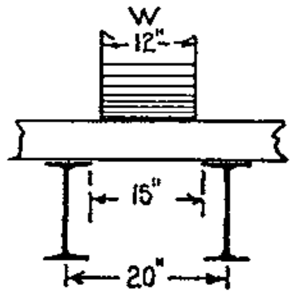


FIG. 6.

Assuming the unsupported length of decking is 15 in. (between edges of flanges), and assuming a 12 in. wheel centrally placed.

$$\text{B.M.} = \frac{W}{2} \times \frac{15}{2} - \frac{W}{2} \times 3 = \frac{9}{4} W = 2.25 W. \text{ In. tons.}$$

The shear should be calculated with the load as in Fig. 7, with the

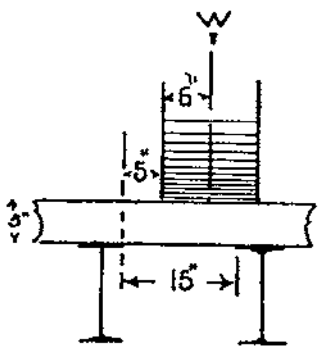


FIG. 7.

edge of the wheel a distance equal to the thickness of the decking from the edge of the flange. If it is any nearer, the decking is found in practice not to shear, owing to the distributive effect of the fibres.

Assuming 5" decking, shear will be seen to be negligible as this arrangement brings the edge of the wheel directly over a joist.

If the vehicle under consideration has narrow tyres this may be the deciding factor.

Referring to the B.M and shear diagram :—

The Maximum Shear is taken where a 12" wheel is not directly over any part of a joist. The shear diagram is made for a concentrated load, but with a 12" wheel it is obvious that the wheel will relieve the decking of shear if any part of it is over a joist. The maximum shear taken is, therefore, 0.305 W, not W.

Now find what W can be with the 10 in. × 5 in. decking chosen. Mr of 10 in. × 5 in decking, assuming pitch pine $= \frac{1}{6}rbd^2 = \frac{1}{6} \times \frac{3}{4} \times 10 \times 25 = 31.4$ In. tons.

$$Mff = 8.33\text{W In. tons from graph.}$$

$$\text{Hence} \quad W = \frac{31.4}{8.33} = 3.73 \text{ tons approximately.}$$

And the axle load can be 7.5 tons.

$$\text{Resistance to shear along the grain} = \frac{10 \times 5 \times 150}{2240} = 3.36 \text{ tons.}$$

$$\text{Maximum shear} = 0.305\text{ W from graph.}$$

$$\text{Hence} \quad \text{W can be } \frac{3.36}{0.305} \times \frac{2}{3} = 7.35 \text{ tons.}$$

or an axle load of 14.7 tons.

A joist has to take 0.792W in the worst case + a proportion of the dead load. The weight of one joist and a proportion of the decking is 1672 lbs.

$$\text{Hence the B.M. on a joist is } \frac{0.792W \times 21 \times 12}{4} + \frac{1672 \times 21 \times 12}{8 \times 2240} \text{ In. tons}$$

$$\therefore \text{Section Modulus required is } \frac{0.792W \times 21 \times 12}{4 \times 7.5} + \frac{1672 \times 21 \times 12}{8 \times 2240 \times 7.5} \text{ — Ins.}^3$$

The Section Modulus of one 12 in. × 5 in. joist is 36.66 Ins.^{3}

$$\text{Hence } W = \left(36.66 - \frac{1672 \times 21 \times 12}{8 \times 2240 \times 7.5}\right) \frac{4 \times 7.5}{0.792 \times 21 \times 12} = 5 \text{ tons.}$$

Allowing for an Impact factor of 50%, W $= 3\frac{1}{3}$ tons.
or an axle load of $6\frac{2}{3}$ tons.

It will thus be seen that the joists are the deciding factor but that decking and joists are of nearly equal strength. The bridge, therefore, is suitable for Medium Loads ($5\frac{1}{2}$ ton axle).

The Maximum Axle according to the calculations is $6\frac{2}{3}$ tons, but this arrangement would be safe for 8 ton axles (Fodens) in practice. The factor of safety throughout is 4, and, as the load is unlikely to be in this extreme position frequently, there is little risk in reducing the factor of safety to 3.65 for this contingency.

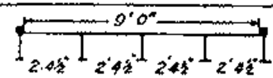
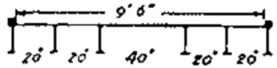
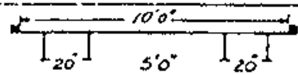
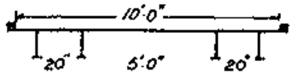
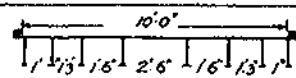
It will be noticed that no Impact Factor is included for the decking. In practice, if a lorry is moving at a speed sufficient to produce Impact, the load on any one piece of decking will only be of very short duration, and it is safe to neglect impact in temporary work.

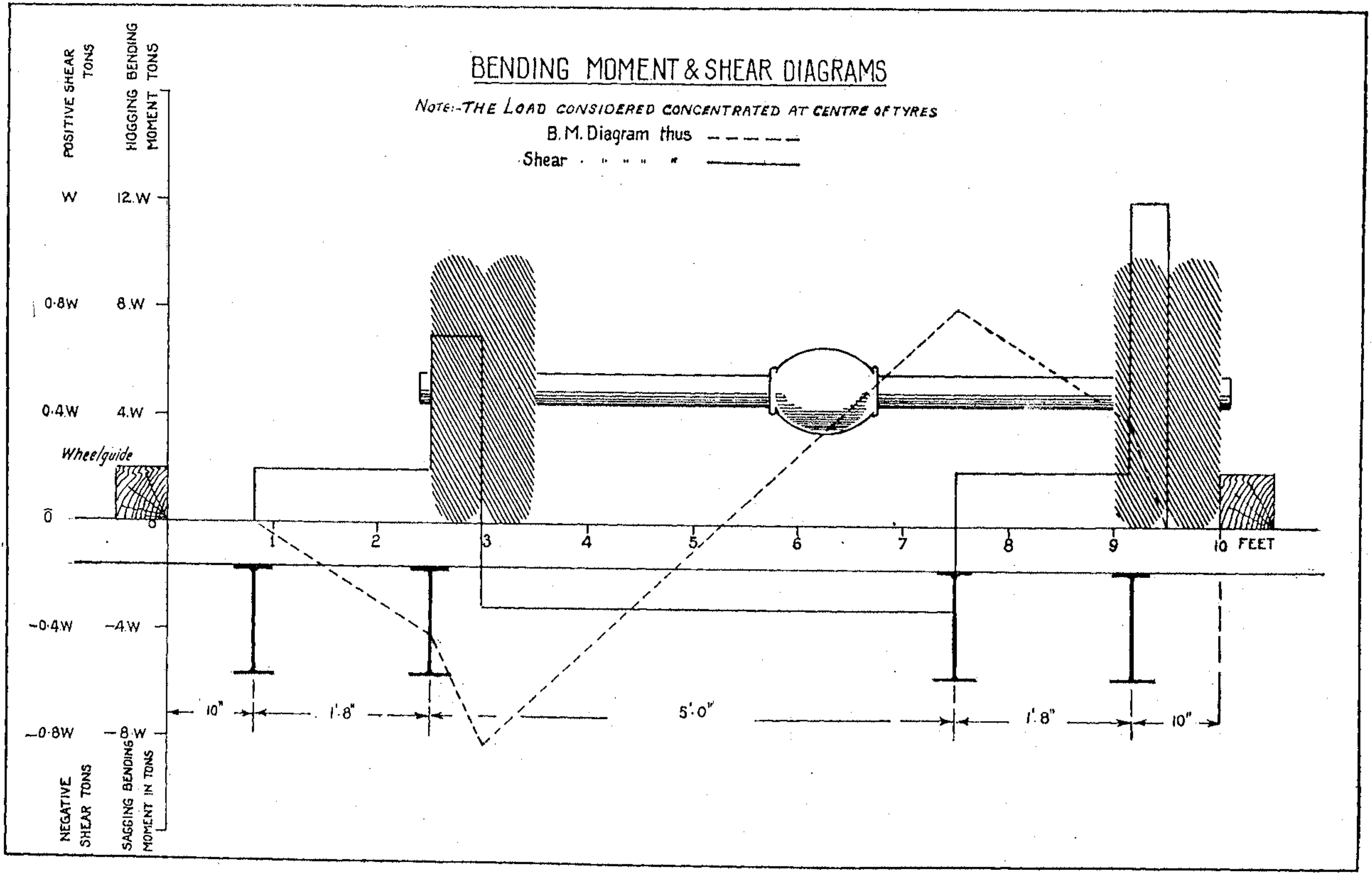
In calculating decking it has been found from experiments that the figures for Group I timber can be taken with safety for any good class building timber, as the conditions met with in practice modify the factors assumed in calculation and tend to make calculated results very much on the safe side if the smaller figures are used.

As an instance of the importance of this calculation a case from the last war may be of interest. A certain bridge in France decked with ordinary $1\frac{1}{2}''$ chesses was crossed by a pontoon wagon well loaded with souvenirs and baggage. The result was that every single chess was broken as the wagon crossed, just holding the load long enough to let the wheel get on to the next chess without going through.

The above results show how important it is to provide decking sufficiently stiff to distribute the load to the joists in the bridge,

TABLE SHOWING SIZE OF DECKING & NUMBER & SIZE OF ROADBEARERS SUITABLE FOR VARIOUS SPANS & CLASSES OF LOADING

LOADING	DISTANCE BETWEEN WHEEL GUIDES	SIZE OF DECKING	CLEAR SPAN	ARRANGEMENT OF ROADBEARERS	SUITABLE SIZE OF R.S.J.	MAX % OF AXLE LD BORNE BY ONE JOIST (APPX)	REMARKS.
Two Ton Axles	9' 0"	12" x 1½"	9'		5"x3"	42	Percentages approximate, and derived from calculation and practical tests on similar types of bridge. 3" Decking would reduce this to about 30%.
" "	9' 0"	12" x 1½"	15'	do	8"x4"	40	
Medium 5½ Ton Axles	9' 6"	9"x3"	20'		9"x4"	25	% Deduced from practical tests supported by calculation. Tests with double 12" x 1½" decking & No 7 - 6"x3" N.C. Joists equally spaced over 21' span gave 22.8%.
" "	9' 6"	9"x3"	26'	do	10"x 4½"	26	
Medium 5½ Ton Axles	10'	10"x5"	24'		12" x 5"	40	Calculated.
Heavy 16 Ton axles	10'	10"x5"	24' / 29'		18"x 6" / 20"x 6½"	41	Calculated with 16 Ton axle on 7' wheel track the factor of safety is rather low when in the extreme position. (Similar to old 30' stock spans which took 35 Ton Tanks up to 30' with 18"x7" joists.)
Ditto	10'	10"x5" or 9"x4"	20'		12"x 5"	18	Calculated approximately by analogy.


BENDING MOMENT & SHEAR DIAGRAMS
NOTE:-THE LOAD CONSIDERED CONCENTRATED AT CENTRE OF TYRES
B.M. Diagram thus
Shear " " " "
POSITIVE SHEAR TONS
HOGGING BENDING MOMENT TONS
W
12.W
0·8W
8.W
0·4W
4.W
Wheelguide
0
1
2
3
4
5
6
7
8
9
10 FEET
−0·4W
−4.W
−0·8W
−8.W
NEGATIVE SHEAR TONS
SAGGING BENDING MOMENT IN TONS
10"
1'.8"
5'.0"
1'.8"
10"

and show that it is not sufficient to calculate the number of joists required to carry the load, assuming each to take an equal share, if the load is allowed to wander about the bridge.

With smaller loads, where the tyres are narrower than 12", the deciding factor may be shear when the wheel is between two joists.

It is manifestly impracticable for anyone to sit down and make calculations of this nature in the field. It is hoped that this paper has shown the necessity for some guiding principles or rules in designing decking. The table opposite has been compiled partly from practice and partly from theoretical calculations, and shows suitable combinations of decking and joists in most of the cases likely to be met with. The percentage borne by each joist in the worst conditions is approximate only, and in some cases arrived at by interpolation, as the calculations are too laborious. These arrangements can be modified to suit other conditions provided that the principles involved are understood.

The author is indebted to Mr. J. W. Landon, M.A., for assistance with the theory on which these examples have been worked out.

MODERN PRACTICE IN E. AND M. ENGINEERING.

II.

MERCURY ARC RECTIFIERS.

By LIEUT. K. H. TUSON, R.E.

Owing to their lack of rotating parts and high efficiency, mercury arc rectifiers are coming and will come more and more into use for the conversion of alternating to direct current.

When an arc is struck between any two electrodes ionisation commences, and the current in the arc may be said to consist of a stream of electrons passing from the cathode to the anode.

To expel these electrons a certain minimum electromotive force is necessary, and a voltage drop occurs at the cathode. This e.m.f., known as the ionisation potential, depends on the material and temperature of the cathode and the degree of vacuum in which the arc takes place.

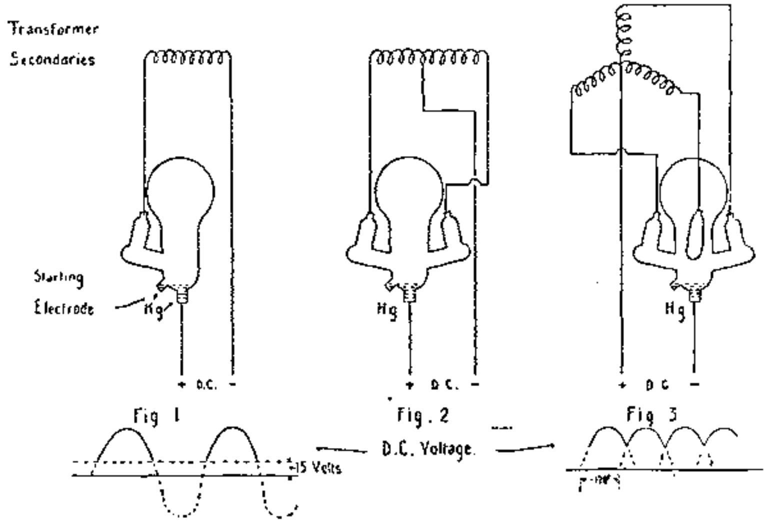
At atmospheric pressure and ordinary temperatures the ionisation potential for most materials is relatively small, but at low pressures it is considerable. Below about half a millimetre of mercury it is several thousand volts for a cold iron or carbon cathode, and only in the neighbourhood of six for mercury.

When an alternating pressure is applied between mercury and, say, carbon electrodes in an exhausted vessel, and an arc is struck, electrons are repelled from the mercury when it is at a negative potential, and attracted by the positive carbon. At the same time the comparatively massive mercury atoms, each minus an electron and consequently positively charged, are attracted back into the mercury, and their bombardment keeps it at a high temperature. The carbon electrode, being only bombarded by the light electrons (which weigh only 1/36,000 the positively charged atoms of mercury and have not a relatively greater velocity) remains cold, and will not emit electrons or function as a cathode.

Directly the carbon electrode gets hot (over 2,000 degrees) it will emit electrons and the valve action will cease.

With the arrangement shown in Fig. 1, a pulsating unidirectional current will flow, as in Fig. 1a. By using two anodes, and feeding the bulb as shown in Fig. 2, both halves of the a.c. wave can be utilised, but a break will occur twice in every cycle, as can be seen from Fig. 2a. This is due to the fact that the sinusoidal a.c. pressure drops below the minimum necessary to maintain the arc (about 15 volts) twice in every period.

A three-phase supply will be seen from Figs. 3 and 3a to give a unidirectional d.c. current without breaks, but a ripple is still present. The greater the number of phases, the smaller will this ripple be, one anode being necessary for each phase employed.



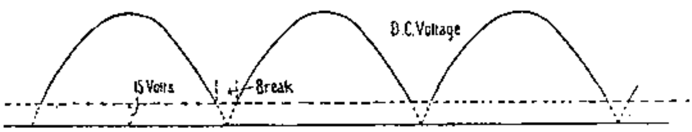


Figure 2a.

There is a constant relation between the a.c. and d.c. voltages, depending on the number of phases. Where this is three, the relation is $E_a = 1.6\ E_c + 24$, E_a and E_c being the a.c. and d.c. voltages respectively. The voltage drop in the bulb is from 15 to 20 volts, and decreases slightly after the bulb has been in use some time and the vacuum improves. For single phase circuits the relation is $E_a = 2.37\ E_c + 30$.

There are two main types of power rectifiers. For large outputs the arc is arranged to take place in a steel tank, and is usually supplied with six-phase current. Two stage vacuum pumps to maintain the vacuum have to be run continuously on all but light loads, thus introducing the complication of rotating machinery. Glass bulbs can be used for currents up to 200 amperes, and for outputs up to 1,000 kw. banks of these in parallel can be used. With these the whole apparatus is enclosed in cubicles with the switch controls in front, as can be seen from Figure 5. Most of the rest of this paper may be read as referring to these glass bulb rectifiers, the most useful type for military purposes.

Unfortunately a great number of elaborations are required before the simple theory can be put into practice. In the single phase circuit previously outlined the direct current passes through zero twice in every cycle, when the arc will extinguish and not relight. (It can be seen from figures 1a and 2a that the current does not only have an instantaneous zero value, but that there is a definite break from the moment at which the a.c. voltage falls below that necessary to maintain the arc—about 15 volts—to the moment at which it rises to this value again.)

To avoid this, an inductance must be placed in each anode circuit to choke back the falling current and keep the arc alight.* In a three-phase rectifier inductances are not necessary for this purpose, but they are found to be essential to secure an equal distribution of load among bulbs running in parallel. These inductances, of course, reduce the rectifier power factor. Then a choking coil must be placed in the d.c. circuit, as, however great the number of phases, there would always be too big a ripple without it for practical purposes.

In steel cased rectifiers an auxiliary anode is pulled into contact with the cathode to start the arc. Until very recently d.c. was necessary, and had to be provided for this purpose, but now a.c. can be used—a great advance.

Some arrangement must be made for starting the arc. This is done in the glass bulb type by tilting the bulb until the pool of mercury forming the cathode comes into contact with a pool forming an auxiliary anode. It is found also that the arc will not keep alight on low loads, and auxiliary anodes, making the equivalent of a small single phase rectifier and complete with inductances, have to be put in.

A fan is provided to blow air over the bulb for cooling purposes. When the anodes get hot enough for electronic emission the arc loses its usual property, and conducts in both directions, with the result that a "flash-over" occurs and the anode fuses blow. (As a matter of fact, flash-overs act as a safety valve and prevent bulbs breaking).

The best and most common method of providing voltage regulation is to connect an auto-transformer with tappings between the main transformer and the bulb. For traction loads this is unnecessary, as the inherent regulation of the bulb (about 7%) is sufficiently good. In automatic gear a small induction motor, controlled by voltage relays, works the tapping switches on the rectifier panels (see Fig. 5).

For all but very small outputs bulbs are used in pairs, connected in one of two ways:—

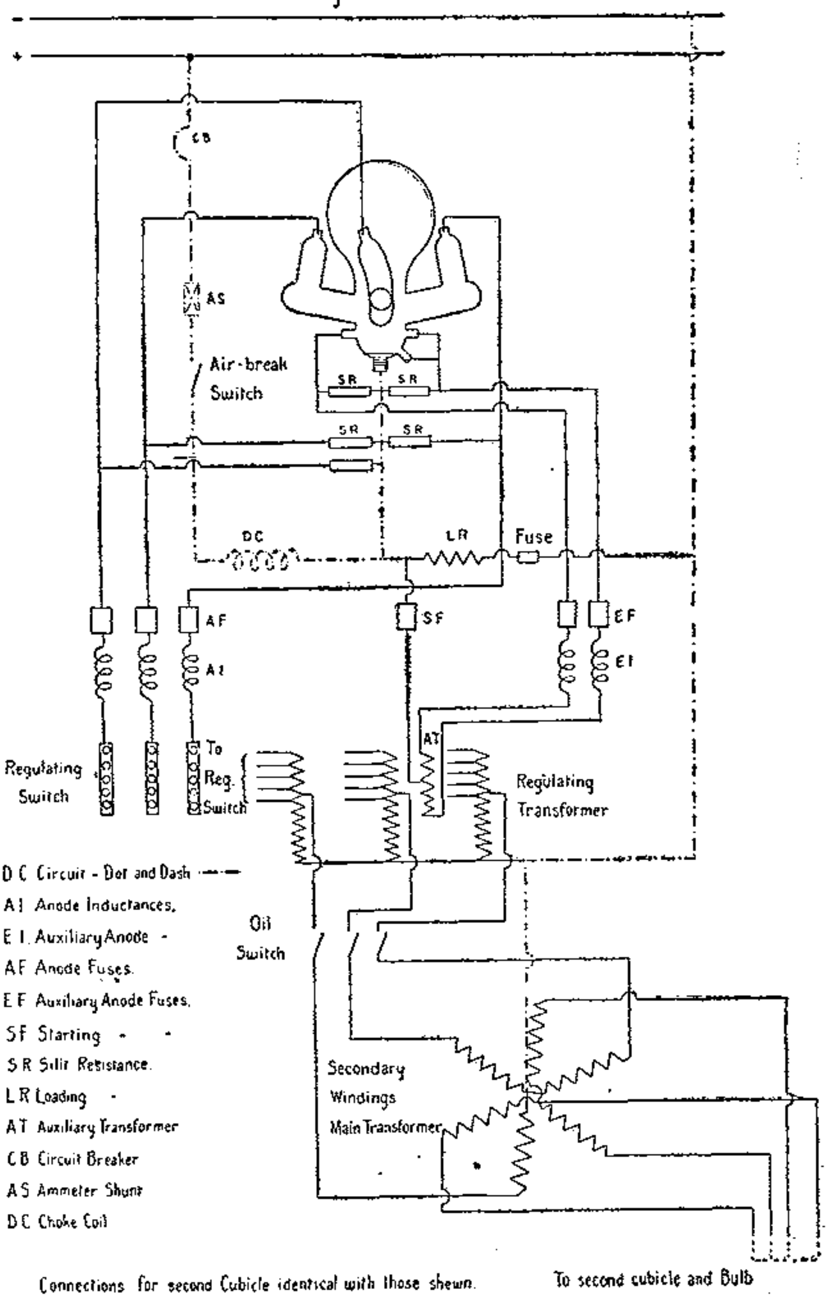
(*a*) The main transformer has a three-phase star-connected secondary winding supplying the regulating transformer, which supplies both bulbs in parallel.

(*b*) The main transformer has two secondary windings with

* See Appendix.

neutral points brought out separately. Each winding feeds one regulating transformer and bulb. The result is to give the equivalent of a six-phase supply, and consequently much less d.c. ripple and better power factor. Figure 4 shows the main connections for a typical example of this case. It is, of course, more expensive than (*a*).

Fig. 4.



Several points in this diagram require further explanation.

(1) The starting and auxiliary electrodes are connected through a relay and solenoid, neither of which is shown, to an auxiliary single phase winding on one limb of the auto-transformer, so that when the a.c. switch is closed the solenoid automatically tilts the bulb and starts the arc; and the auxiliary electrodes maintain it until the load rises sufficiently to bring the main electrodes into action.

(2) In every anode circuit a " silit " resistance, made of carbon, is fitted across the arc to damp out surges arising externally or internally. Surges often occur which, without these resistances would cause a flash-over.

(3) The fan is supplied with three-phase current from separate windings on the regulating transformer. It is brought into operation by a relay (not shown) when the load rises to about 30% of the bulb rating, and cut out when the load falls below this.

(4) For traction purposes where voltage regulation is less important the regulating transformer can be dispensed with; a small transformer only being necessary to supply the fan and auxiliary electrodes.

(5) When a bulb is under load the core of the d.c. choke coil is magnetically saturated, and a considerable voltage drop occurs in it. A current of 3 amperes is required to produce saturation, and when the load falls below this the voltage absorbed in the coil becomes of course very small, and a rise of about 15% in the d.c. busbar pressure would take place were not a loading resistance (LR in Fig. 4) provided and arranged to be brought into operation by a relay when the load falls off.

CHARACTERISTICS.

Efficiency. The main loss in a rectifier is occasioned by the voltage drop across the arc. This being constant, the power loss is proportional to the load, giving a nearly constant efficiency at all loads. Also, as this voltage drop is constant, the efficiency of a rectifier will rise as its supply pressure rises. With three wire d.c. distribution, therefore, rectifiers should always be put across the outers.

For a d.c. voltage of 550 the efficiency varies from 95% at full load to 90% at ¼ load, including transformer and all other losses. For a pressure of 400, the corresponding figures are 93% and 88%, while for 110 volts 81% is a fair full load efficiency.

Overload. Momentary overloads, such as occur on traction systems, cause no damage, but the overload performance of rectifiers is poor and can in no way be compared with that of other converting apparatus; even 10% for an hour being dangerous, causing overheating and possibly damage to bulbs.

Power Factor. With a three-phase system such as (*a*) on page 488, a value of .89 over all loads is usual. If a higher figure is required .93 — .94 can be obtained by using the six-phase arrangement.

Owing to the shape of the d.c. current wave, a rectifier has an inherent lagging power factor, quite apart from that caused by the use of reactances. When fed with six-phase alternating current this is .965, and cannot be improved by condensers. However, experiments have shown that when this current is superimposed on a lagging sinusoidal current, the resultant wave sometimes has a higher p.f. than either wave alone, and practical results may ensue from this discovery.

Bulbs. The vacuum obtained on manufacture is .003 mm. of mercury; the sealing off process is a more or less secret one. The vacuum improves with use, and if not overheated the life of a bulb should be indefinite, lives of 40,000 hours being reported from America.

In England many breakages occur in the first year after installation; in Birmingham, where a large number of rectifiers are in use, the *average* life to date is 8,000 hours. This figure can easily be improved upon; the bulbs at Birmingham are supplying an increasing load and running under exceptional conditions. Cracks usually occur where the anode wires are fused into the bulb.

The golden rule is to instal a large enough fan and to avoid overloading.

Regulation. As previously stated, the inherent regulation is about 7%. This is good enough for traction loads, but for lighting purposes a regulating transformer has to be provided.

Load sharing. It sometimes occurs that one bulb in a bank will not take its share of a light load. This failing is often due to the anode reactances of the various bulbs not having precisely the same value, but, when these have been checked and found to be correct, a cure may sometimes be effected by placing a metal band round one arm of the slow bulb and connecting it to the cathode. Presumably the action is analogous to the "grid" action in a thermionic valve.

Forming. With a steel cased rectifier the anodes have to be "formed," *i.e.*, subjected to a light load for fairly long periods, on installation and, except in the very latest types, reformed after being out of use for some time. Glass bulb rectifiers do not require this and can be switched straight on to full load.

Main Transformer. Paradoxical as it may appear, the secondary windings of a transformer to supply rectifiers have to be designed for, in the six-phase instance, 160% of the rectifier output. This is due to the fact that each phase in turn has to supply the whole d.c. output for that portion of each period during which the voltage in that phase is higher than in either of the other two. Consequently the alternating current wave form is much distorted, and the ratio of the root mean square to the average value is high.

Advantages.

(1) Their high efficiency at low loads is one of the main advantages of rectifiers. It is specially important for rapidly fluctuating loads and places where the load is growing and the load factor is low. Rotating converters under these conditions show an extremely poor efficiency.

(2) Simplicity. Starting up is done by closing one a.c. switch, and an automatic rectifier sub-station is far simpler than an automatic rotary one with starting and synchronising relays, and the rest.

(3) Low first cost and maintenance. The makers claim that rectifiers are cheaper than rotaries, but, for non-automatic stations of 500 kW. and over, it is not considered that this claim can be justified. The cost for both types of plant is at present about the same.

(4) Neatness. As can be seen from Figure 5, a rectifier sub-station presents a very neat appearance.

(5) Silence in running.

Disadvantages.

(1) Low overload capacity. As a result of this a bigger plant capacity must be installed with rectifiers than with rotaries, but this is largely balanced by the high efficiency of rectifiers at low loads.

(2) Reliability. It must be remembered that rectifiers, although in common and increasing use, are at present in the development stage, and not yet as standardized as rotary and motor converters.

(3) Telephonic interference. The peculiar shape of the d.c. wave has in some instances given serious trouble when mains have run close and parallel to trunk telephone lines. Where this has been unavoidable the trouble has after much experimenting been cured by introducing a resonant shunt (a condenser and reactance in parallel, and tuned to resonance with the troublesome harmonic) across the rectifier. It should be added that rotaries are by no means free from objectionable d.c. ripples.

Most of the usual troubles occur during the first six months of working, and it is believed that where the engineer is prepared to give the plant close attention and adjustment during this period it will afterwards prove satisfactory.

Bulbs are made in sizes up to a capacity of 200 amperes, and a voltage of 600. Small sizes can be had for any voltage.

Fig. 6 gives a view of two cubicles from the back, with their enclosing plates removed.

The cost of plant varies widely with the degree of automaticity and voltage regulation required; a three-phase arrangement is also considerably cheaper than a six-phase one, one regulating transformer being sufficient for two cubicles. The cost of the complete plant was in 1925 from £5 to £10 per kilowatt continuous output. Bulbs to carry 150 amperes were from £45 to £50 each.

It is of interest to note that the prices of equipment to supply the same current at 600 and at 200 volts are as four to three. Three times the power output at the lower voltage is thus obtained at the higher for an increase in capital cost of one-third. For this reason also, therefore, rectifiers are always put across the outers of three-wire systems, separate arrangements being made for balancing.

No trouble need be feared from vibration. Experiments were carried out at Woolwich, bulbs being suspended near 12-inch guns in action, but no breakages occurred.

Latest Developments.

The use of resonant shunts is mentioned elsewhere. English and German manufacturers are experimenting with (and will now quote for) plant embodying oil cooled bulbs, and delivering 500 amps. d.c. per bulb. The problem of oil cooling is different from that met with in transformer practice, as in the latter case there are no definite hot spots, such as the anodes and cathode, to interfere with convection currents.

Bulbs with six arms for six-phase supply have also been manufactured.

The writer would like to express his thanks to the Hewittic Electric Company for their courtesy in allowing him to visit their works and in supplying him with many of the figures in this article.

APPENDIX.

The action of the inductance is not very clear without analysis.

If $e = E \sin\theta$ is the E.M.F. applied to each anode circuit the current i at any instant is given by the equation

$$e = E\sin\theta - 15 = ri + L\frac{di}{dt} \quad \dots\dots\dots \quad (1)$$

15 being the voltage absorbed in the bulb.
r and L the resistance and the inductance respectively.

Now $\theta = 2\pi ft.$, and if $x = 2\pi fL$, $\qquad x\frac{di}{d\theta} = L\frac{di}{dt}$

and $\qquad ri + x\frac{di}{d\theta} = E\sin\theta - 15$

This is a linear differential equation of the first order, from which we find

$$i = Ae^{-\frac{r}{x}\theta} + \frac{r\sin\theta - x\cos\theta}{r^2 + x^2}E - \frac{15}{r} \quad \dots\dots\dots\dots\dots\dots (2)$$

To determine the constant A

we may put $i = 0$ when $\theta = \tan^{-1}\frac{x}{r} = \alpha$

Substituting the value so obtained for A we find

$$i = \frac{E}{\sqrt{r^2 + x^3}} \sin(\theta - \alpha) - \frac{15}{r}\left\{1 - e^{-\frac{r}{x}(\theta - \alpha)}\right\} \cdots\cdots (3)$$

The curve of Figure 7 is mainly plotted from this equation, making the following assumptions:

$E \;=$ 100 volts.
$r \;=$ 9 ohms.
$x \;=$ 4.36 apparent ohms.

from which the power factor is found to be .9 and $\alpha =$ .455 rads.

This curve and the equation (3) show the two effects of the inductance. The second term is the "spreading out" of the current past the zero point; the term that includes $\sin(\theta - \alpha)$ shows the lag of the current on the applied pressure by the angle α.

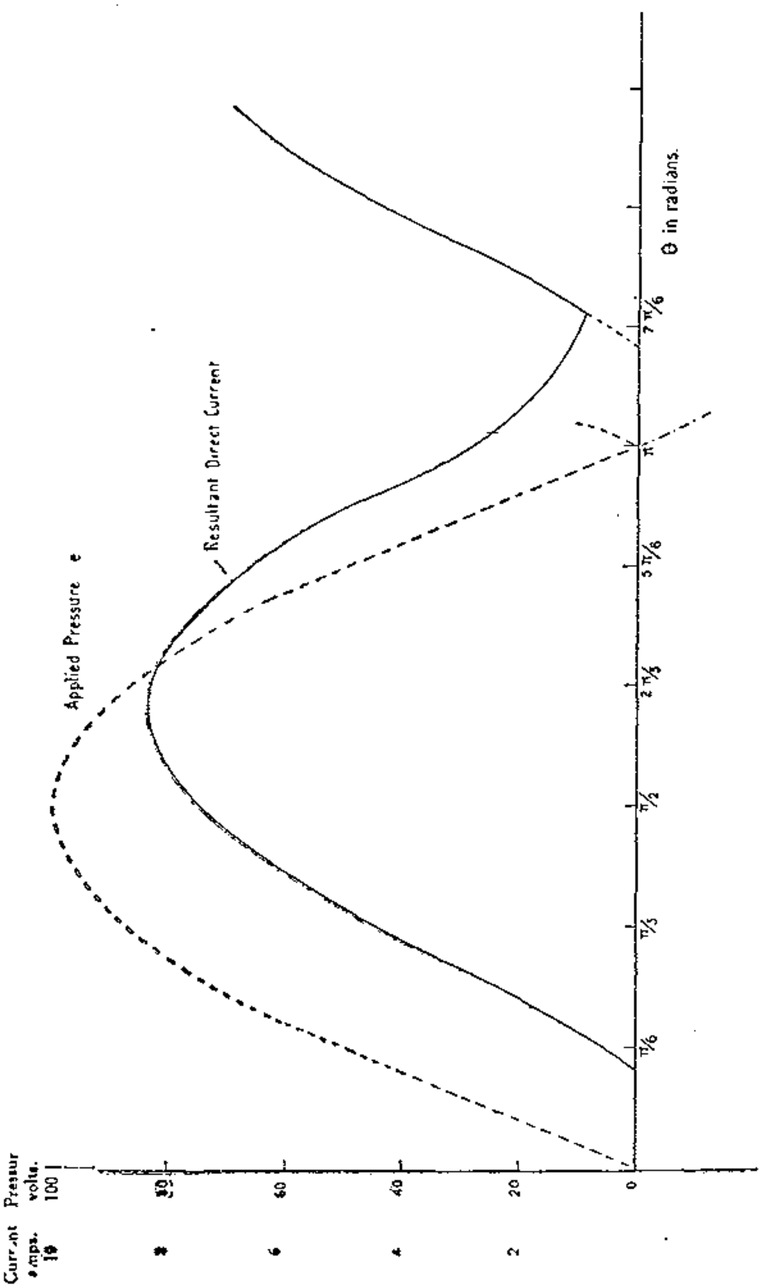


Figure 7.

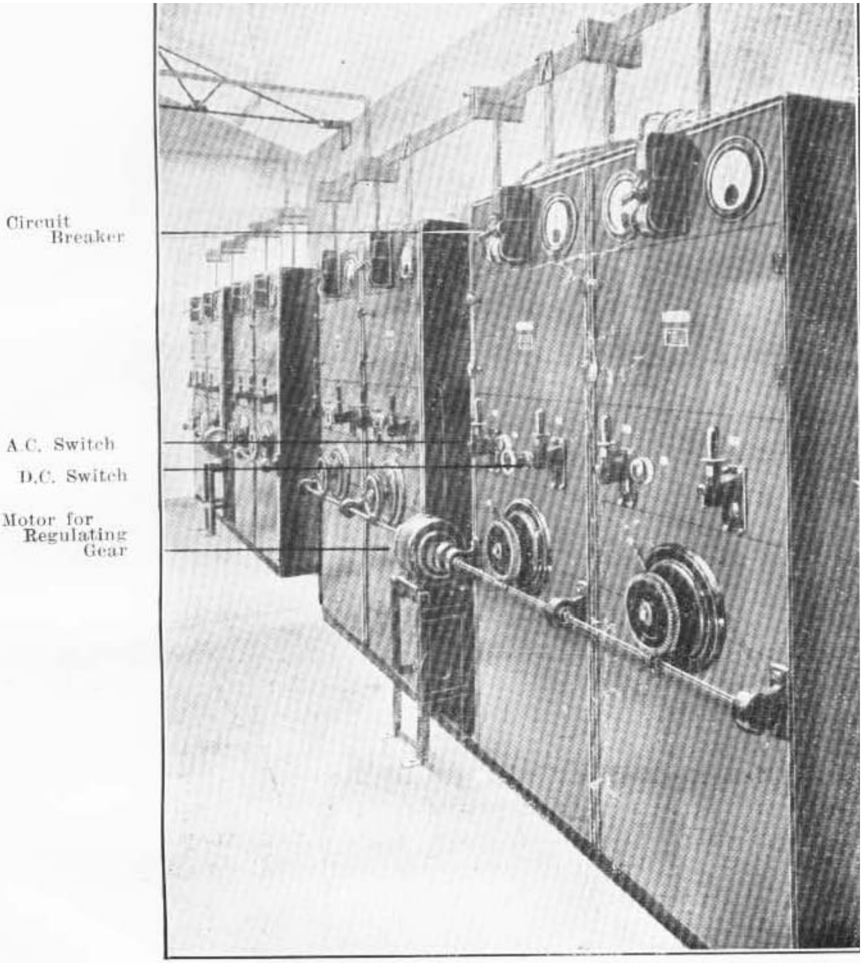


Fig. 5

By permission of the Hewittic Electric Co., Ltd.

MOTOR FOR REGULATING GEAR

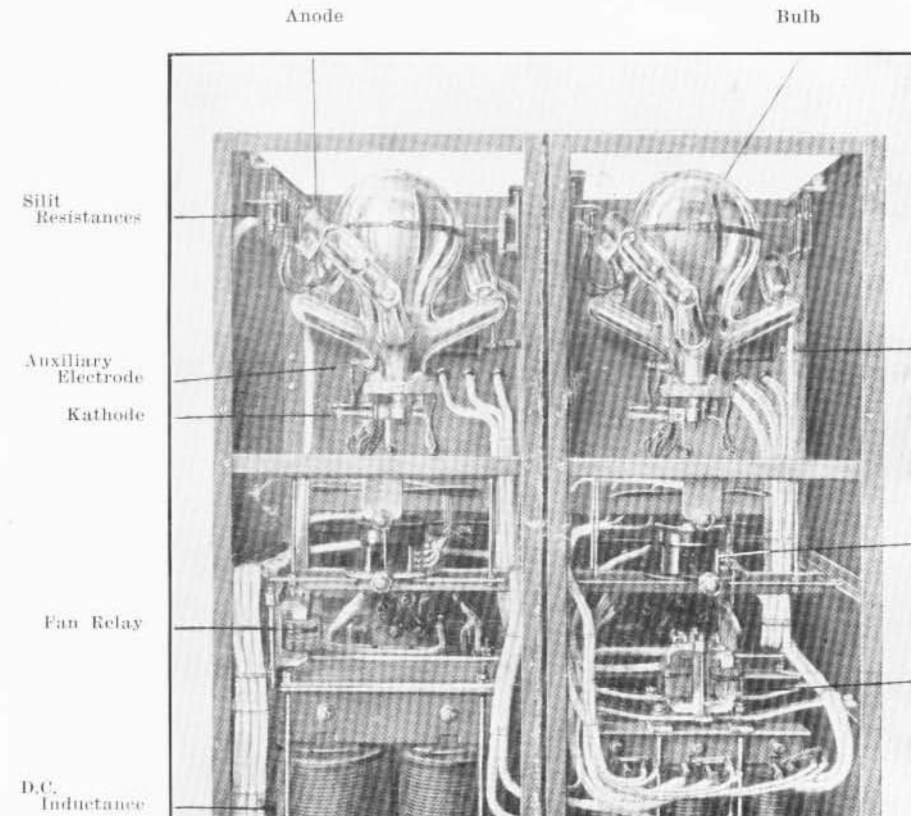


Fig. 6.

By permission of the Hewittic Electric Co., Ltd.

ELECTRICAL

THE BOYS' TECHNICAL SCHOOL.

By A PARENT.

The experience during the years succeeding the Great War completely demonstrated the impossibility of continuing to rely on the recruiting of tradesmen from civil life for the technical personnel of the Army and the only practical solution was the training of boys in much larger numbers than before 1914.

A Central Training School for this purpose was opened at Aldershot in 1922, but this was a temporary measure pending a decision as to its permanent location. Blandford (Dorset) was originally selected, but this was subsequently changed to Beachley, near Chepstow (Monmouth), and to this place the transfer of the School was effected, and the 25th September, 1923, is officially recognised as the Foundation day of the " Boys' Technical School," the change in name being effected at the same time as the change of station.

It was decided that 1,000 boys should be enlisted for three years boys' service as apprentices under training, and that on being posted to the ranks they should serve for eight years with the colours and four on the reserve, and be drafted either to the R.A., R.E., R. Signals, Royal Tank Corps, R.A.S.C. or R.A.O.C., as required.

By process of elimination it was decided that of the sixteen trades required in the Army the following should be taught at the School in required proportions :—

1. Blacksmiths.
2. Carpenters and Joiners.
3. Electricians.
4. Fitters.

For these, boys would be enlisted at the rate of about 330 a year, so that from the end of the third year there would be a constant supply of that number of trained tradesmen available to meet the needs of the Corps mentioned.

It must be readily admitted that the idea is very sound, as not only will it bring great benefit to the Army generally, at the time in its history when the importance of mechanicalisation is paramount, but also it is of the greatest benefit to the youth of the country at a most unfavourable period, resulting from the effects of a long period of warfare. The expense involved in this enterprise is obviously not light, and it was not projected in any spirit of philanthropy, but with the main view of attracting the best type of youth to carry out the important duties of skilled mechanics in the Army.

To ensure this a competitive examination is held every four months at the various regimental depots and other centres throughout the country, and 110 boys are selected in order of merit for admission to the School.

The standard of the examination is equivalent to the old 2nd Class Certificate of Education, and candidates must be between the ages of 14 years and 15–4/12 years at the date of the examination.

While at the School they receive pay at the rate of 1s. per day, increasing to 1s. 2d. as they become efficient.

After being clothed and equipped the new entrants are put through a course of regimental training, drill, physical training, barrack routine, etc., the main object being the formation of a disciplined body for delivery to the workshops, there to commence the chief role of their life, to be trained as apprentice tradesmen.

The organisation of the shops, compilation of a suitable syllabus and the supervision of instruction devolves upon the Chief Instructor, assisted by Assistant Instructors and a staff of expert N.C.O. tradesmen drawn from the various Technical Corps.

Education is carried out under an Education Officer of the Army Educational Corps and embodies Mathematics, English, Chemistry, Heat and Applied Mechanics, and from "Reveillé" to "Lights Out," the boys are fully occupied in carrying out a syllabus which must be described as wholly comprehensive, containing something of everything vital to the training and welfare of a young soldier. Two afternoons a week are devoted to sport and the lads are insatiable in this respect. As they develop in size and weight they will, no doubt, provide formidable school teams and perhaps make history in Army Sport. Each week progress is noticeable, and thanks to the example of Officers and N.C.O.'s who are indefatigable in their efforts to make the boys happy, "Esprit de platoon" is soon created.

This has since been extended to company and workshop, without which, competition, the greatest incentive to progress, is lacking.

The seed was sown at Aldershot in a garden represented by those few boys who first formed "A" Company. Most of it fell on fertile ground—very little on stony patches—and, soon fertilizing, produced a pattern for those who came after to be guided by and enlarged upon. Some of the seed proved more fertile than the rest, standing out by reason of character.

Leaders among the boys themselves sprang into being, possessing personality, tact and understanding. Such boys were promoted to Boy Lance Corporals and have proved invaluable. Each commands a section of about a dozen other boys; certain privileges are accorded them, and in their barrack room their word is law. Each of these Lance Corporals is selected for his good character and influence, and a boy must prove his all-round worth before he is considered for promotion to this exalted rank.

No doubt, as time goes on, the idea will be enlarged upon. Indeed, even at this date we find Boy Corporals (the correct term is "Apprentice Tradesman" Corporal, as the rank of "Boy" has now been superseded) and in time to come, no doubt, promotion to A.T. Sergeant will occur and there may even be an A.T. Sergeant-Major.

Every effort is being made, and with some considerable success, to introduce the Public School System—there is no better—but this can only be realised when the boys become older and gain more experience. Not an instance has occurred of a boy N.C.O. taking advantage of his position. On the contrary they are respected and looked up to by the others, and to see them "father" the new arrivals at the School is a pleasing revelation.

The material is excellent and the scheme is progressing well, but the responsibility of the Platoon Commanders (selected Infantry N.C.O.'s) is very great. Their example can be beneficial—or detrimental.

At this stage it may be desirable to give a brief description of Beachley.

The situation is unique, a glance at the map will prove this, consisting of a peninsula separating the mouths of the two large rivers, the Severn and Wye, being thus enclosed by water on three sides. Beachley, about four miles from Chepstow, at one time a beauty spot for visitors, has been the scene of two large Government enterprises. In 1916 a National Shipyard, designed as one of the largest ship-building yards in Britain, was commenced in conjunction with another of similar type at Chepstow, and by the end of 1919 the expenditure on it had exceeded five million pounds. Early in 1920 these were sold to a company and remained idle for a considerable time.

In 1923 the Boys' Technical School took up its position there, with, we feel sure, more successful results.

It was no mean task to adapt the site to suit the requirements of the youngsters so as to afford maximum comfort, facilities for military and technical training, recreation and adequate accommodation for the large staff, both married and single, but already things are beginning to approach the ideal and Beachley Camp is becoming more complete as time goes on.

The first thing that strikes the newcomer is the cheery aspect of the barrack rooms, institutes and buildings generally. There is none of that drab colour about them, the predominating colour is bright green, with white painted ceilings, the whole well lighted with electric light, while red roofs complete the picture. The exterior walls are colour-washed in light buff.

The Barrack Rooms, of the same pattern for the staff and the boys, are considered to be among the most up-to-date and comfortable in the kingdom. They are lined with match-boarding, sanitary annexes are connected with each, thus preventing unnecessary discomfort in inclement weather, and in the original buildings double fireplaces are substituted for that horrible invention, a stove.

Each platoon sergeant has a well-appointed quarter adjoining one of his barrack rooms, while an important innovation in each room is the boy corporal's bunk, which affords him privacy, one of the many advantages of his rank.

Much keenness and ingenuity are shewn among the boy N.C.O.'s in making their bunks attractive, and already a competition has taken place in which the judges had a most difficult task in awarding the prize for the best kept bunk.

The Supper Bar is a most attractive room capable of holding 500 at one time.

The Billiard Room forms an annexe wherein are displayed trophies and photographic groups, while the several tables are daily in use from opening to closing time. This forms the favourite rendezvous of the Padre, who unless something very pressing prevents him, devotes as much time as he can afford to assisting the boys in some way or other, and getting to know them better.

Another large room is the Reading, Writing and Games Room—with a first-class dancing floor—the scene of many successful social functions. The huge Dining Halls and the various labour-saving devices for the cookhouse are of the best. When it is understood that some 4,000 plates have to be washed daily, the necessity for the plate washing machine is immediately established.

Two large Bathhouses, fitted with shower and slipper baths and capable of dealing with 100 at a time, are working and to pass by these buildings during " business hours " reminds one of a certain part of the Zoo.

The Gymnasium has been described by a senior officer of the A.P.T.S., as the best lit and one of the best equipped in the Army. It is needless to remark that the boys enjoy every minute of the unavoidably short time allotted to physical training, and are frequent voluntary visitors to the building.

Recreation Grounds are available and sufficient and provide for cricket, hockey, rugby and association football.

A Swimming Bath is an urgent need, as although two rivers are quite handy, they are unsuitable for bathing owing to the dangerous currents and mud.

The Staff quarters are in a separate part of the Camp and are self-contained with their barrack rooms, institutes and dining hall. They are of a similar type, though on a smaller scale, than those of the boys.

Accommodation is not sufficient at present for the families of the officers but hopes are entertained that this drawback will be soon overcome by the erection of several attractive houses on an existing delightful site. The married Warrant Officers and N.C.O.'s are, however, well catered for. Their quarters are in Pennsylvania —a model village composed of semi-detached villas, each containing three bedrooms, one sitting room, bathroom, kitchen and scullery, with gardens back and front. They are, therefore, larger than the "C" Type quarter and more artistic. The only disadvantage is their distance from the Camp—two miles away—and travelling to and from work constitutes a certain amount of inconvenience, especially in bad weather. Furthermore, there is the serious danger of the married families getting out of touch with the social life of the school, which is vital to the maintenance of good feeling and family spirit. However, by means of a really excellent Cinema Hall at Sedbury, opposite Pennsylvania, gatherings of the pupils and their instructors have taken place on several occasions, when the "off duty" spirit has prevailed and thus opened the way of getting to know each other.

Anything more unlike the typical Officers' Mess building than the accommodation for the officers cannot be imagined. Instead, Beachley Camp is fortunate in possessing a charming old mansion, standing in beautiful grounds, with a view across the Severn, which is really delightful. The rooms are large and artistically decorated, while two excellent tennis courts are available. Legend has it that a ghost completes the inventory, in the form of a butler carrying drinks, but although one or two sympathetic and non-teetotal spirits have attempted liaison after hours, no success has so far crowned their efforts.

The Workshops consist of magnificent structures and are capable of accommodating 900 boys at one time. Every modern device has been introduced and appearances tend to the belief that they are the best of their kind in the Service.

A large number of excellently equipped classrooms for education, each seating about 40 boys, as well as two Laboratories, Mechanical and Chemical, are also in use.

The School, under the Commandant, is organised in three branches, (*a*) Headquarters; (*b*) Administrative; (*c*) Instructional; each being directly responsible for its particular business. At the same time the fact that each is an integral part of the School is not lost sight of. It would never do to work in watertight compartments, and by interchange of ideas, mutual co-operation in arranging social functions and liaison between Barrack Room and Workshop, this feeling is inculcated.

The Headquarters comprise the Adjutant and Quartermaster and the Instructors and Dutymen.

The Administrative branch comprises four companies, each of about 220 boys, each divided into four platoons. The Company Staff are :—One Captain, C.S.M., C.Q.M.S., four Lance-Sergeants and a Storeman.

The platoon sergeant has an important command in controlling some fifty boys and is assisted by the four section commanders (boy N.C.O.'s). No finer opportunity exists for a young N.C.O. to develop, with the material at his disposal, those qualities which make leaders.

The instructional branch is supervised by the Chief Instructor, assisted by three assistant instructors, whilst each workshop is under the direct control of a Warrant Officer Instructor assisted by certain N.C.O.'s, who remain in charge of the same boys as long as is practicable.

The Education Officer is responsible with his staff for the general education and for a great portion of the technical instruction which forms a vital part of trade training.

The messing at the School is really excellent, even supper being served to the boys on four nights weekly.

Education, a high moral standard, sportsmanship in its true sense, esprit de corps, self-confidence, respect for superiors, and discipline, are a few of the keywords of the B.T.S., and no parent, however fastidious, need have the slightest qualms about the company a boy mixes with at the School.

One has but to speak to the boys to realise that in the majority of cases they have been well brought up and come from good homes. Competition to obtain admittance is so keen that the places of any delinquents could, if necessary, be filled a dozen times over.

A School Concert Party is now in being and has given several successful shows—a revue " Laugh Now " was accorded a very warm reception at the Town Hall, Chepstow, a few months ago.

The School journal, "*The Robot*," is published periodically, and I am indebted to its Editor for much of the information contained in this article.

"Maskee."

DISSECTION OF HEPTAGON.

With reference to the Dissection of Heptagon published on page 368 of the June, 1926, *R.E. Journal*, a correspondent writes :—

" I read the letter to mean that the heptagon was accurately dissected into a square, whereas it is only an approximation. If the dissected parts are to fit accurately together, the resulting figure is a rectangle whose sides are (left to right) 1.93586 and (up and down) 1.87715 times the side of the heptagon respectively."

MAJOR SIR ROBERT HANBURY BROWN KCMG late RE

MEMOIRS.

MAJOR SIR ROBERT HANBURY BROWN, K.C.M.G.

HANBURY BROWN, the son of Dr. Robert Brown, F.R.C.S., was born on the 13th of January, 1849. He was educated at Marlborough College and at the Royal Military Academy at Woolwich. He joined the army as a second Lieutenant of Royal Engineers on the 8th of January, 1870, and was at the School of Military Engineering, Chatham, until July, 1872. He went to India in November of that year. In 1878 he was married to Marian, the daughter of the Revd. Edwin Meyrick, who was at that time Rector of Allington, Wiltshire. He had two sons and one daughter. His younger son, Bt. Major Austen Hanbury Brown, D.S.O., M.C., Royal Engineers, served with the 8th Division in the 2nd Field Co. R.E. and was killed at Rosières, Somme, in March, 1918.

On his arrival in India, Hanbury Brown was posted, in the first instance, to the Bengal Sappers and Miners at Roorkee. In March, 1873, he was appointed an Assistant Engineer in the Public Works Department of Bengal and served in the Irrigation Branch of that Department until 1884. During his service in India he was called up for military duty in the Afghan campaign of 1878-80, and was mentioned twice in despatches. In 1884, Egypt badly needed Irrigation Engineers to control and develop the great Irrigation works of the Nile, and Hanbury Brown was deputed, with others, for the work; he did much for Egypt and lived to see the land he had helped to irrigate increase vastly in fertility and value. His service in Egypt extended over nearly twenty years. He was awarded the Egyptian Orders of the Osmanieh, 2nd Class, and the 1st class Medjidieh. In 1902, he was made a Knight Commander of St. Michael and St. George in recognition of his services in Egypt. He was Inspector General of Irrigation of Lower Egypt for some years before he retired from the Egyptian Service in 1903. He was elected a Member of the Institution of Civil Engineers in 1904.

The writer recalls a little incident in the life of Sir Hanbury Brown which is typical of the man. When he, with two or three others, was walking one day along the crest of an embankment in India the bank suddenly collapsed under his feet and he, and a coolie who was walking close by him, fell together into a cavity in the heart of the embankment. The position of the two was somewhat critical and decidedly unpleasant. He refused to be helped out of the pit until the coolie had been first hauled up.

Nearly the whole of the professional life of Hanbury Brown was spent in the design, construction and administration of Irrigation works. As a young Assistant Engineer he helped in the construction of the Patna Canal, which is one of the main branches of the system of Canals drawn from the Sone river, which irrigate some 600,000 acres of rice and other lands in the Behar district of India.

In Egypt, one of the most useful works constructed by him was the Zifta Barrage on the Damietta branch of the Nile. This work regulated the distribution of the water, and the cultivators realised a rich harvest in the improvement in the area and out-turn of their crops. But the work which firmly established his reputation as an Engineer, and which he himself probably regarded as the most interesting and satisfactory, was the work he did in ensuring the stability of the great Delta Barrage across the Nile below Cairo which was constructed by Mougel Bey before the British occupation of Egypt. This stability was secured, first, by a system of grouting the original Barrage itself, and then by the construction of two subsidiary weirs below that Barrage. In 1902, Major Hanbury Brown published a book, "The Delta Barrage of Lower Egypt," which describes the work which was carried out. The two subsidiary weirs were built by a novel system which was mainly, if not entirely, his own. He described this system in a paper, read before the Institution of Civil Engineers in March, 1904, entitled "The use of cement grout at the Delta Barrage in Egypt." For this paper he was granted the Telford Medal. In the discussion on the paper, Sir Benjamin Baker said, "He was convinced that when the paper by Sir Hanbury Brown was carefully studied, and the novelty involved in the details was seen, the work would be valued very highly. He believed that nowhere throughout the world, up to the present, had the capabilities of cement been demonstrated to the extent which had been shown in an unostentatious way by Sir Hanbury Brown." Sir Benjamin further remarked that the author of the paper had overcome certain difficulties which had arisen, "with the result that he had carried the two weirs across the two branches of the Nile very rapidly, and had done what had never been done before, namely, made locks on the grouting principle without any Dams or pumping."

After his retirement from the Egyptian service, Hanbury Brown was called upon, on several occasions, to give a professional opinion on irrigation matters. In this he worked in partnership with the writer of this memorandum. In Dongola, in Spain, in South America and in the Sudan his advice was sought and given. He was ready with his pen and contributed not a few articles to the Engineering Press. His article in the "Engineer" in November, 1912, on "Land values in Egypt" dealt with the benefits which the Assuan Dam in Upper Egypt had conferred both on Government and the people. He showed by statistical statements that the value of the land, which came under the influence of the great reservoir formed by the Dam, had increased in a period of only three years from about £192,000,000 to about £488,000,000, and, at the same time, the increased land taxes collected by the Government were equivalent to five per cent. on the Capital outlay. So that not only had the Government received full value for their investment, but the people of the country had vastly increased their wealth.

Sir Hanbury Brown was the author of several books. Among those on engineering subjects, the one entitled "Irrigation: its Principles and Practice" passed through three editions, and is one of the standard books on the subject. He wrote also on other subjects than professional ones: his "Land of Goshen and the Exodus" is a book containing an interesting study of a portion of the history of the Children of Israel, and "The Fayum and Lake Moeris" is another of his books which is fascinating in its description of that interesting depression in the desert.

Sir Hanbury Brown was always a photographer of no mean ability, as many exhibitions in the village of Crawley Down, where he lived, could testify. In his later years he took up wireless telegraphy with his usual enthusiasm. He taught himself the Morse code and amused himself, in his leisure moments, in writing down numerous messages received from all sorts of people, many of them quite uninteresting in themselves.

During the Great War Sir Hanbury was in command of the 7th Battalion (East Grinstead) V.T.C., and was subsequently second in command 3rd Vol. Bn. R. Sussex Regiment. He was always an active member of the little community of Crawley Down and Copthorne in Sussex. The Boy Scouts, the British Legion, and the Parochial Council, all felt the value of his kindly help and cooperation, while the few who now remain of those with whom he worked in India and Egypt remember how he always inspired esteem and respect in all who were associated with him.

R.B.B.

COLONEL CHARLES FREDERICK COBBE BERESFORD.

Colonel C. F. C. Beresford, whose last appointment was that of Colonel on the Staff, Chief Engineer in Ireland, was born in 1844, being the elder son of the late Rev. Charles Claudius Beresford, and great grandson of the Rt. Honorable John Beresford, *M.P.*, brother of the 1st Marquess of Waterford.

He joined the Corps as a Lieutenant in December, 1865. Of those early days, General Sir Bindon Blood writes: "I first met Beresford when I went to Chatham from Aldershot with "A" Troop in November, 1866. He was then a tall, rather slight, but very strong lad, very good looking, and always one of the best and most charming fellows that ever stepped. He was very fond of sailing and rowing, and he was very good at both, a first-rate hand in a boat, and a good waterman.

"We had many pleasant trips together in the R.E. Yacht Club boats, and we were in the Corps four-oar together in 1867. I remember also having a very hard tussle with 'the Long-un' in one of the heats for our Corps Sculling Race in 1867, when I won 'all out' on the post."

After speaking of later meetings, especially of a walk together in 1878, Sir Bindon Blood says: "I should put him down as a specimen of an Anglo-Irishman of the best sort, a man you could trust and depend upon anywhere and everywhere.

"His abilities were of a high order, I know, and he did well with them in the Corps."

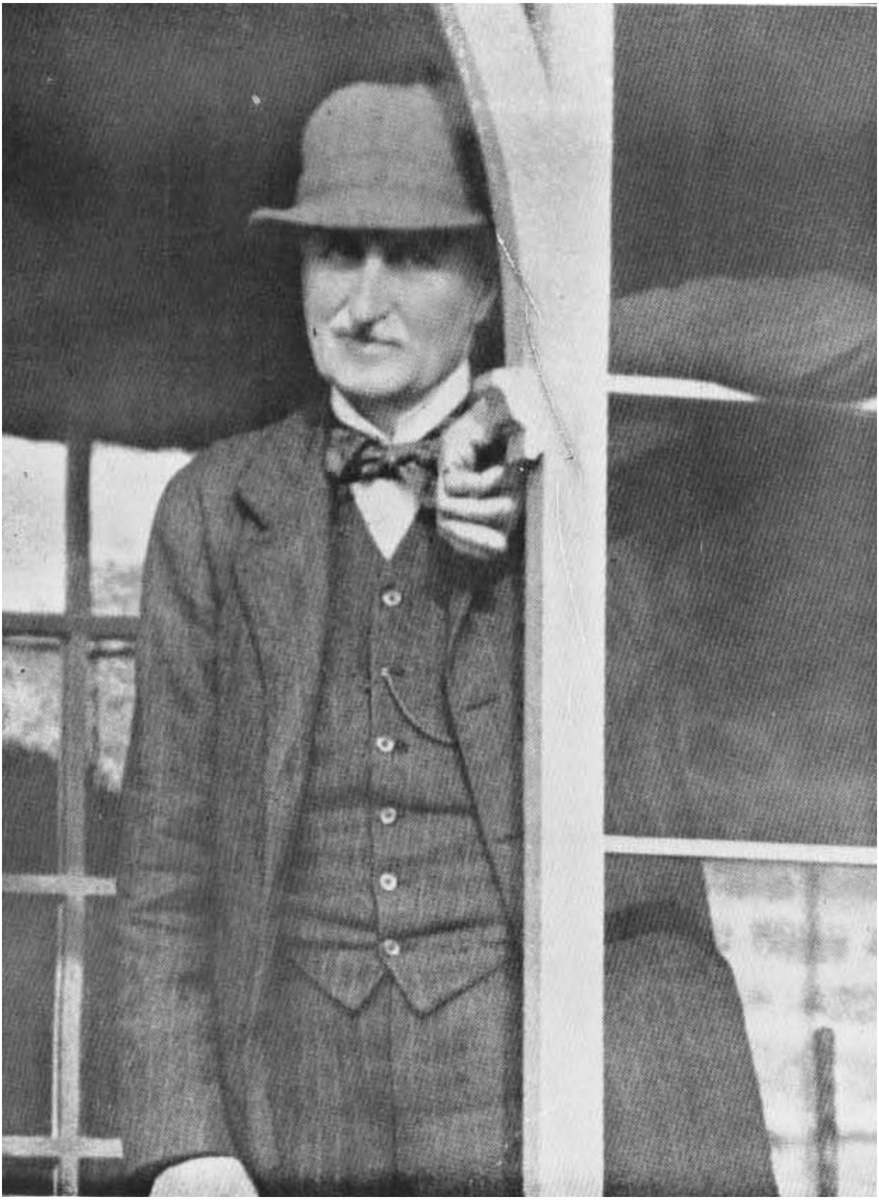
Serving for 3 years in Ireland, after leaving Chatham, he went on for a tour of foreign service to Canada, and then to Bermuda, where he sailed his 'Mudian' with success in many races. He was always a first rate horseman, and ran the drag hounds. It is recorded by one of his oldest friends, Colonel C. Chenevix Trench, R.A., that after an attack of enteric fever, he was taken to Government House to be well looked after, and when asked by Lady Lefroy, the wife of the Governor, what he would prefer for breakfast, laughingly answered "Please give me a red herring every time."

On his return home, after a spell of leave, and some hunting in Ireland, he was posted to the G.P.O. Telegraphs in 1873, before joining, for 4 years, "C" (Telegraph) Troop at Aldershot, under Major Durnford. He was always an ardent advocate of the alliance between military and civil telegraphs, but those were days when military telegraphs were in their infancy, and the equipment available was farcical, signalling being also the business of the troop, and the more important of the services.

In 1877, he joined the Institution of Electrical Engineers as a Member, being elected to the Council of that Institution ten years later.

Of those happy days at Aldershot, when most of the training of the army was carried out in the Long Valley, and on the Fox Hills, and the principal thing insisted on by H.R.H. The Duke of Cambridge was that officers who could should be allowed to hunt four days a week, very little beyond the joy of life can be recorded.

General Sir Richard Harrison remembers Beresford then as a tall dark man, good at his work, and at anything he undertook, especially tent pegging. His friends of those days will remember the good horse "Cockchafer," who bore him to victory in the Army tent pegging at Lilley Bridge in '76, and again at Aldershot, and later on in London, when he won the lemon cutting also. Those



COL CHARLES FREDRICK COBBE BERESFORD

were the days also of his constant friend "Smut," the bull terrier, who never let go when he accepted battle.

It was in '75 or '76 that Beresford, Bagnold and Mackean built what Colonel A. H. Bagnold now speaks of as "a monument of his talent for initiating good useful movements," the R.E. Theatre at Aldershot. "I still have," says Colonel Bagnold, "a photo of the skeleton of the building, C.F.C. standing on the ridge, self sitting on it, and Kenneth Mackean perched on the eaves. It might well have been named 'the Beresford Theatre.' Todd, Beresford and MacGregor were the three senior subalterns whose friendship and influence I have ever been grateful for."

Colonel Bagnold also records a certain fancy dress ball at Guildford, at which Beresford appeared as a White Knight, the coming out ball of his future wife.

The following year he was married to Edith Gertrude, daughter of Salisbury Baxendale, Esq., of Bonningtons, Ware. To the never-failing happiness of that union, and to the added joy to his many friends, we may only thus briefly refer.

Colonel Stanier Waller, another old friend of that time, says: "My principal recollection of the 'Long 'Un' is his extreme cheeriness under all circumstances. I don't think I ever saw him seriously put out."

Though his fun, cleverness of wit, and cheeriness come first in all memories of Beresford, those who knew him well, can tell of his strong purposeful character, and capacity for hard work. His fine riding and reckless gallantry, his single-minded pureness of heart, and intensity of purpose made him a beau ideal soldier, but chance prevented him from the opportunity of fulfilment of the brightest of early promise.

Beresford, in 1878, was promoted Captain; in 1879 he passed high for the Staff College, completing his course at the end of 1880. To his disappointment, he had not been, therefore, able to go to the Zulu campaign. It was there that an old friend, McDowel, of the R.E. Troops, was killed at Isandhlwana in 1879, and there also "C" Troop was first extended, learning the necessity for a far larger equipment, using heliographs successfully, and for the first time making use of the Bell telephone.

His first active service was in the disastrous campaign in the Transvaal of 1881, where he rendered excellent service, the campaign in which his old friend John MacGregor, formerly Adjutant of the R.E. Troops, and then Military Secretary to Sir G. Pomeroy Colley, was shot through the head.

Of the disaster of Majuba, the death of Colley, and the winding up of the campaign politically without honour, the story is well-known.

On his return from Africa in 1881, he was posted to the Intelligence Branch of the War Office, serving there till September, 1883. He, therefore, missed employment once more in South Africa, with that wonderful little force under Sir Charles Warren, known as the Bechuanaland Field Force, which took many of his old friends, under Major R. H. Jelf, from Aldershot, clad in corduroy and wideawake hats, with beards on the cheeks and chins of those who could grow them. Of how the Boers, missing the familiar red coats, could make nothing of them, and, puzzled by the skilful manœuvres of Sir Charles Warren, sued for peace, is not part of this memoir.

Beresford's chance came again in 1885, when he was sent to the Soudan as Director of Telegraphs, but fate decided that the campaign should collapse after 3 months of his service there, and though he received the medal and clasp, and bronze star, his time with the Force was too short for the gaining of honours, though again the record of his work was excellent.

That year he was promoted Major, and following his bent, he was given command of the 2nd Division of the Telegraph Battalion, employed on the Postal Telegraphs, in which he remained for four years, with his headquarters in Leicester Square.

Of this time, Sir Ralph Anstruther, one of his subalterns, writes: "Well do I remember his cheery optimism under a very severe snow breakdown, we drove together in a waggonette with various changes of horses all the way from Polegate to Bromley, deep snow, brilliant sunshine, and devastation all along the Newhaven main line. He was a versatile companion at all times, and an inspiring C.O., for his subalterns. He was always for pushing on both officers and men to the limits of their capacity. I recollect his reproaches when I deprecated the removal of my right-hand man at New Cross to some more exalted sphere. 'My dear fellow, you must not talk like that; always let your best men go to something better, and their successors will be tumbling over each other to get advancement too.' He was so clever and quick-witted, and the humorous element in all situations appealed to him strongly. Altogether a man who could not fail to be admired and liked by all who served with him."

In 1889, he was selected to command the 1st Division of the Telegraph Battalion, and it was his good fortune to see the progress so far made in Military Telegraphs, which he had so ardently furthered throughout his service.

Even so, the standard was still far below that to which the T.B. attained later on. What was attained was a real foundation on which the war edifice of Military Telegraphs, culminating in the splendid Royal Corps of Signals, was built.

Major General Sir H. Bruce-Williams bears witness that "Beresford was a very kind C.O., and always took the kindly view of officers or men. He took it for granted that they were doing their best, and under him the 1st T.B. was a happy family.

"Colonel Beresford, being an Irishman, was a good horseman, and encouraged the mounted portion of the unit."

General Bruce-Williams speaks of how the standard of horsemastership, and the technical training, in 1890 were still far below that of the Great War; the army being in a state of transition, only beginning to learn and to teach itself, and life being not so strenuous as it gradually became after South Africa, and as it is now. He adds, "But if it had not been for him I could not have boasted of having a 'chit' to the effect that the horsemastership of the 37th Division in 1917-18 was the best in the 3rd Army during the war. He delegated authority freely to all subordinates alike. 'Out of School,' of course, he was a charming man. I have never seen him angry or ill-tempered in or out of school."

Perhaps one of the most charming testimonies of his old subalterns is that of Lt.-General Sir John Fowler, who writes: "When I joined the old 'T.B.' as a subaltern in 1888, Charley Beresford was in command of it. All we subalterns loved him. Very keen and practical in his schemes for our training, he always contrived to make it really practical. He constantly sent off small detachments 'on their own' to make good as best they might, and it was this training which established traditions and habits which had good results in the South African and Great Wars.

"He took the greatest interest in the welfare of the unit, and saw to it that Officers and men shared every form of active sport, especially if a horse came into it. His subalterns of those days did well in their careers, and I am sure owed something to Charley Beresford. Bruce-Williams, Godfrey-Faussett and Boys were some of them. He always took the greatest interest in how those who had served under him were getting on.

"A good judge and keen lover of a horse, he was unable to ride much on account of rheumatism, but however much he was crippled by this, he was always out to see what was going on, cheery and light-hearted, with some little joke on the success or failure of officers and men.

"Meeting in after life, he was always full of anecdotes of the old 'T.B.' days, and many will deplore the loss of Charley Beresford as that of a very real old friend."

In the same strain Sir H. Bruce-Williams, says: "It was always a pleasure to meet Colonel Beresford long after one left the 1st T.B. He always met one in a cheery way. He had a way with him, like so many Irishmen, and both I and my wife have the happiest recollections of the kindness of Colonel and Mrs. Beresford to us."

Sir Bindon Blood says: "I cannot put a date to the last time I saw him, but it must have been at a Corps dinner. I remember he was as good-looking and as pleasant-mannered as ever."

In 1892 Beresford was promoted Lieut.-Colonel, and posted to Ceylon, where he served three years. During his time in the island, he earned the love and trust of the natives by his advocacy of their claims when he thought they deserved it. He used to tell with laughter how on one occasion he was led, garlanded, in a great procession. He then received his Brevet-Colonelcy and was transferred to Plymouth as C.R.E.

In 1898 he was promoted substantive Colonel, and received his last appointment of Colonel on the Staff, Chief Engineer in Ireland.

In 1902, he was placed on retired pay, and after a few years in London went to live at Camberley, so as to be near his old haunts at Aldershot. There he designed and built himself a house looking out on the Camberley Heath Golf Course, laying out a charming garden round it. The following tribute from the builder who worked under his direction is worthy of record:—

"Kindly accept on behalf of myself and sons our respectful sympathy in the great loss you have sustained. It was always a pleasure to do anything for Colonel Beresford, and his kindly, courteous and genial disposition will be missed by all who knew him. He was a gentleman in every sense of the word."

There is a fine studio in the house, where he passed many hours. Friends who visited him there found always the same cheery, bright and witty personality, hard at work painting, or working in his garden. To those who knew him well, in the early days and in the evening of his life, he was always an inspiration and a joy.

The Great War found him as keen as ever to serve his country, but his age (then nigh on 70) denied him more active service than he could find in 1915 as Colonel of the Frimley Volunteers. Into this work he threw himself with his whole heart, and never spared himself in night marches, nor in all the work involved in the disposition of his men in Defence. One of his officers writes:—"I am writing on behalf of many old members of the Frimley Volunteers to say how much we sympathise with you in the loss of our Colonel. We all loved him.

"Personally I shall look upon the times I spent under him as among the most privileged and happy days of my life."

Beresford served with his Volunteers till February, 1918, though from May, 1917, onwards his activities were gradually less.

During his active life he was a constant contributor to the *R.E. Journal*, and published nine or ten articles on the use of Telegraphs and Telephones in the field, as well as on the collection and transmission of intelligence.

When a new cover was required for "The Sapper" and a competition was opened, he sent in a very clever drawing, which was placed third. The detail, giving all the wars in which the Corps had been engaged, together with its varied uniforms, was too great to allow of its being accepted.

Devoted with a great affection to the land of his birth, his belief in the future of Ireland, even in the darkest days, never wavered.

In retirement, amongst his many interests, for 19 years he was a member of, and a very regular attendant at the meetings of the Grand Committee of the Benevolent Society of St. Patrick. The Secretary writes:—"His never-failing kindness and help will always be one of my happiest recollections."

At their meeting on the 5th March, 1926, Viscount Massareene and Ferrard in the chair, the following minute was recorded:—

"It was unanimously resolved that the Grand Committee of the Benevolent Society of St. Patrick desire to convey their heartfelt sympathy to Mrs. Beresford and her family in the bereavement they have sustained, and to express their appreciation of the long and valuable services rendered by Colonel C. F. C. Beresford to the Society."

It is sad to record that a crushing sorrow fell on the happy home at Camberley and on the mess at Aldershot in 1910.

Captain Charles Claudius de la Poer Beresford, the elder son, one of the most promising young officers in the Corps, at that time commanding the 1st Field Troop, gallantly lost his life in trying to stop a runaway horse. Undoubtedly he saved the life of the rider, a batman, as the horse was heading for his own stable door, when he thrust the horse he was riding across its path.

Colonel Beresford died on the 13th December, 1925, at the age of 81, and memorials to father and son will be side by side in St. George's Church, in the Stanhope Lines at Aldershot.

Had opportunity of greater service come his way, there is little doubt in the minds of his friends that Colonel Beresford would have risen to the occasion.

Officers and men would have followed him anywhere, and his vigorous personality, his clever brain and rapidity in making decisions, would have made him a leader of the highest order.

He had no thought of self, and was never known to complain of the rebuffs of fortune, nor to lose his bright outlook, or keenness of purpose. To put his whole soul into what he had to do, and to expect those under him to play the game, and to trust them to do it, was the secret of his entire service.

That there is now no Beresford in the Royal Engineers to carry on the tradition is a matter of lasting regret.

F.G.B.

COLONEL C. A. R. BROWNE.

COLONEL Clement Alfred Righy Browne, who died at Ealing on the 28th December, 1924, was born in 1860, the son of General Clements Metcalfe Browne, R.E., and received his first commission in the Corps in April 1879. After completing his course at Chatham he was employed at Chatham and Aldershot until 1883, when he went to India, and was for some time employed on the construction of the road over the Bolan Pass. He was a keen cricketer and association football player, but owing to an injury to his knee he joined the Accounts Branch of the P.W.D. in 1885 and worked in the offices of the N.W. Railway in Bombay until he came home for the India class at Chatham in 1891. On his return to India he served on the Assam-Bengal Railway and afterwards in the office of the Accountant-General, P.W.D., in Baluchistan. In 1901 he was lent to the Military Department to manage the railways in China during the Boxer troubles. In March 1901, the Germans had handed over the administration of the Peking-Tientsin-T'anku-Shan-hai-Kuan railway to the British, and after Colonel (now Major-General) Sir J. R. L. Macdonald had acted as Director of Railways for a short time, Browne took over the work and managed the railways, with the co-operation of German and Japanese Deputies, until they were handed over to the Chinese late in 1902. So successful was his administration that the revenue of the line not only paid working expenses, but contributed $500,000 towards repairing the Boxer damage, expended $1.200,000 on new works and paid the bondholders interest amounting to £115,000. He was twice mentioned in despatches and in 1903 received the brevet of Lieut.-Colonel. He afterwards held several important appointments in the Indian Railways, and retired in 1915, after holding for over two years the post of Manager of the Eastern Bengal Railway. On his return home he was given the command of a Labour Battalion and served in France for six months in 1915. He was afterwards placed in charge of the Munitions Factory at Leeds until the end of the War and retired in January, 1920.

BOOKS.

THE STUDY OF WAR.

An inaugural Lecture delivered before the University of Oxford on 23rd February, 1926. *By* MAJOR-GENERAL SIR ERNEST SWINTON, K.B.E., C.B., D.S.O., Chichele Professor of Military History in the University of Oxford. (The Clarendon Press, Oxford.) Price 2s. 6d.

OXFORD University has been fortunate in its Professors of Military History since the foundation of the Chair. The first holder was Mr. Spenser Wilkinson, the eminent publicist and writer on military questions.

The second was Professor C. W. C. Oman, now Sir Charles Oman, M.P., whose "History of the Peninsular War" is a standard work. The third we all know as the author of "The Green Curve" and other books, and one of the official military correspondents who, under the name of "Eye-Witness," described the early fighting in France and Flanders in the Great War.

In his inaugural address Major-General Sir Ernest Swinton acknowledges the honour done to the Army and to the Corps of Royal Engineers by his appointment to the professorship. In him Oxford obtains a lecturer who has not only gained a reputation by his writings on military affairs, but has the advantage, denied to his predecessors, of having had personal experience in the field.

Shortly after the conclusion of the campaign in South Africa, where he had gained much experience as Adjutant of the Railway Pioneer Battalion, under the command of another distinguished Sapper, Major-General Sir John Capper, Swinton launched into a literary career as a side-show to his military work. One night, returning as "daily-breaders" from the War Office to our homes in the country, the future Professor discussed with the writer his experiences during the South African War, and broached the question of publishing his ideas on the subject of the tactical defence of localities He outlined his plan for the book, and before parting asked whether it would be worth publishing. The reply was—"Certainly, but don't let it be known that it is written by a Sapper." A few months later there appeared a modest pamphlet entitled, "Duffers Drift," purporting to be written by one "B.F.," whose portrait appeared on the cover, and depicted a khaki-clad subaltern fully equipped for war, and covered like a Christmas tree with all the impedimenta, from revolver, holster and belt, to water-bottle and field glasses, with which the British officer is wont to adorn himself for his first campaign. In it the writer gave a progressive course of lessons, in the guise of dreams, of "How not to do it," taking for his subject the defence of an important drift on an African river. In the final dream "B.F." managed "to do it" and scored, like the pamphlet, a remarkable success.

Published by Clowes, the pamphlet had a large circulation—slow at first, but steadily increasing. Two or three years afterwards a distinguished officer of the Brigade of Guards let out that he had presented a copy to every N.C.O. under his command. Unfortunately, the American copyright had not been reserved, or the royalties would have been larger. It was republished in the United States, where interest in the study of war was awakening, in the Army at all events, as in Great Britian.

But to return to the inaugural lecture. In these days one is constantly faced by the problem of how to combat the arguments of enthusiasts who preach the doctrine that there can be no more wars, and that consequently an Army is unnecessary. It is useless to remind them of the Holy Alliance, the Universal Peace Society, or the Hague Conference, or to plead the cause of the poor professional soldier whose bread and butter are being taken from him. But one can read General Swinton's address and use his arguments, and if the pacificists can be persuaded to read it for themselves, it is possible that they will not sleep quite so soundly in their beds. He provides us with a reasoned reply, which will even cheer the budding soldier who thinks he has chosen the wrong profession.

General Swinton told his audience that as regards the general attitude of the nation towards the study of military history, it was reasonable to hope that his task, by reason of the lapse of time and the course of events, would be easier than that which confronted Professor Spenser Wilkinson in 1909. But he finds that, although a great change has taken place in the nature of the opinions held then and now, there is not so much difference in the attitude which is the outcome of those opinions.

Professor Spenser Wilkinson held that the people of this country had been gradually aroused during a period of 50 years to a recognition of the fact that war is, unfortunately, a part of the life of the world, the latest step in the process of their enlightenment having been the crisis of the South African struggle, which had finally brought home to the nation the reality of a phenomenon too long ignored.

General Swinton disagrees with this last conclusion. Our insular position had prevented us seeing war at our doors. After nearly 50 years without any serious conflict to shake our complacency we were faced by what was sometimes called the *Great* Boer War. Though that war had jarred us into acquaintanceship with unpleasant realities, they had been limited, and were no measure of what might be.

In spite of its revelations, the influence of that conflict, save in the Army itself, was neither deep nor lasting. The current of our national life was not seriously disturbed. No lasting impetus was given to the study of war outside the Army.

General Swinton quotes Colonel Henderson, who wrote not long after the South African War was over:—

"History, as taught at the present day, includes an immense variety "of subjects, but there is one subject which is sedulously shunned, "and that subject is the defence of Empires. Hardly any well-known "political writer, except Spenser Wilkinson, appears to have the least "inkling that such knowledge should be part of the intellectual equip-"ment of every educated man, and no great teaching body has yet "endeavoured to supply the deficiency."

At an international historical congress held in London in 1913, Professor Oman ascribed the systematic depreciation of the study of military history "to the tendency to regard history as being purely evolutionary "and not cataclysmic—war being in the latter category—and to ignore "the influence exercised on events by individuals and personalities"—which was truly a far-seeing remark in the light of recent events. His conclusion was that the general knowledge of military history is as important as that of social, economic and political history.

The fact was that there existed, in 1913, an unjustified complacency born of a lack of knowledge, and an unwillingness to face facts or to read the signs of the times.

Since the Great War we can no longer plead ignorance as an excuse for living in a fool's paradise.

To quote again—"To urge the importance of military matters, "therefore, at the present time, even upon those not directly concerned "in the preparation for or conduct of war, should be far simpler than "it was.

"But there is still a lack of enthusiasm, in part attributable, strangely "enough, to overmuch knowledge—of a kind.

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"The desire to wipe out the past has crystallized into a revulsion "against war and a deep disinclination to think of it.

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"An indifference to military matters has to some extent replaced "the ignorance of former days. There is a theory that we are not "for a specific term of years likely to be engaged in a serious struggle. "Moreover, there is no obvious menace such as existed before 1914.

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"Finally, there is a school of thought that holds that by the gradual "conversion of all to the desire for peace and goodwill war can be "avoided, the process being accompanied by agreed disarmament or "a limitation of armaments."

The cry of "Never again" was in part responsible for the birth of the League of Nations, the covenant of which, formulated when world conditions were not what they are now, provides among other things for the reduction of national armaments to the lowest point consistent with national safety.

General Swinton is specific on the question of a Disarmament Conference. He says: "I say without hesitation, and at the risk of being "accused of advocating a selfish nationalism, that the law of self-"preservation demands that our first care should be the continued "existence and well-being of that particular Commonwealth of nations "to which we belong.

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"Apart from the question of degeneration (the result of a prolonged "peace), disarmament, unless universal, may be provocative of war. "At present there is the danger that the States which disarm may be "lulled into a false sense of security, while other States are still struggling "in the birthpangs of a new social system."

He proceeds to discuss the spread of Bolshevism, and presumes that it could not have been present in the minds of the members of the Peace Conference which created the League of Nations.

The important fact from the British point of view, which is our first interest, is that—"Its action appears to be directed mainly against "us. Apart from its onslaught on the mind, amounting almost to a "religious appeal, the Soviet Government shows no signs of neglecting "the argument of force. There can be no talk of abandoning armaments "while Bolshevism is in being and active with its dual threat."

Fortunately we have a Foreign Minister who has no illusions on this point Last autumn Sir Austen Chamberlain spoke as follows:—

"Our object is not merely that there should be peace, but that all "should feel that peace is secure. Disarmament through security,

"security through arbitration; arbitration, security, disarmament, are "the common platform of the whole League of Nations. But there is "another disarmament which, indeed, is more urgent, for it is the "necessary preliminary to the physical disarmament of the nations. "It is the moral disarmament of the world."

"This," says General Swinton, "puts the question in its proper "place. Perhaps progress is being made towards this desirable state "of the world, but it has not yet been reached.

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"Until moral disarmament at least is achieved we cannot regard "the more remote prospect of physical disarmament as a reason for "not preparing for war or for neglecting the study of it."

General Swinton then proceeds to discuss the effect of the recent strides in scientific achievement on the future conduct of war.

Wireless means propaganda made easy. Aviation is still in its infancy. So are submarines. The employment of poisonous gases is a certainty, notwithstanding what may be said to the contrary. The development of mechanical traction is only limited by the cost of experiments in time of peace.

Finally, he sums up as follows:—

"One thing stands out. It is that, however great may be the changes, "however devastating as compared with the past may be the new "weapons, and however feeble may appear the human being in opposition "to the forces to be let loose on him, it is still the man that counts most.

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"An idea of the future evolution on the technical and material side "and in the actual fighting can be obtained only by a search of the past "for principles, and by an estimate of the direction and extent of the "changes in progress—in other words, by gauging tendencies. If my "reading of the tendencies now discernible is correct, there is every "sign that less and less will strength be said to lie necessarily on the "side of the 'big battalions.' It will be on that of the best trained, "equipped, maintained and led, and most mobile forces if properly "employed. And in our case the question of employment is governed "more by the proper exploitation of sea-power than in the case of any "other nation. For us aviation has increased the difficulties of a would-"be invader, in the old sense of the word, because it has rendered "surprise more than ever difficult of attainment, but it has magnified "the risk of attack in another form, and has put an end to the long-"treasured insularity of our country.

"More than ever will physical action be accompanied by a simultaneous "psychological offensive employed in reciprocal support."

It is satisfactory to hear from undergraduates that the lectures of the new Professor are popular and well attended. If our other great universities would follow the lead of Oxford, future generations will, perhaps, be spared the perils of that amateur leadership which landed us in Gallipoli in 1915 and is now, under the cloak of economy, endeavouring to close our eyes to the possibility of war.

H.B-W.

THE PERILS OF AMATEUR STRATEGY.

As exemplified by the attack on the Dardanelles Fortress in 1915. *By* LIEUTENANT-GENERAL SIR GERALD ELLISON, K.C.B., K.C.M.G. (Longmans, 1926.) Price 5/-.

EVERY soldier—to say nothing of thinking civilians—should read this five-shilling book, with its valuable preface by Lord Esher. Its publication has already had a result, in that the Imperial Defence College is shortly to be established to deal with the questions of the defence of the Empire. Probably the idea of the college was well on its way to being carried out before Lord Esher's note was written, but the appearance of the book—delayed as it was by the General Strike—was opportune. It would seem as if Lord Esher and General Ellison had been plotting. General Ellison puts up the idea of a Ministry of Defence as a solution of the difficulties. Lord Esher knocks it down and out. He admits that when the Committee which bears his name reorganised the Defence Committee (note the omission of the word Imperial) and created the General Staff (not Imperial General Staff), it failed to foresee that when war broke out the Defence Committee would be swept away altogether, and that the General Staff would be merged in the active command of our armies in the field, and expresses the conviction that if we had possessed in 1914 a Joint General Staff, presided over by such a Minister as Lord Milner, the war would have been shortened by two years.

Two years—think of what that means! No Revolution in Russia—no abdication of the Kaiser—no United States in the War—no abject surrender of the German Fleet—no Wilson at Paris—how many lives saved? But would Europe have been better off?

Lord Esher approves of the idea of a Minister of Defence, but not a Ministry of Defence, and says:—

"The machinery exists in embryo in the admirable Secretariat under "Sir Maurice Hankey, pending the growth of a Joint (real) Imperial "General Staff. Some slight advance was made when the Prime Minister "appointed a Minister under himself as Chairman of the Defence Com-"mittee. But the experiment was not seriously tried. Still, along "that road we are bound to travel, if, as General Ellison contends, "the financial necessities in time of peace, and the demands of strategy "in time of war, are to be complied with in a manner consonant with "a form of government that rests on Parliamentary institutions."

Sir Gerald Ellison was stimulated to write his book after revisiting the scene of the Gallipoli Campaign.

His text is a quotation from "The Life and Letters of W. H. Page":—

"The horrible tragedy of Gallipoli, where the best soldiers of the "world were sacrificed to politicians' policies."

He sets himself the task of examining the facts to ascertain whether Mr. Page was right. He comes to the conclusion that the statement is in no sense an exaggeration:—

"I hold firmly," he says, "that neither the naval attack on the "fortress nor the subsequent military campaign could, or would, ever "have occurred, had the naval and military experts been called on "to consider the problem deliberately, and in conjunction. In fact, "we know that, when a few years previously this very problem had been "submitted to them to report on, their considered opinion had been "so adverse that the Government of the day had been forced to rule "the operation of forcing the Straits altogether out of account."

The point he makes is that "In so far as the higher control is "concerned, our system of conducting war remains to-day exactly "what it was in 1914, and there is nothing whatever to prevent the "astounding happenings of 1915 being repeated on some future "occasion."

Lord Milner states that he agrees with General Ellison's perfectly sound conclusion, while disagreeing with the main argument by which he reaches it.

That main argument appears to be that one man was responsible for the disaster; for, had Mr. Winston Churchill not existed, the Gallipoli expedition would not have taken place. Of that there can be little doubt. But against this we have to remember that had some other than Mr. Winston Churchill been First Lord of the Admiralty in July, 1914, the suggestion of Lord Fisher not to disperse the Fleet after the manœuvres might not have found favour with the Government of the day. Lord Esher is right in deprecating the blame being all put on Mr. Winston Churchill's shoulders. The system was at fault.

The Report of the Dardanelles Commission probably hits the nail on the head. It says:—"What actually happened was that the stress "laid upon the unquestionable advantages which would accrue from "success was so great that the disadvantages which would arise in the "not improbable case of failure were insufficiently considered."

The marvellous thing is, how was it that "this short cut to victory" was allowed to be persevered with in face of the previous decision of the General Staff (and of the Government of the day)?

Plans of campaign—Sir Gerald Ellison points out—take years to think out. Count Schieffen's plan for the next war—with France and Russia in alliance—was first formulated in 1905. Lord Fisher's plan for the redistribution of the British (and French) Fleets was conceived in 1904, in view of the Entente.

It was only in December, 1914, that on his return from a flying visit to France, Mr. Lloyd George sorrowfully realised that the Great War was not to end in six months. It is reasonable to suppose that it was not earlier than December, 1914, that Mr. Winston Churchill conceived, or assimilated, the idea that the deadlock on the Western Front could be solved by an attack on the Straits. On January 2nd, 1915, there came an appeal from Russia for a demonstration against Turkey.

At that time both the experts, Lord Kitchener and Lord Fisher, had secret plans of their own.

Lord Kitchener, with the East always in his mind, had his scheme to cut the Turkish communications with the East from Alexandretta.

Lord Fisher had his plan to envelope the north-western salient of the German Empire from the North Sea and Baltic, as the logical corollary to his strategical scheme of 1904.

Both were experienced fighting men, and did not divulge their secrets.

Suddenly comes "the short cut to victory." Conceived in December, 1914, or even later. Cabinet approval for attack by the Fleet alone on

January 28th, 1915. Planned by telegraph. It would have required more than Pitt's proverbial luck to have brought off this *coup*. Even the element of surprise was eliminated by a reckless advertisement of our intentions. The amazing thing is, how could Kitchener and Fisher have then been inveigled into the subsequent adventure? General Ellison's book gives an answer, and his quotation (p. 62) from Mr. Churchill's "World Crisis, 1915," p. 172, is significant :—"So obliquely "were these issues presented, so baffling were the personal factors "involved, that the War Council was drawn insensibly and irresistibly "into the gulf."

It is truly an amazing story. Sir Gerald Ellison has unravelled it only in part. It remains for the future historian to probe into the depths when, if ever, the whole of the evidence given before the Dardanelles Commission is published.

It is interesting to note that both Sir Gerald Ellison in this book and Sir Ernest Swinton in "The Study of War" make reference to the study of chess problems when writing of war. There is no doubt that the analogy exists, and that a mind trained by the game of chess is assisted to the solution of the problems of war.

It only remains for the reviewer to urge all young officers to read the book, in spite of the feeling, referred to by Sir Ernest Swinton at Oxford, that the war, and especially the Dardanelles Campaign, is an unpleasant memory, to be forgotten.

There is only one criticism to be made of the form of the book, and it has been made before; and that is that it is a mistake to print many paragraphs in heavy type. However important some of those paragraphs may be to the eye of the author, there are a great many other paragraphs equally important, and they are apt to be overlooked by the reader. It is an axiom that underlining is to be avoided.

H.B-W.

A SHORT HISTORY OF THE BRITISH ARMY TO 1914.

By CAPT. E. W. SHEPPARD, R.T.C. (Constable.) 14s.

THE preparation of a short treatise on a subject of considerable extent demands from the author a clear vision of the object in view. In the present case, where the author deals in some 300 pages with a subject, the standard work on which is to fill 13 large volumes, some such object needs to be carefully considered when deciding what is to be included and what is to be left out. The author in his preface complains, from his own personal professional requirements, of the lack of such a work in up-to-date form, and trusts that the book will be of interest to the general reader and of use to his brother officers. From this we may assume that his object is to produce a book which will be of value to officers in studying, for professional purposes, the growth and history of the Army to which they belong. At the same time it must be sufficiently non-technical to interest the general reader. If this be the correct view, it is to be feared that Captain Sheppard has not achieved his object in either respect. The book is really not a history of the British Army at all, but a skeleton military history of the British Empire;

a very different matter. An Army is essentially a living organism, and no history of it can be complete which does not deal with the life and soul of that Army, so that one can appreciate once again the spirit which inspired it, and enter into the life which it lived. The book under review is very largely composed of extremely condensed narratives of the many hundreds of campaigns in which the British Army has participated, interspersed at wide intervals with notes on the characters and capabilities of the more important leaders, and accounts of imaginary battles of various periods, but in one case the account is of an actual battle.

The author's judgments on some of the great leaders are stated with the frankness of a Lytton Strachey, without the reasoned justification which gives such value to the writings of that author. The very attributes which have led men to be specially respected by posterity are often slurred over. It would almost seem that in his anxiety lest "personalities should rank in popular esteem rather than achievements," the author endeavours to cast down the popular idols from their pedestals. For example, Moore's failures in the Corunna Campaign are specially stressed, while his work as a trainer of troops is barely mentioned, and the revolution in the systems of training and discipline which he fostered is entirely neglected. We also search in vain for any references to Wellington's staff which has been recognised by such authorities as Moltke as the prototype of modern general staffs. At the same time, he very rightly presses the claims for recognition of less known men, such as Amherst, Stringer Lawrence and Moira.

The principal events in the reorganization of the Army are dealt with clearly, but in view of the fact that the book is a history of the Army, some of the details of minor marches and counter marches and actions might have been omitted to make room for fuller discussion of changes in organization, equipment, armament and training.

An indication of the principles which guided the author in his selection of material may be gained from his criticism of Sir E. Wood's "Our Fighting Services." This he finds to be "patchy, many campaigns being dealt with in detail and others omitted or only briefly narrated." In endeavouring to avoid this, which he conceives necessarily to be a fault, Capt. Sheppard has produced a book so full of dry historical facts that it loses the interest of the general reader without giving sufficient information on any one point to the professional student.

The arrangement of the campaigns in the book, admittedly a difficult problem, seems to have been dealt with more from a geographical point of view than from the point of view of a history of the whole British Army. It therefore fails to show how the inter-relation of various campaigns affected the problems which faced the statesmen and the Army as a whole.

The author has dealt with a great mass of information, and his style is always pleasant, and at times quite stirring. We can only regret that he has not given us a more living history of that very human organism which is his theme. A laudable endeavour to show only such detail and names in his maps as are mentioned in the text has been overdone, so that many of the sketches which illustrate the book are of little value.

R.P.P-W.

TALKS ON LEADERSHIP.

By "BASILISK," R.A. Institution, Woolwich. (Second Edition, 1926). Price 1/4 post free.

This little pamphlet is intended by the author for those to whom leadership does not come naturally, but it is doubtful if even the born leader would not benefit greatly by a study of its 38 pages. The tyro in the art of command will find much valuable advice, and the experienced commander will find ideas crystallized and expressed delightfully, so delightfully that those whose duty has taken them away from direct command of men will itch to get back once more into closer touch with Tommy Atkins. Though the author finishes with three pages of Dont's, his advice is chiefly positive. He divides the book into 4 chapters. No. I deals with general principles, and these may be summed up in the French proverb "Tel chef, telle troupe." Chapter II treats of dealing with men collectively. In this the author's hints on giving instruction and lectures will prove invaluable. Those who know the S.M.E. lecture theatre will smile at the advice: "It is better that the men should be so comfortable that there is even a tendency for them to go to sleep, than that they should have to struggle to turn their minds from their physical discomforts and concentrate them on the lecture." The art of giving orders and the subject of Esprit de Corps are well treated. Chapter III deals with men individually, the keynotes being "sympathy" and "justice." Last of all come the "Don'ts."

We can imagine no better gift to a young officer going to his first unit than this excellent little book. R.P.P-W.

THE WORK OF THE SURVEY OF INDIA IN THE GREAT WAR.*

In peace time the Survey of India employs about thirty Royal Engineer officers and a smaller number of officers of the Indian Army. This great Survey has always been connected with the Corps since 1764, when James Rennell was commissioned as ensign in the Bengal Engineers and was, at the same time, appointed Surveyor-General of the East India Company's dominions in Bengal. We notice, by the way, that the device on the title-page of the book under review bears the date 1767, and the names of Lambton and Everest, but not of Rennell. The department had thus, when the war broke out, the benefit of the accumulated traditions and experience of a hundred-and-fifty years, and it is quite safe to say that no organisation could have coped with the immense difficulties of mapping the war areas, chiefly in the tropical and sub-tropical regions of the Near and Middle East, in the very successful way recorded in this book, if it had not had this mass of experience to draw upon.

The volume in question describes the surveys and explorations carried out by the Survey of India, during the operations in Mesopotamia, Kurdistan, Macedonia, Arabia, Persia, Palestine, East Africa and

* Records of the Survey of India, Vol. XX. The War Record, 1914-1920. Published under the direction of Colonel Commandant E. A. Tandy, R.E., Surveyor General of India. Dehra Dun, 1925. Price 3 Rupees, or, 5 shillings and 3 pence.

Afghanistan. In the Preface, the present Surveyor-General remarks that "these explorations and surveys were accomplished in the face of many difficulties and in every variety of terrain, from the icy highlands of Central Asia to the waterless deserts of Persia and Arabia." But, from the nature of this case, most of the space is devoted to work in Mesopotamia and Persia, which, in fact, occupies four-fifths of the account; a few pages only, in each case, sufficing for the war surveys in Macedonia, Sinai and Palestine, East Africa and the North-west Frontier. In fact, the Survey of Egypt was actually responsible for the mapping of Sinai, Palestine and Syria. Throughout the whole of the war the Department was administered by Col. Sir Sidney Burrard.

At the outbreak of the war the strength of the Survey of India was 55 Imperial officers, 148 Provincial and 37 Upper Subordinate officers. Before the end of 1914, twenty-seven Imperial officers had reverted to ordinary military duty, leaving half the original number to provide for the survey requirements of the war. And this will serve to give an idea of the difference in the character of the problem which was set before the Survey of India, from that which confronted the Geographical Section of the General Staff and Ordnance Survey in the western theatre of war. In the latter case, owing to the immense size of the armies and the stationary and intensive nature of the fighting, the utmost elaboration became necessary, and we find a large survey establishment employing, at its maximum, some 250 officers and some 4,000 men. Matters in Mesopotamia had, of course, a difficult complexion, and we may note that the Basrah Party in September, 1915, was composed of only six officers and 12 subordinates; and, after the occupation of Baghdad, the Survey Directorate consisted of 15 officers and 30 subordinates, in addition to a Compilation Section, with Army Headquarters, of five officers and 60 other ranks. The Survey Directorate was under the command of Col. F. W. Pirrie, I.A. The Compilation Section was under the command of Major C. P. Gunter. Up to July, 1916, the surveys were carried out chiefly in the neighbourhood of Basrah, and along the banks of the Tigris; by the end of that month some 7,000 square miles of ½-inch work had been completed, with an additional 2,000 square miles of rougher reconnaissance surveys. For the next 20 months the surveys were mainly in the regions near Baghdad and Kirmanshah, with isolated areas elsewhere. And, after March, 1918, the surveys were chiefly in the region of Mosul, and in areas joining up previously executed work. By this latter date, in Mesopotamia and Western Persia, a great block of accurate mapping had been accomplished, stretching from the Persian Gulf to Amadia, and from Hit to Kirmanshah, with an outline as far as Tehran. We may picture it as a block of country 500 miles long and 300 miles wide, but of somewhat irregular shape. Whatever else the war may have done, it has greatly increased our knowledge of the geography of this region.

Lt.-Gen. Sir Percy Lake, writing in August, 1916, after expressing his appreciation of the energy and zeal shown by Colonel Pirrie and his staff, remarked that, "A noticeable feature of the work has been the entire absence of friction with the peculiarly uncertain elements of the population, settled and nomad, of the tracts surveyed; a fact which speaks as highly for the professional advice and assistance rendered by the Political Department as for the tact and intelligence exercised by the Survey Staff."

The Surveyor-General, in his Preface, draws particular attention to the circumstances attendant upon the long march of over 20,000 men to the Dujailah Redoubt, on the night of the 7th March, 1916, expressing the opinion that "if the opportunity presented by this very successful night-march had been promptly seized, Kut would almost certainly have been relieved." Further on, in the body of the book, it is stated that the map used for this operation was compiled from various sources, from the old pre-war river maps, reconnaissances, air reports and sketches. It is asserted that the official accounts "tend to give the impression that the inaccuracies of the map prejudiced success. This is not the case, as a critical study will show." A capable and experienced Survey officer guided the force; the column was accurately led to the point laid down for deployment. This officer does not believe "that any delays in the march, nor any inaccuracies of the map had any effect whatever on the arrival of the head of the column at the time or place appointed nor on the subsequent disaster." Military historians, please note.

It is difficult fully to realize the condition under which much of the surveying was carried out. The floods, which obliged the surveyors to set up their plane-tables in the water, the legs lengthened by bamboos, the surveyors themselves standing in *ballams*; the mist in the early morning, the dust, the haze, the mirage; the suspicious attitude of some of the inhabitants; the storms in the water areas; the reeds, sometimes twenty feet high, in going through which only a time compass sketch could be made; and the heat. As to the heat, it is stated that, when Col. Pirrie guided some armoured cars for sixty miles across the desert, in July, 1917, the shade temperature was 126°, and that during June, July and the first half of August, of that year, the heat was so intense that neither our Army, nor the enemy's, undertook any extensive operations, but "the surveys were continued in spite of the heat."

A point of considerable technical interest is that, at Aleppo, the Mesopotamia triangulation joined on to that carried out from Egypt, so that there is a continuous triangulation, via Aleppo, between the Persian Gulf and the Nile. The discrepancies found at Aleppo, which are partly due to the use of different initial data, and partly also due to the use of different figures of the earth, are not large; namely, about 8" in latitude, 1" in longitude and 30 feet in height. And we may put the direct distance from Aleppo to the Gulf at about 800 miles, and from Aleppo to Cairo at about 600.

The work in N.W. Persia joins on to that in Mesopotamia, and was carried out by a small survey party, under the command of Capt. W. E. Perry, R.E., attached to the Russian Army, with headquarters, early in 1917, at Hamadan. The report on this work gives an interesting view of the almost complete want of discipline in the Russian forces in May and June, 1917. "About the 8th June...the Russian rank and file decided to quit the Diyalah front, and forced the hand of the divisional general. . . . The G.O.C. and the officers generally were in a hopeless position. . . ." The survey party found it impossible to return at once to Baghdad, but had to retire into Persia with the Russians. After many difficulties and some fighting with the Kurds in the Chehar Zabar Pass, Kirmanshah was reached on the 24th June. A good deal of plane-table work was done in September, October and November in the neighbourhood of Kirmanshah, and a junction was effected with Colonel Ryder's Turco-Persian boundary commission survey of 1913-14. This party returned to Baghdad in January, 1918, having surveyed about 4,500 square miles on the ½-inch scale. Shortly after this, a survey detachment, under Lt. D. K. Rennick, was sent to accompany General Dunsterville's force on its way to the Caspian. Then, in February, 1919, Major Rich went to Tiflis to organise a drawing office for advanced G.H.Q., Black Sea Army, an office which was staffed with six Russian ladies and one man! "By the end of the first month the ladies were all very satisfactory 'draftsmen,' good hand printers, and could transliterate names." This office was closed down in September.

As to North-East Persia, in September, 1918, a survey party, consisting of six officers and 32 surveyors and computers, under Colonel H. L. Crosthwait, R.E., was sent to map a large area in the east and north-east of this country. Existing maps of this region were very faulty and the whole survey had to be undertaken *ab initio*. This party travelled to the railhead at Duzdap and then proceeded by road, for 300 miles, to Birjand. The work was carefully organised and there was no opposition; some 40,000 square miles was completed by June, 1919.

A "Miscellaneous" section of the book deals with the work of Survey of India Detachments in Macedonia (under Col. H. Wood, R.E.), Sinai, Palestine and East Africa. As to Sinai and Palestine, the Survey of India was not officially concerned with the mapping of those countries, but Major J. D. Campbell, R.E., was attached to the 7th Field Survey Company of the E.E.F. Excellent work was done on the 1 : 40,000 scale, and various reconnaissances were made in Sinai. It should, perhaps, have been mentioned in the report that Northern Sinai had been completely mapped on the 1:125,000 scale and reconnoitred, *before the war*, by the joint efforts of the Geographical Section of the General Staff and the Survey of Egypt.

Perhaps enough has been said to give an idea of the contents of this interesting War Record of a Department which has never failed, in its long war history, to justify its high reputation. C.F.C.

ENGINEERING SURVEYS.

SURVEYING. By W. NORMAN THOMAS, M.A., D.PHIL., M.SC. B.SC. (Edward Arnold and Co. 1926.) Second Edition. Large 8vo.; 548+viii; 298 illustrations and diagrams. Price 25*s*.

JUST as the term "electrician" may be applied to the necessary individual who attends to the domestic uses of electricity, or to a Lord Kelvin, so the term "Surveyor" may be used of one who sets out the foundations of a house, or to the explorer of a continent, or the investigator of the figure of the earth. It is, therefore, desirable, in reviewing a book on surveying, to indicate its scope and the particular readers for whom it is written. Mr. Thomas, in his Preface, states that the aim of the author "has been to present the subject in such a form as will be useful to students of Civil Engineering at Universities and Technical Colleges, and to those who are going up for examinations held by the Institution of Civil Engineers and the Surveyors' Institution, and to Civil Engineers and Surveyors who are already in practice"; the word Surveyor, in this sentence, meaning the civil surveyor who deals with houses and estates, valuations, the setting out of plans, and such very necessary matters which come generally under the consideration of the Surveyors' Institution.

The first edition was published in 1920. In this second edition the section on Aerial Survey has been re-written and some notes have been added on the Prismatic Astrolabe and Wireless Time Signals. In the body of the book there are, as before, chapters on Spherical Trigonometry and Field Astronomy. But, in the main, the book is devoted to those methods of surveying which may be useful to the engineer, and the whole tone and character of the book is conditioned by the engineering outlook.

It fulfils its purpose well, and engineers who may have large scale surveys to undertake will find it a useful book of reference. It will be equally useful to engineering students; and, indeed, all interested in surveying, will find in the book much to interest them. It is well got out and is generously illustrated. An excellent feature of the book is that the author has been careful to point out and discuss the errors to which the various surveying operations are liable. Thus we have a discussion of the errors which occur in chaining; a discussion of traverse errors, with the derivation of Bowditch's Rule for the adjustment of traverse errors; a discussion of levelling errors; and so on.

As the book is, no doubt, intended chiefly for British engineers, Ordnance Survey practice is freely quoted; a very reasonable thing, in view of the large use made of ordnance maps by engineers and surveyors in this country. We notice on p. 202, the statement that, "It is expected that the field work of the geodetic levelling [of England and Wales] will be completed early in 1920." Now, as the date of the second edition of the book is 1926, this sentence should have been revised; for the Report on the *Second Geodetic Levelling of England and Wales* was published in 1922, the work itself having been finished in 1921. Mr. Thomas would have found some matters of interest in the report.

On p. 385, an account is given of the measurements in 1783 (it should be 1784), and in 1791, of the Base on Hounslow Heath, and the remark is made "bases of verification were measured at the following places, and the measured lengths compared with the calculated lengths:—

Salisbury Plain Base.
King's Sedgmore in Somerset.
. ...
Lough Foyle in the North of Ireland.
Lossiemouth on the Moray Firth (1909-12)."

This might, and probably would, give the impression that the fundamental base is that measured on Hounslow Heath, and that the other bases were measured to ascertain the amount of error accumulated. Actually, the lengths of the bases at Hounslow Heath, Sedgmore, Misterton Carr, Rhuddlan Marsh, and, we may add, Romney Marsh, do not enter at all into the computation of the Principal Triangulation of this country. The Triangulation depends on two bases: that measured on the shores of Lough Foyle in 1827-28 and the Salisbury Plain base of 1847.

Perhaps the least satisfactory chapter is that on Plane Table Surveying; and this chapter appears to the reviewer as unsatisfactory, not because it is erroneous, but because it gives the impression that plane-tabling is a difficult art. The diagrams are really alarming, and are the sort of thing that would be worked up for an examination and that examiners would delight in; it would have been better to have relegated them to an appendix, or to have put them in a note at the end of the chapter. Generally, in fact, there is a certain amount of excellent matter which is not essential for the practical man, and might, perhaps, have been printed in smaller type with advantage.

There is a small slip on p. 109. The Arc of Meridian in question was measured not "north of Lake Tanganyika," but in the Semliki-Ruwenzori region, to the west of Lake Victoria. In the account given of the determination of the Meridian no mention is made of that most useful method, the observation of the altitude of an east, or west, star, near the Prime Vertical.

These, however, are small matters. The book can be recommended, not only to engineers, for whom it was primarily written, but to all interested in the subject. It contains much valuable information, and is written in an excellent critical spirit. C.F.C.

RAILROAD CONSTRUCTION.

By Walter Goring Webb. 8th Edition. (Chapman and Hall.) Price 25/-.

The necessity for the issue of a new edition of this work, after a period of four years, is further evidence of its usefulness and popularity. It continues to be one of the leading treatises giving in a small compass a general survey of all points affecting the design of railway location.

The amendments in the new edition, which occur on fifty-four of its pages, are chiefly concerned with the present recommended practice of the American Railway Engineering Association and post-war operating conditions and costs. Most of these alterations do not call for individual comment, but a list of them will be useful to those who possess copies of the previous (7th) edition.

Chapter II (*a*) Correction of the arithmetical constant in formula (30), for superelevation, from 0.0000572 to 0.0006865.
(*b*) Superelevation in practice.
(*c*) Minimum length of transition curves.
(*d*) Practical formulæ for the 10-chord spiral.

Chapter III	(a)	Classification of railways transferred from Chapter VII.
	(b)	Sodding of slopes.
Chapter IV	(a)	Sizes of stringers for wooden trestles.
	(b)	Sizes of bridge sleepers and fastenings for timber guards.
	(c)	Working stresses in timber.
	(d)	Loads on various parts of trestles.
	(e)	Numerical example of design.
	(f)	Commercial sizes of timber.
Chapter V	(a)	Tunnel cross sections.
	(b)	Tunnel linings.
Chapter VII	(a)	Classification of ballast.
	(b)	Specifications for ballast
Chapter IX	(a)	A.R.E.A. 150 lb. rail.
	(b)	Length of rails.
	(c)	Cant of rails.
Chapter X	(a)	Maintenance of rail joints.
	(b)	Fish bolts.
	(c)	Anti-creep devices.
Chapter XII	(a)	Platform surfaces.
Chapter XV	(a)	Chilled cast iron wheels.
Chapter XVIII	(a)	Tractive effort at various speeds of locomotives using superheated steam.
Chapters XIX and XX	(a)	Post-war operating conditions, operating ratios and costs.
Chapter XXIII	(a)	Variation of draw bar pull due to changes of speed and its application.
	(b)	Operating costs of pusher grades.
Chapter XXIV	(a)	Changes of grade as effected by (a) in Chapter XXIII above.

On page 443, paragraph (*f*), line 5, the word "vaporized" is used instead of "condensed." In line 8 of the same paragraph "vapor" should be taken as meaning condensed steam.

On page 347 the following sentence near the bottom of the page is worthy of the greatest attention. "This is a further illustration of the futility and even danger of quoting costs, or even *unit* costs, except to show the method of applying the particular unit costs which are locally applicable to any individual case." In this connection it should be noted that all the costs in Chapter III, "Earthwork," are the same as those which appeared in editions published before the war. These figures would have been more generally useful if converted to time units for men, animals and equipment and for expendable materials to which local costs could be applied for individual cases.

The instructions for the use of the "automatic slope stake rod," given on pages 116 and 117 of both the 7th and 8th editions, can be greatly simplified, with elimination of considerable arithmetic, if the rules for its use are amended to read—

(1) When setting slope stakes at the top of a *cutting*, read on the face of the rod on which the graduations increase from *top* to *bottom*, and when setting slope stakes at the foot of a *bank*, read on the face of the rod on which the graduations increase from *bottom* to *top*.

(2) Having set up the level, place the rod on ground level on the centre line and adjust the rod-tape so that its reading is equal to the depth of cutting or embankment at that point. Other readings at any points on the ground will then give the heights of these points above formation level in cuttings or below formation level in banks. As the special distance tape gives the same information regarding the side slope of the earthwork coincidence of readings will determine the correct positions of slope stakes.

(3) In sidehill work the above procedure still holds if the centre line and slope stake both refer to cutting or both to bank. When the slope stake is at the top of a cutting and the centre line is on a bank or when the slope stake is at the foot of a bank and the centre line is in cutting, use the rod in the position appropriate to the nature of the earthwork at the slope stake and consider the centre line depth as negative, *i.e.*, the reading through the level, when the rod is on ground level on the centre line, should be 20 minus the depth. When the reading on some other point on the ground becomes zero the earthwork will change from bank to cutting or *vice versa*.

(4) Record in the notes the height of the slope stake above or below formation and its actual distance from the central line as read on the normal side of the tape. A stake should be put in where change from bank to cutting occurs, and duly recorded.

W.G.T.

THE BOOK OF THE LIGHT CAR.

By E. T. BROWN. (Chapman, Hall, Ltd.) Price 7s. 6d.

THE author has set out to explain as simply and briefly as possible the construction of the modern light car. He follows this with advice on the best type of car to buy, how to maintain and drive it, together with hints on how to enjoy a motoring holiday.

Section I deals with the internal combustion engine, 4-stroke and 2-stroke, giving the cycle of operations, etc. There is no new subject matter in this Section, but it is notable that nothing is said about valve timing, or reasons for early opening of exhaust, valve overlap, etc.

Section II deals with fuel supply, lubrication, ignition, transmission, cooling, steering, wheels, springs, etc. The explanation as to how the proportions of air and fuel are regulated by different forms of carburettor are sketchy, and could not convey much to a novice. The section on "Ignition Secrets" is no better, and no worse, than has been published in many other handbooks. The same may be said of most of the rest of this section.

In order to dry the interior of the water jacket and pump during cold weather, the author recommends draining off the water and then running the engine. This seems an unnecessary precaution, since nearly all modern cars have special drain cocks for pumps, and pockets in the cooling system.

Steel cement is recommended for sealing cracks caused by frost in cylinder water jacket. A weld will always make a better job; such repairs can now be cheaply and efficiently carried out by specialists in this kind of work.

Copper rivets are recommended for the fastening of brake linings to brake shoes. The use of aluminium rivets for this purpose is now almost universal.

Section III deals with the choice of a new car, and the various advantages and disadvantages of purchasing a new or second-hand vehicle.

A section is devoted to running costs. The calculations on this subject appear to be on the optimistic side.

Section IV treats of the care of the car, and contains a "Trouble Chart." Various causes of trouble are tabulated, and a reference made to the paragraph where the remedy is to be found in the text.

Some of these references are not very helpful; *e.g.*, a broken piston ring is given as a possible cause of engine stoppage, and a reference made to paragraph 22. This paragraph merely says that a broken piston ring may be a cause of scoring the piston, and that the remedy is to dismantle the engine. No hint is given as to what noises or symptoms indicate a broken ring.

The sections on overhauling assume a higher degree of mechanical knowledge than could be gained from a study of the previous chapters.

The sections on the electrical equipment are rather too general to be of great use. Very little useful advice is given on the care of the battery.

The patching of tyres, and the carrying of a tyre garter, presumably in place of vulcanizing, and the carrying of a spare wheel are recommended. Both patches and garters are abominations in the opinion of the reviewer.

Section V deals with the art of driving; double de-clutching, etc., is explained, cross-road risks, skidding, and driving in fog are also touched on,

Section VI gives a number of facts that should be known by all motorists. Most of these are almost self-evident. There are many illustrations of doubtful types of light car, but these are merely pictures, and show nothing of the mechanical details of the types selected.

Generally speaking, the book is amateurish, and there is little in it which has not appeared in print many times before. G.C.G.

MAGAZINES.

REVUE MILITAIRE FRANCAISE.

January, 1926. In the second number of *Verdun—Le Premier choc à la 72e Division*, Lieutenant-Colonel Grasset gives a vivid description of the original onslaught on February 21st, 1916. The sudden change from peaceful conditions to the unparalleled violence of the opening bombardment is most realistically described, and the author succeeds in bringing out the terrible uncertainty and chaos which were nearly always a characteristic of the early stages of a great trench warfare attack. The climax was reached when the Commander of the 72nd division was suddenly ordered to move his headquarters forward during the day, further dislocating the organisation of the sector and crowding up an already harassed infantry brigade headquarters. The number closes with the various commanders in a state of suspense, ignorant of their losses both in terrain and troops.

Lieutenant-Colonel Baills, " Directeur du Génie " at Nantes, completes his *Essai sur l'Emploi tactique du génie* in this number. The role of divisional engineers in attack and defence is discussed, the general conclusions being similar to those arrived at in our own Army, with the exception that the author envisages the C.R.E. of the division, accompanied by the bulk of the divisional engineers, moving with the advanced guard, in readiness to undertake any engineer work which may arise. It would appear that there is a risk of divisional engineers being used up at an early stage of the battle under this system. The article concludes with a discussion of the effect of track vehicles on demolitions.

L'offensive de Bonaparte contre l'Angleterre begins in this number with a preliminary discussion of Bonaparte's strategy and a description of his voyage to Egypt in 1798, during which he was successful in evading the attentions of Nelson and the British Fleet. It is interesting to see how, even in the days of the French Revolution, an occupation of Egypt by France would have proved a menace to our far Eastern possessions; Bonaparte's object in invading Egypt was to attain a secure base for an attack on India. The manœuvres of the French and British fleets are illustrated by a sketch map.

Une attaque de nuit au Maroc, by Capitaine Damidaux, is chiefly interesting in the description of the methods by which the attacking troops were able, by careful preparation and minute precautions, to surprise the Rifis and occupy their positions in sufficient strength to beat off the inevitable counter-attacks. The sketch maps are rather meagre and give an inadequate idea of the country.

In *Dressage des Cadres à la recherche du renseignement*, Lieutenant-Colonel Paquet describes the preparation of an exercise carried out with the object of training the intelligence organisation of a division in the field. The various intelligence staffs and personnel, together with sufficient signals and aircraft are involved, the whole operation being controlled by a directing staff and made realistic by the employment of a skeleton enemy. The most interesting part of the article is that devoted to the action of the skeleton enemy, particularly with a view to producing appropriate air reports. The importance and difficulties of umpiring are fully discussed.

In *Les cables téléphoniques souterrains*, Capitaine Jaubert discusses the inadequacy of the present overland system of telegraph and telephone lines, and gives a forecast of future developments in underground electrical communications.

February, 1926.—In the third number of *Verdun—Le Premier choc à la 72e Division*, Lieutenant-Colonel Grasset deals with the night of February 21st-22nd, and the various attempts at counter-attack made by the 72nd division. In particular, a brilliant little operation conducted by Lieutenant Robin, with the remnants of a company of the 59th battalion, succeeded in clearing the northern outskirts of the Bois des Caures. All efforts to re-capture the Bois d'Haumont, which had been lost in the original onslaught, were unsuccessful. Throughout this period the inadequacy of the signal communications are most apparent, especially when all the heavy guns of the 30th Corps were placed under one commander at midnight, although adequate communications were not available. The sketch map illustrating this period is to be found in the March number.

L'offensive de Bonaparte contre l'Angleterre is concluded in this number. The author points out that, once the French Army had landed in Egypt, a fleet in being was essential to the success of Bonaparte's plans. He suggests that Admiral Brueys should have occupied a secure base on the flank of the communications between Toulon and Alexandria, *e.g.*, at Corfu, with the view of changing the French base from Toulon to Venice. By moving to Aboukir Bay, Brueys laid himself open to destruction by Nelson, thereby making the realisation of Bonaparte's plans impossible.

Commander " X " begins an interesting article entitled *Réflexions sur la Compagne Riffaine.* He describes the methods employed by Abdel Krim in the subjugation of the tribes under French influence and points out the alternative methods for opposing the Rifi chieftain. Owing to the failure to provide adequate support for the friendly tribes in the early stages of the campaign, the employment of strong forces of all arms, especially tanks, became necessary to crush the Rifis.

Lieutenant-Colonel Paquet completes his article, *Dressages des Cadres à la Recherche du Renseignement*, with a detailed description of the methods employed to train the intelligence organisation of a division (particularly the " 2e Bureau ") during an exercise on the ground. The control of operations by the directing staff, with particular reference to the methods of obtaining reality in the photographic reconnaissances ordered by divisional headquarters, is well worth study. The value of this type of exercise depends almost entirely on the skill of the umpires and the handling of the skeleton enemy.

In *Une Opération de Guerre de Montagne (Carpathes*, 1916), Capitaine Flipo describes a series of actions between the 61st Austrian Division and the 7th Rumanian Division, taking place from October 15th to 17th, 1916. The Austrian troops were unaccustomed to mountain warfare, while the Commander of the 14th Rumanian Brigade, which was chiefly involved, had been accustomed to the theatre of operations throughout his service. The result was the defeat of the Austrians, rendered incomplete, however, by faults in execution on the part of their adversaries. The interest of the article is rather spoilt by the inadequacy of the sketch maps.

Commandant Besnard, in *Synthèse du Mouvement*, points out how mobility has always been a characteristic of the operations of the great commanders. He then discusses the various means of locomotion of modern armies, from the men's muscles to the tank, and continues with a description of the various phases of movement, leading up to the encounter battle. Movement in battle is discussed in the next number.

March, 1926.—The fourth instalment of Lieutenant-Colonel Grasset's *Verdun—Le Premier Choc à la 72e Division* describes the resumption of the German attack on February 22nd. It was not till the evening that the defenders were able to stem the tide by the occupation of the second main line of resistance, two regiments having been sent up as reinforcements by Corps headquarters. The outstanding features of this phase are the heroic but unsuccessful defence of the Bois des Caures by Lieutenant-Colonel Driant with the remnants of the 56th and 59th Battalions, and the difficulties of General Bapst, commanding the 72nd Division. Orders from higher authority, to the effect that not an inch of ground might be given up, fettered his initiative; when he considered it essential to evacuate Brabant on his left flank he was unable to obtain a definite authority to do so; and he had to move his headquarters again owing to lack of communications at Vacherauville.

Commandant " X " completes his *Réflexions sur la Campagne Riffaine* by an interesting discussion of the political and military organisation best suited to the local conditions. He considers that Marshal Lyautey's principle of combining the political and military direction of the various districts is thoroughly sound, and that an organisation of mixed brigades would allow of greater mobility and freedom of action than the more rigid divisional system introduced by the appearance of the Metropolitan Army.

La Prise de Contact et l'Engagement, by Capitaine Nalot, is really an expansion of the principles laid down in Field Service Regulations with regard to the preliminary stages of the modern battle, together with a comparison with the doctrine of the pre-war regulations.

Les Debarquements Alliés aux Dardanelles, by Commandant Desmazes, gives an excellent outline of the events leading up to the operations and of the original landings. The author offers no criticisms, but the facts are presented clearly, and a paragraph on the action of the Turkish forces during the various stages of the operation is of particular value.

Commandant Besnard completes his article, *La Synthèse du Mouvement*, by a discussion of the principles of fire and movement as applied to the present day tactics. The article concludes with the transition from the unbroken firing line to the modern methods of attack by small groups at irregular intervals, caused by the development of automatic weapons.

Les Transmissions au Maroc describes the development of Signal communications during the operations against the Rifis. A considerable portion of the article is too technical to be of general interest, but it is instructive to note the great lack of communications at the outset of the campaign and the enormous strides that were made as the supreme importance of communications in such dispersed operations became evident.

REVUE DU GENIE MILITAIRE.

April, 1926.—*The Launching of Metal Road Bridges*. The conditions for launching a road bridge differ from those for a railway bridge in that the latter can usually employ a launching nose—whereas with the former the slope of the approach and sharp curves frequently preclude this method.

The "Pigeaud" bridge of the smaller type (up to 37.5 metres span) in use in the French Army is assembled across the gap by means of a footway slung on cables. This method can be used for bridges of one or more bays, but is not so convenient for the heavier bridge of 51 metre span—for which four methods are discussed:

(1) A constructional bridge of light piles or trestles;
(2) Trestles erected on floating supports;
(3) Derricks and tackle.
(4) A combination of (2) and (3).

These methods are discussed in detail and the application of No. 3 to the Hopkins Bridge is noted with approval and formulæ for calculations are given.

The writer sums up that it is undesirable for the Engineer units to be encumbered with special equipment for the erection of bridges, and considers that a suitable collection of winches, blocks, tackles and derricks should enable any type of bridge to be erected, repaired or removed in any position.

The Bamboo. Points out the merits of the material and gives figures for compression and transverse strength of poles of the male bamboo and the value of the female bamboo for transverse strength and as a material for a raft.

The latter is useless as a pile and has little or no resistance to compression.

The Demolition of eight Chimneys. Details of the chimneys and the method of destruction, time and labour involved.

"*Données Numeriques.*" Details of time, material and labour on various works executed by units of engineers.

Ordonnance du Roi. The text of a Royal Order in 1744 creating the "Corps du Genie."

May, 1926.—*Study of the Stresses on a Cable laid across a River.* An elaborate calculation ending with the statements that conditions of the river bottom usually render such calculations useless and that the greatest stresses are incurred in the process of laying the cable.

The Organisation and Operation of Military Workshops in the Field. The author affirms that good operation follows early from a satisfactory organisation; he points out the many difficulties which distinguish a military workshop in the field from a civil shop, together with the advantages, and gives advice that would be useful to any Officer starting or operating a military workshop.

June, 1926.—*The Theory of Land Mine.* A theoretical investigation of the height and distance of projection of soil and of the shape of the projected mass from a mine.

New Locomotives for Express Trains. A description of 2-4-1 engines adopted for heavy expresses on the French Railways.

Pack Transport of Pile Drivers. A description, with illustrations, of a method designed for carrying the equipment type pile driver on mule transport—one mule hauled a two-wheel truck carrying the monkey.

The load (including harness) for eight other mules was about 150 kg. each mule.

A 66-foot Single Span Footbridge. Built of light spars, not exceeding 5 to $5\frac{1}{2}$ inches butt diameter, and wire, and erected by 120 men in 24 hours.

A bridge of similar design to carry a single vehicle of two tons axle load could be erected by 120 men in 36 hours.

H.G.K.W.

BULLETIN BELGE DES SCIENCES MILITAIRES.

(1926. Tome I. Nos. 1-3 inclusive.)—*Les Opérations de l'Armée Belge* (1914-1918). On the evening of October 8th, 1914, the situation at Antwerp, as disclosed in reports reaching the Fortress Headquarters, was such that General Déguise felt justified in authorising the abandonment of the "Second Line of Defence," but, before sanctioning this course, he held a conference at his Headquarters at which the Commandant of the "Second Line of Defence" and the Commander of the Royal Naval Division were present. Further reference is made in the original article (No. 1 of the issue) to the part played by the R.N.D. at this time, and it is stated therein that, although it was known at Fortress Headquarters that General Paris had during the day been in telephonic communication with London, General Déguise was given no information as to the tenour of what had passed during the conversations between Antwerp and London, nor was he aware of the nature of the instructions left with the Commander of the R.N.D. by the First Lord of the Admiralty on his departure for England. We have here another unfortunate example of the difficulties which arise, as they are bound to do, when two or more authorities attempt, independently of one another, to conduct military operations in a restricted area; from every point of view, the wisest of all courses would have been to have given General Déguise supreme authority in the Antwerp zone and to have allowed him to conduct the operations for the defence of the Citadel as seemed to him best in the light of the "intelligence" reaching his Headquarters. In the actual circumstances, nothing could have prevented the Fortress falling eventually into German hands, but it could not then have been suggested that the surrender was accelerated by this or that independent act of an Ally.

The measures taken for the withdrawal of the R.N.D. and the Belgian 2nd Division are described; in connection therewith instances of bad staff work are brought to light; fortunately, no very serious penalty had to be paid therefor. The Germans seem to have still remained unaware of the fact that the Anglo-Belgian troops had begun to abandon the defence of the outer positions of the Fortress. In view of the decision to withdraw from the "Second Line of Defence," steps were now taken by General Déguise to transfer his Headquarters to Calloo, on the left bank of the Scheldt. At this time some of the forts of the principal line of defence were still holding out; no modification having been made in the orders issued on October 6th, the Commanders of these works had to act independently of one another and to the best of their own judgment. The German effort was now being directed chiefly against the Anglo-Belgian positions in the 3rd and 4th Sectors of Defence, and on October 8th the enemy's main attack was being pushed against the works covering the bridge over the Rupel at Boom.

Particulars of the situation in the forts of the principal line of resistance are given in No. 2. A description is also given of the old enceinte designed by Brialmont and its condition at this date. Orders were issued at 6.30 p.m. on October 8th by the Commandant of the Enceinte to Commanders of the two Sectors under him to put up an obstinate defence on the old ramparts of the city. Instructions had already been issued for the demolition of the temporary bridges at Sainte Anne and Burght as soon as the withdrawal of the R.N.D. and the Belgian 2nd Division, *via* these bridges, had been completed; the necessary orders had also been given for the destruction of the drawbridges, etc., on the roads leading through the ramparts. It was intended that the fortress troops should, when the necessity arose, be transported across the river in tugs, ferry-boats and other craft collected for the purpose—chiefly at Lillo. However, owing to the hurry and confusion in which the retreat of the Belgians was carried out, the demolition work was not done systematically and with thoroughness; in consequence, several bridges, etc., were left intact and became available for the use of the enemy.

At 8 p.m., on October 8th, General Déguise and his Staff crossed the river and the Fortress Headquarters were now established at Calloo, between the 5th and 6th Sectors which formed the retrenched camp on the left bank of the Scheldt. There seems to have been no end to the chapter of accidents connected with the defence arrangements; General Déguise's difficulties appear to have been increased owing to the fact that the Fortress Supply Officer closed down his office in Antwerp and moved his headquarters to Ostend; he acted under instructions issued to him direct by the War Minister, of which intimation was not passed on to the Fortress Headquarters.

A description of the retrenched camp on the left bank of the river—which was the weakest part of the Antwerp defences—and the situation at this time in the 5th Sector—are dealt with in No. 3.

La Bataille des Frontières. The articles under this title in these three numbers are contributed by Major van Overstraeten and deal with the operations on the French frontier at the commencement of hostilities in 1914 and are of considerable interest.

La Problème de la Direction de la Guerre. In this article, contributed to No. 1, Captain-Commandant Dendal deals with the conditions under which a modern war between great nations is conducted. He points out that the considerations which now affect military operations are no longer confined mainly to the factors associated with the field of battle, but those lying in the political, economic and social domains also come prominently into play and create most powerful influences in military plans. A modern war is waged, he reminds us, on four fronts, viz., *le front militaire, le front diplomatique, le front économique,* and *le front intérieur.* The article is a valuable contribution to military literature.

Le rôle et le fonctionnement des assemblées parlementaires en temps de guerre. Captain-Commandant Dendal is also the author of the article under this title appearing in No. 3; the theme of the same is really a continuation of the subject dealt with in the other article by him previously mentioned in this notice. Complex questions relating to the functions of a Government and a Legislature and the part they are required to play after the outbreak of hostilities, and during the continuance of an important war, are ably discussed, but cannot with advantage be summarised in the space available for the purpose in this *Journal*.

REVUE MILITAIRE SUISSE.

(1926. Nos. 1 to 6 inclusive.)—*L'organisation Général de l'Armée Moderne.* The original article, which appears in No. 2, is contributed by General Rouquerol; in it he points out that, in spite of the aims of well-intentioned people who are seeking to establish an era of perpetual peace, it still behoves nations which value their freedom and characteristic institutions to be prepared to defend them in the old-fashioned way. Armies, therefore, are still a necessity, and must be maintained in the highest state of efficiency. The requirements in connection with the recruiting of conscript armies are discussed, and the outline of an organisation for such armies suggested. The probable course of the opening phases of a war of the immediate future is sketched by the author, who points out that, although aerial warfare is likely to play an all-important part in the very early phases of a campaign, land defences have not lost their value; therefore, where permanent fortifications exist, the question of their "rejuvenation" should be considered, and, where necessary, the defence system should be remodelled to bring it up to date.

La défense anti-aerienne. In an article, in No. 2, under the foregoing title, Lieutenant E. Naef deals with the several defensive measures against aerial attack and the requirements in each case. Defence by means of air-craft counter-attacks; by means of anti-aircraft artillery; by means of *camouflage;* and by the employment of aerial entanglements, are each briefly reviewed.

L'évolution nécessaire de notre Stratégie Défensive. The problem of the defence of Switzerland, as affected by the progress in armaments and the changed conditions under which wars are waged, is discussed in No. 3 by Colonel R. de Diesbach.

Oppositions Tactiques Franco-Allemand. Captain R. Masson, in an article contributed to No. 3, examines, under the foregoing title, the contents of two recent publications—*Material oder Moral*, by General von Taysen, and *La Guerre n'est pas une Industrie*, by Colonel Alléhaut—in which the German and French views in relation to the tactical employment of troops, based on the experiences of the Great War, are set out.

Quelques Notes sur le Plan de Feux dans la Défensive. The original article appears in No. 4, and is contributed by Captain Montfort, who deals therein with the role of infantry, armed with machine-guns and automatic rifles, in a prepared defensive position.

Les Ailes de Demain. The progress in aviation made in recent times is briefly reviewed under the foregoing title by Lieutenant E. Naef, in No. 6.

W.A.J.O'M.

CORRESPONDENCE.

OURSELVES.

DEAR SIR,

Captain Kerrich's most interesting article gives abundant food for reflection, but there is one matter which does not seem to have been sufficiently considered, and that is, What is expected of R.E. officers "from the point of view of the Army (which is the only thing that really matters)"?

The points of contact between R.E. officers carrying out their work and officers of other arms are too plentiful to enumerate, but when they turn to us in their trouble, whether it be a choked drain behind the cookhouse, failure of light in the officers' mess, lack of water in a camp, or a thousand and one things on service, it is as Engineers that they seek us, and it is by the manner in which the engineering difficulty is overcome that they will judge us. Tact is, of course, essential, but the officer with whom you are dealing will very soon spot whether you are competent to diagnose the source of trouble correctly, and, in the case of a piece of machinery, put it right with your own hands, or have to call in the assistance of your M.F.W. or a mechanic before you can make a start on the job.

In these days of mechanical and electrical appliances, I am much surprised that Captain Kerrich should suggest any reduction in the time spent on those subjects at the S.M.E. Any subaltern on active service may find himself confronted with damaged or worn-out engines, pumps, or electrical apparatus, which he has somehow or other got to make to go, and the Army at large will expect him to do it.

It was their technical qualification and experience as engineers that made our temporary officers so valuable in the Great War, and the extraordinary efficiency of the Australian Pioneers was largely due to the fact that their officers were engineers by profession before they joined up.

To revert to Captain Kerrich's article: what are likely to be the feelings of a junior R.E. officer after carefully studying it? Let us hope that he is optimistic, as he may very well be, considering the variety of the upward paths open to him, along which Providence and the A.A.G.R.E. will guide his steps. He will have his own tastes to consider, and he will probably look round to see which way the plums lie. If his ambition leads him to aspire to Westminster Abbey, or St. Paul's, or even to decorate the walls of the Chatham mess, he will quickly realise that bricks and mortar, or pumps and switch boards, are not going to help him much in that direction. Obviously he must get *p.s.c.* after his name as soon as possible. Thereafter he will aspire to command something other than the R.E. of a Division, in fact, a Brigade of Infantry, since Brigades of Cavalry and Artillery, and the Higher Commands of Tanks are "close boroughs." A staff job will come to him in due course: he should find Q work as easy as falling off a log; G work would be more to the taste of one aspiring to a command in the future, but the competition is fierce.

The R.E. officer who deliberately goes in for a career on the Staff must recognise that he will to a certain extent lose touch with his own Corps, and he will never have that feeling towards it, and especially to our incomparable N.C.O's. and Sappers, which is only to be acquired through continuous service in R.E. units and R.E. appointments.

Further, in the matter of picking up the rewards that military service holds out to the successful, though in peace time his prospects may be good, on service he will have to rely solely on his own performances, and will not be in a position to accumulate automatically the credit achieved by the R.E. units serving in his General's command, or by other R.E. officers serving directly under him. If he fails to give satisfaction on the Staff, he can revert to Corps duty, and may arrive at the position of C.E. of a Command, but he will then be lacking in up-to-date engineer experience, and may find it difficult to conceal the fact; possibly he may fail again.

On the other hand, an Officer who sticks to the Corps, and spares no trouble to keep himself up-to-date both as regards engineering and the military art, will fill with credit to himself all the posts in the Corps that his seniority leads him up to, whilst on his way he may get the chance to switch off to a job in civil life, and find his reward in a reduced pension, but a considerable private income for life.

The great charm of continuous service in the Corps is the variety that it offers: even simple matters of building construction are differently handled in the various parts of the world in which we serve, and there is always that satisfactory feeling that all the officers and men whom you may have under your command will, under all circumstances, play up.

R. U. H. BUCKLAND,
Major-General, R. of O.

THE LATE COLONEL HENRY VERO BIGGS.

DEAR SIR,

In the obituary notice of Colonel Henry Vero Biggs, R.E., there was no mention of his greatest achievement, the achievement which perpetuates his name, *i.e.*, the invention of the "Biggs's Arm-Rack" for rifles and carbines. This pattern was approved by the Government of India to the exclusion of all other designs, and is in use from end to end of India. By means of cleverly arranged bolts, actuated by a small key in a countersunk lock, all the rifles (or carbines) are "locked" simultaneously in the stand. If any rifle is not correctly inserted in its place, the lock won't "work," and so discloses the carelessness which must be rectified. This pattern of rack has saved the theft of numberless rifles, especially on the frontiers, and Biggs got a monetary reward from the Government of India for his invention.

I would have written before, but I felt sure someone else would have drawn your attention to the omission.

Biggs was a most ingenious inventor of all sorts of appliances for shikar expeditions and building operations.

Yours sincerely,
G. P. CAMPBELL.

ARTHUR FFOLLIOTT GARRETT PRIZE ESSAY, 1926.

Subject selected :—"Survey on Active Service."

The Essay is to take the form of a Report and recommendations on the following points which arise in connection with the particular case outlined in paragraph 2 :—

(a) As Director of Surveys, appreciate the situation from the survey point of view and state the policy and programme that you would adopt. Is it likely that more than one scale will be necessary? What projection would you employ and what steps would be taken to begin Survey operations?

(b) Do you consider the resources of the Field Survey Company adequate in personnel to undertake the programme you have outlined? If not, what additional personnel do you consider necessary? What reply would you make to the offer of the Colonial Survey given in paragraph 7? The issue of maps and photographs is to be done by you down to Brigades and Divisional Troops. What arrangements would you make?

2. The Force consists of 2 Divisions and 1 Cavalry Brigade with the normal proportion of Non-Divisional and L. of C. Units. These include 1 Field Survey Company plus Photographic Section and 1 Map Depot. All are at small war establishment. A third Division with additional non-divisional troops is to be sent out later if required.

3. The Base will be a small seaport town of about 10,000 inhabitants in a somewhat backward country. The objective will be 100 miles inland. Landing and advance will be opposed. The attitude of the civil population is uncertain. Operations are not expected to last more than six months, but are expected to include one decisive battle. The enemy is in possession of 3 Batteries of Modern Field Artillery and is plentifully supplied with modern machine guns and rifles.

4. Local topography may be divided broadly into the following zones :—

(i) The coastal part, average width about 20 miles, is heavily timbered (virgin forest) and includes large areas of mangrove swamp. Visibility poor.

(ii) The second zone, 5 miles in width, is composed of small foot-hills rising to the terrace edge of zone 3. The conditions are those of open English park land. Visibility fair.

(iii) Zone 3. Starting at a height of 3,000 feet the country rises progressively to 5,000 feet at the objective. There is little or no timber and the visibility is known to be good.

5. There is no railway and there would be considerable difficulty in constructing one across Zones 1 and 2. Roads are not numerous and are all unmetalled except the main highway to the objective. Country transport includes both carts and pack transport.

6. The Base selected and its immediate environments are fairly well mapped at the scale of 2-inches to the mile. A very bad ¼-inch map, almost blank for Zone 3, contains the only detailed topographical information.

7. The Survey Department of a neighbouring Colony has offered the services of a small volunteer geographical unit raised from its staff. The offer has been provisionally accepted and further details as to what is required have been promised.

Notes on Stores and Equipment.—1. The topographical section armed with revolvers and issued with pantaloons may be mounted if necessary.

2. The stores and equipment for trigonometrical and topographical surveying may be taken as adequate (for the numbers) for any method given in the Text Book of Topographical Surveying.

3. The printing machinery includes 1 double demy flatbed machine (500 copies per hour in one colour) and two proving presses. The camera takes double demy negatives and both helios and vandykes can be made.

Essays must reach the office of the Secretary, Institution of R.E., not later than the 30th November, 1926. Essays must not be signed, but each essay must bear a pseudonym, and the name of the writer, enclosed in a sealed envelope marked with a similar pseudonym, must be attached.

The following are the conditions of the Arthur ffolliott Garrett prize :—

1. The prize, which will take the form of a piece of plate, to be chosen by the the recipient, was instituted by Mrs. Garrett in memory of her late husband, Major Arthur ffolliott Garrett, O.B.E., R.E.

2. Qualifications of the recipient: To be an officer on the Active List of the Royal Engineers, not above the substantive rank of Captain on 1st January, 1926.

3. The essay must not exceed 6,000 words.


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BOWLS
AND
TROPHIES
MAKERS of Silverware for nearly half a century, the Goldsmiths and Silversmiths Company place their experience at the disposal of Secretaries, Committees and others interested in the choice of prizes. They invite inspection of their large and varied stock of Cups, Bowls and Trophies, and will be pleased to send a selection for approval at their own risk and expense. A Special Catalogue of Prizes will be sent on request.
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MONTGOMERIE PRIZE.

ATTENTION is invited to the conditions under which this prize, in value about £10, is offered for competition each year.

1. The Prize shall be awarded by the Council of the Institution of Royal Engineers in the manner considered best for the encouragement of contributions on professional subjects, by R.E. officers, to the Corps publications. From the beginning of 1920 it was decided that the Prize should be offered to officers on the Active List not above the rank of Substantive Major.

2. The Prize shall consist of (*a*) a book on Survey, Exploration, Travel, Geography, Topography, or Astronomy; the book to be whole-bound in leather, and to have the Montgomerie book-plate with inscription inside; (*b*) the remainder of the year's income of the Fund in cash.

3. The name of the recipient of the Prize shall be notified in the Corps publications; and copies of the contribution for which the Prize was awarded shall be presented to the representatives of the donors.

The following are suggested as subjects for contributions:—

- (*a*) Descriptions of works actually carried out in peace or war.
- (*b*) Inventions.
- (*c*) Design (excluding works of defence).
- (*d*) Labour organization on work.
- (*e*) Scientific investigations generally.
- (*f*) Accounts of exploration work and surveys.

KARACHI AND CARDINGTON AIRSHIP SHEDS.

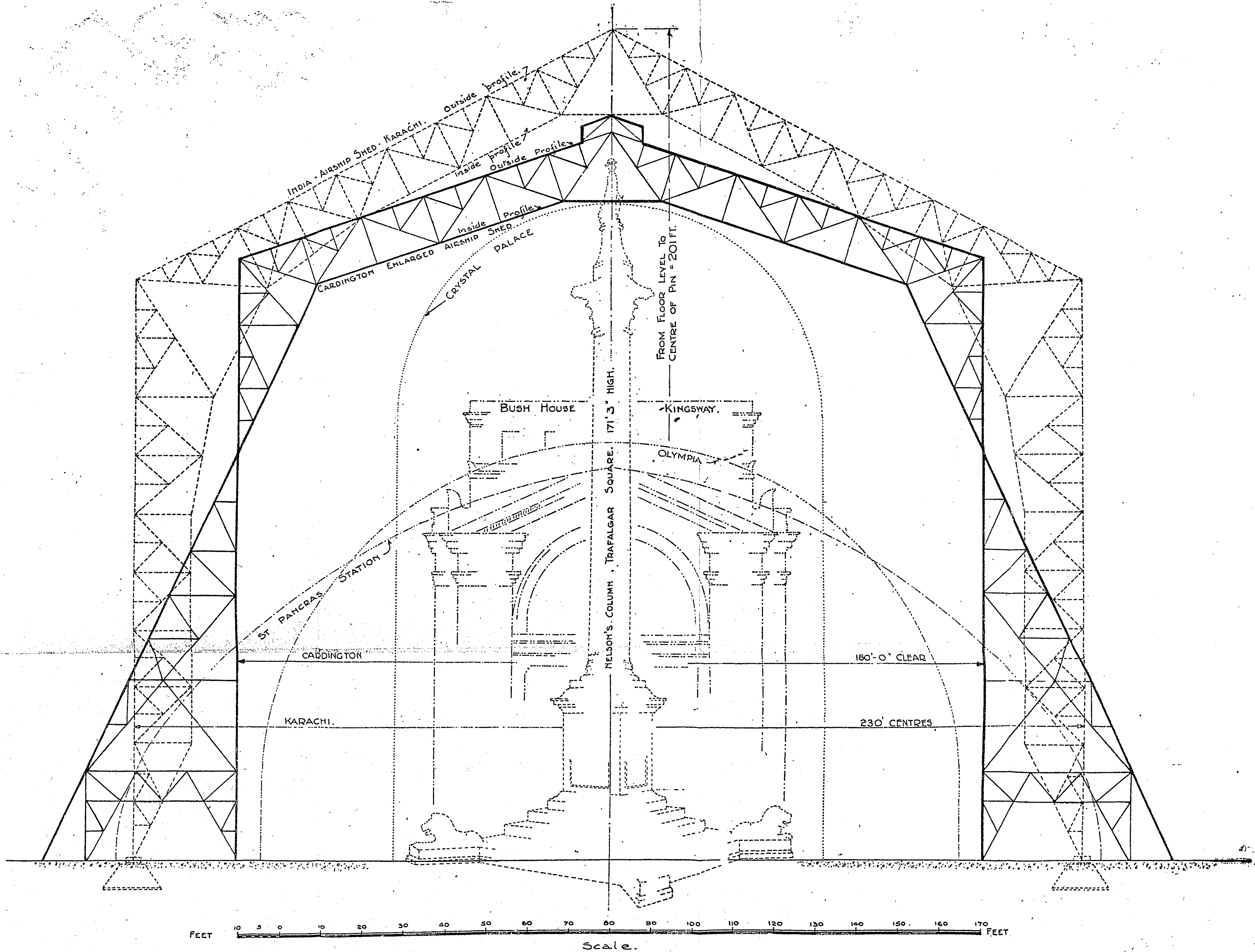


FIGURE: 9.

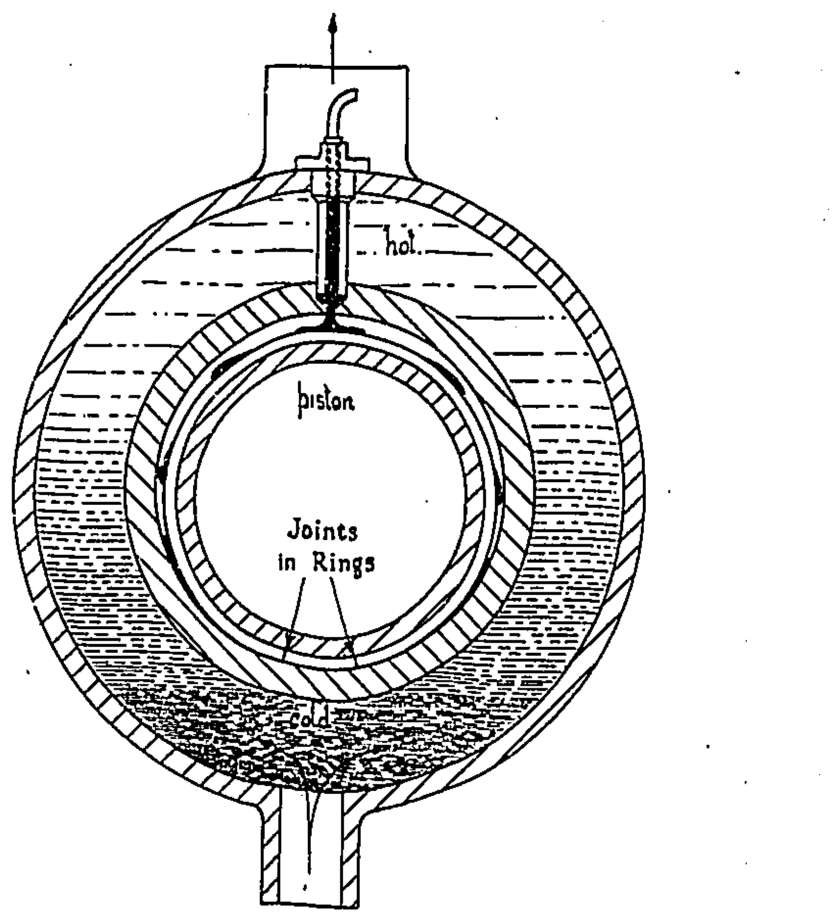


Fig. 5. Diagrammatic Cross-Section of Horizontal Cylinder. Note how the oil fed on top of piston works round it and gravitates to the bottom where it is most needed. Also how the coldest water is at the bottom, thus making lubrication there more effective. Also that the joints of the piston rings are at the bottom, where the body of the piston makes contact with the cylinder, and prevents the high pressure gases getting behind the piston rings.

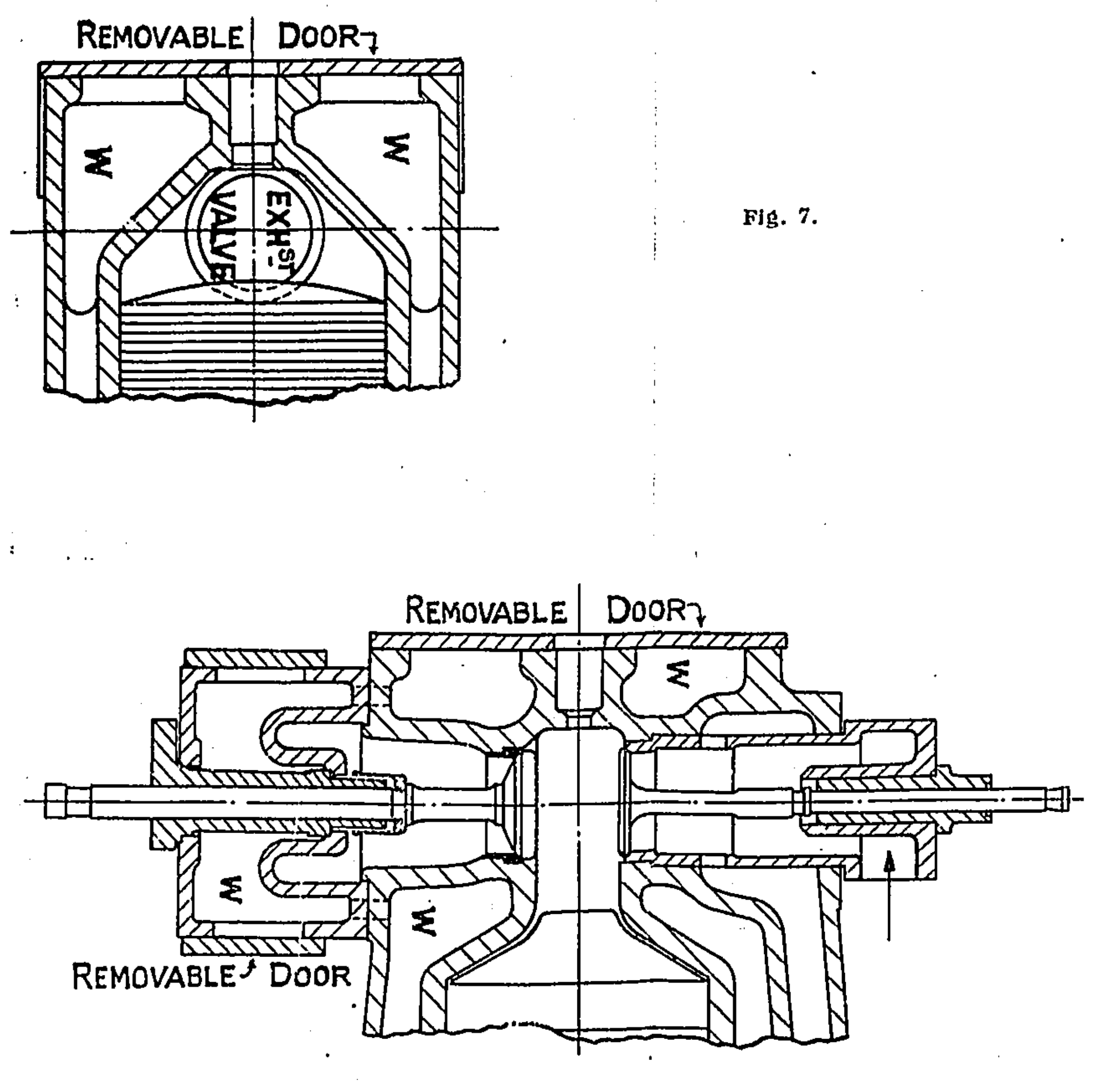


Fig. 7.

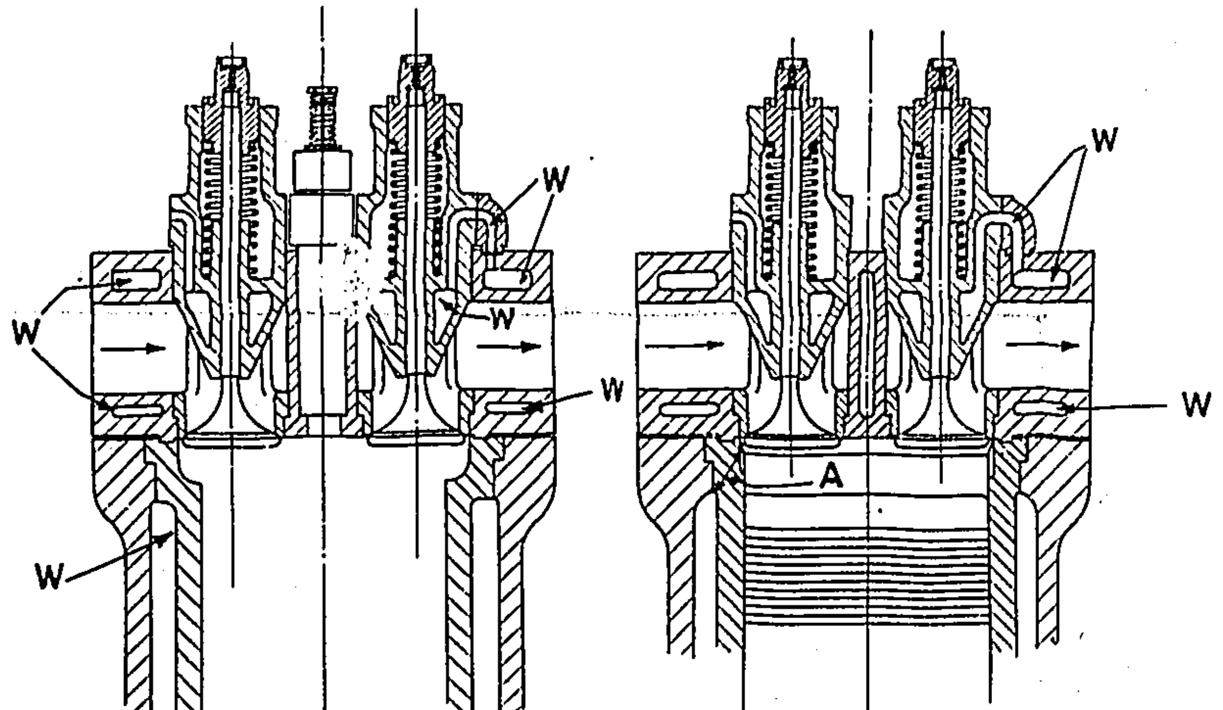


Fig. 6. Section through cylinder heads of Vertical Oil and Gas Engine of usual construction. Note the defects of this design as to heat conduction from the top of liner along passage A to badly circulating water. Also constricted water passages W, difficult to clean and easily blocked with scale. These defects may result in cracked castings.

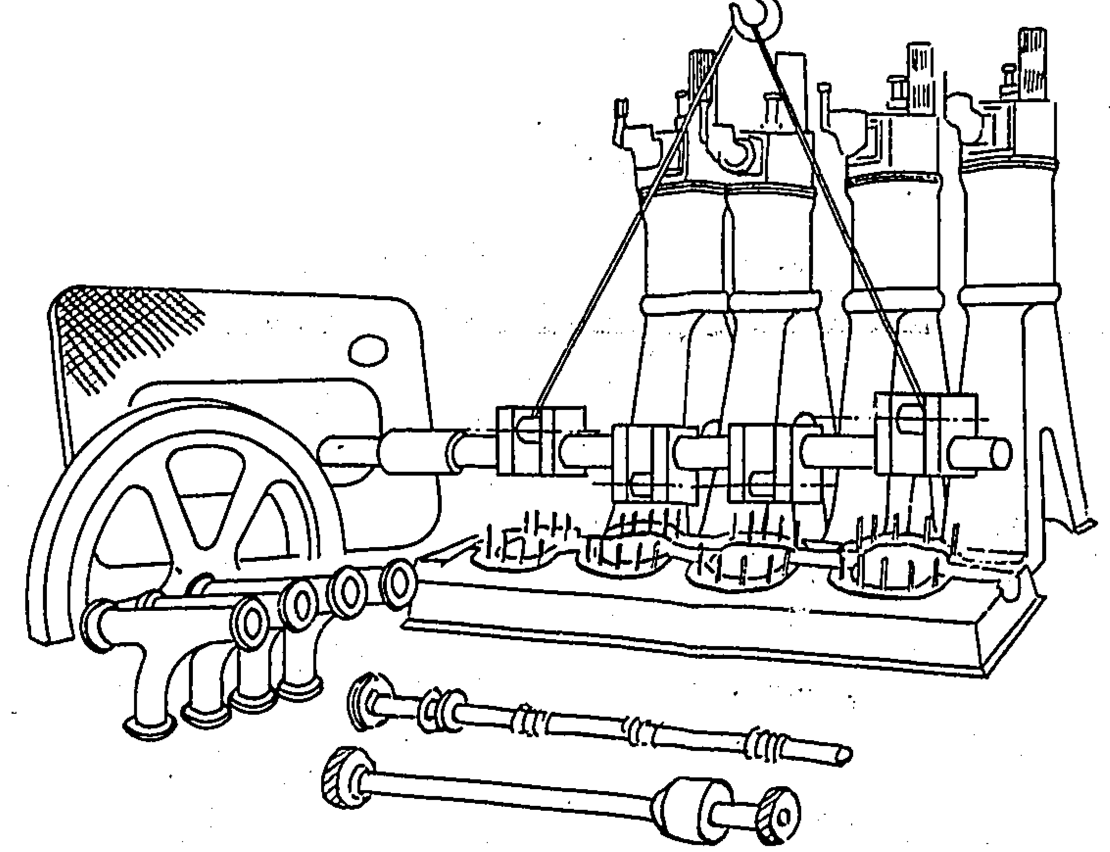


Fig. 8. To carry out an inspection, repair, or replacement of a crankshaft, practically the whole of this Vertical Engine must be dismantled, as shown.

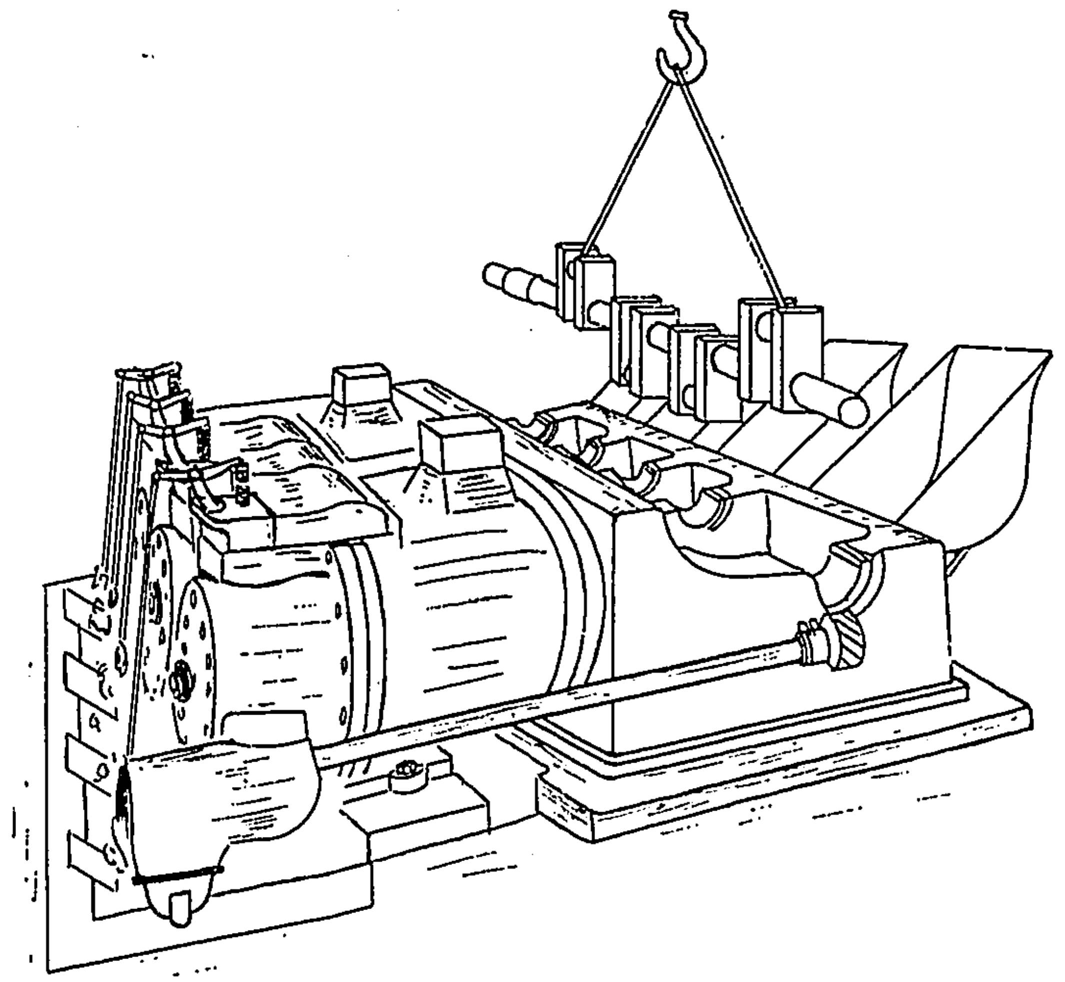


Fig. 9. A horizontal crankshaft can be inspected in place after disconnecting the big ends and removing caps and top halves of bearings, as it is all in the open. Or it can then be removed from the engine after taking off the flywheel.

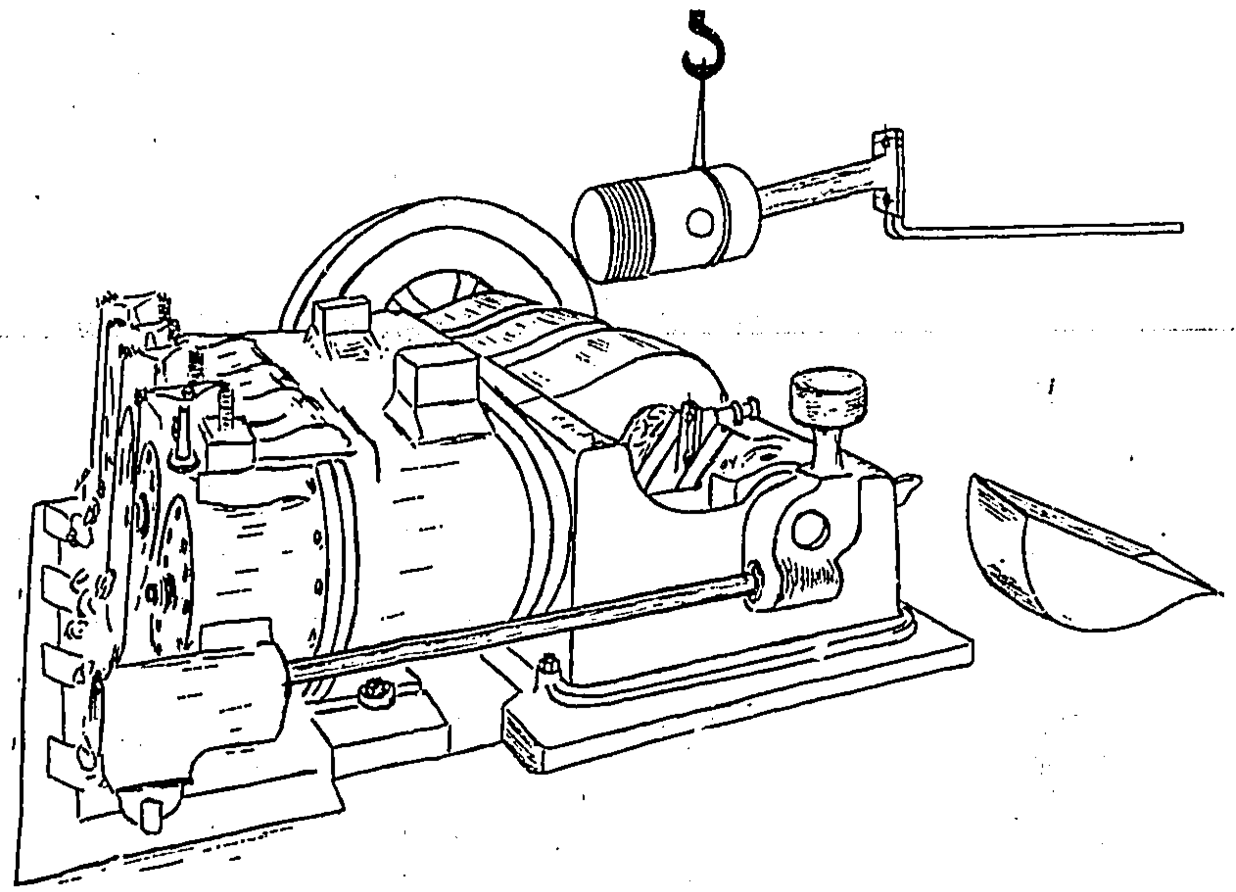


Fig. 10. Showing ease of piston removal in a horizontal engine.

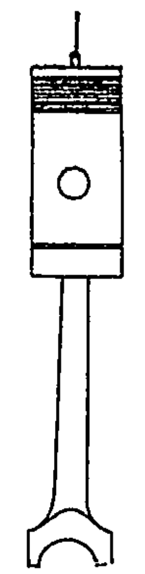
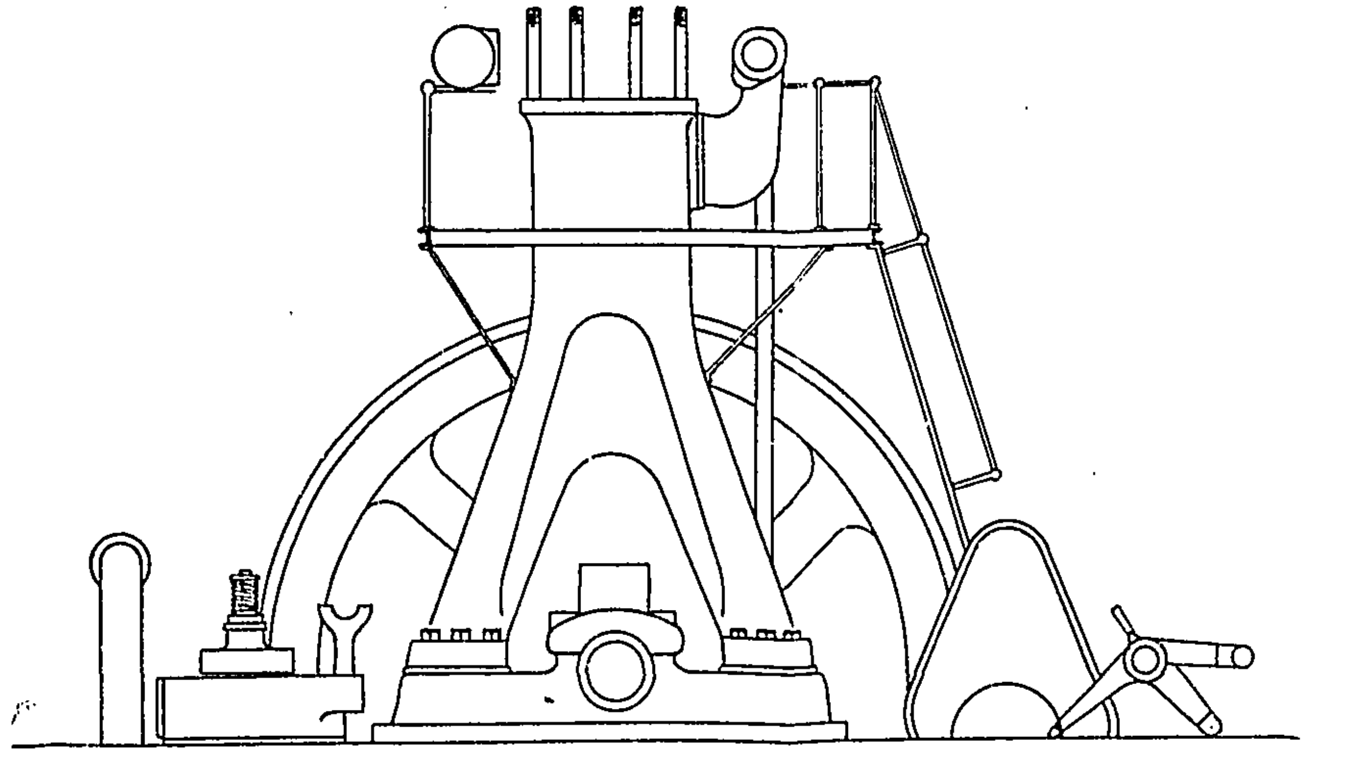


Fig. 11.



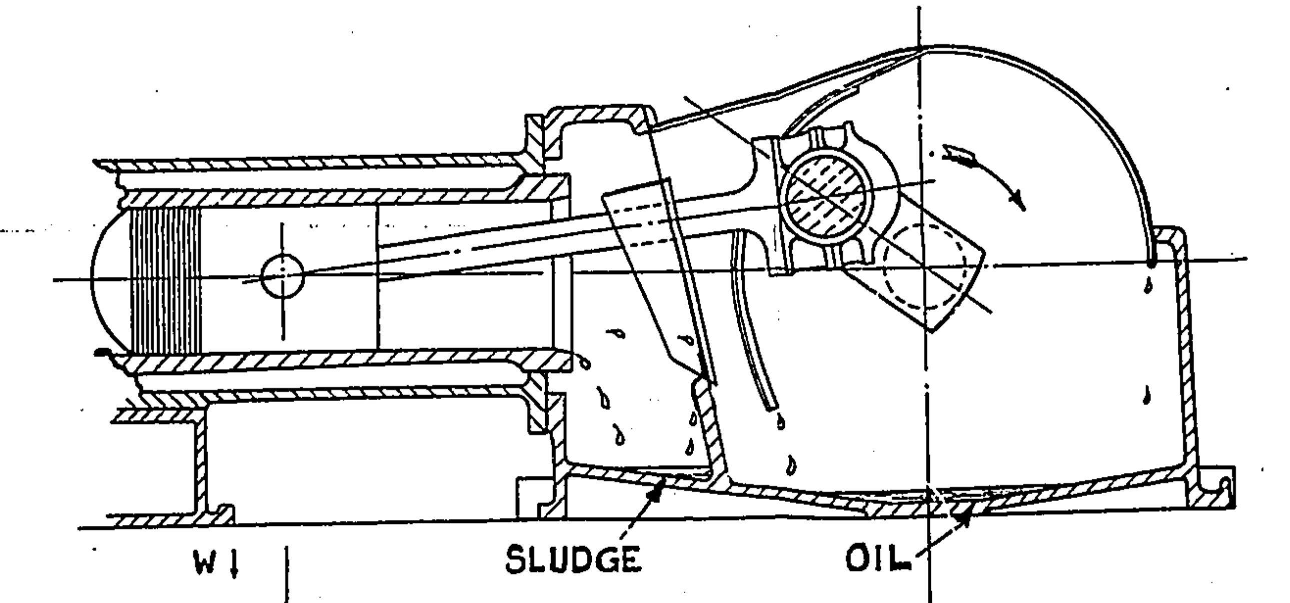
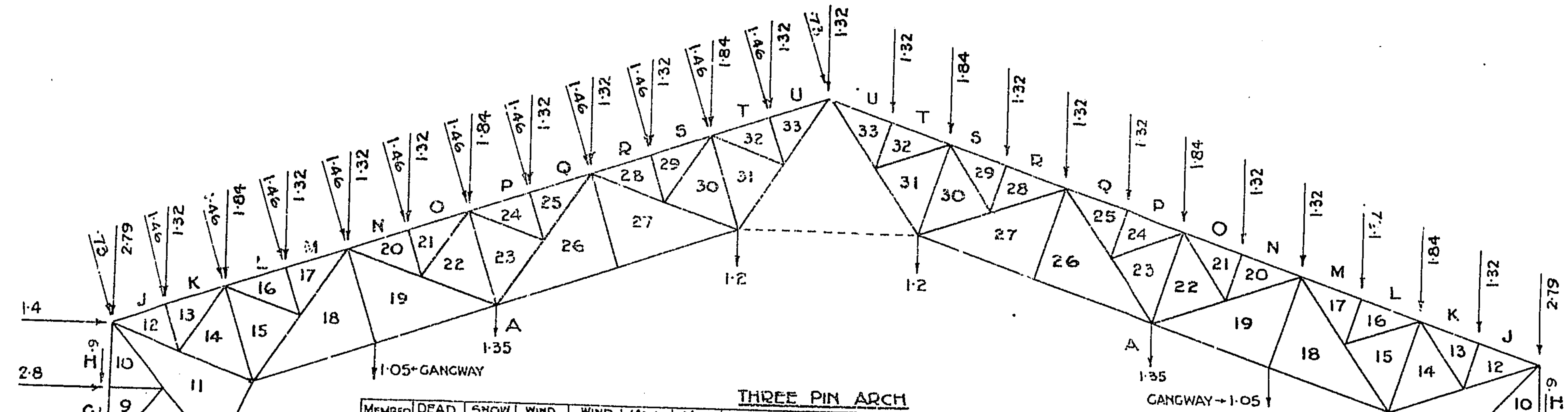
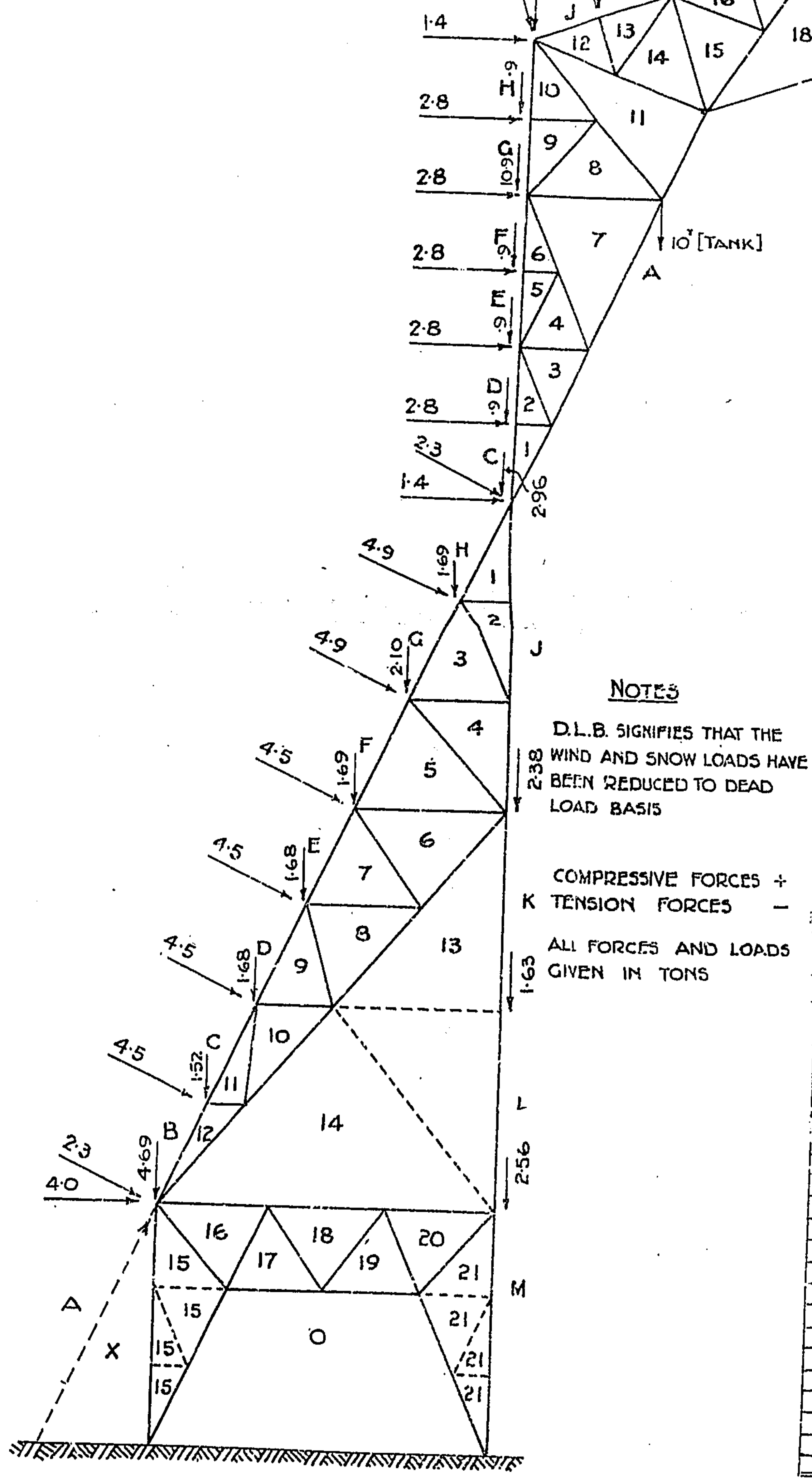
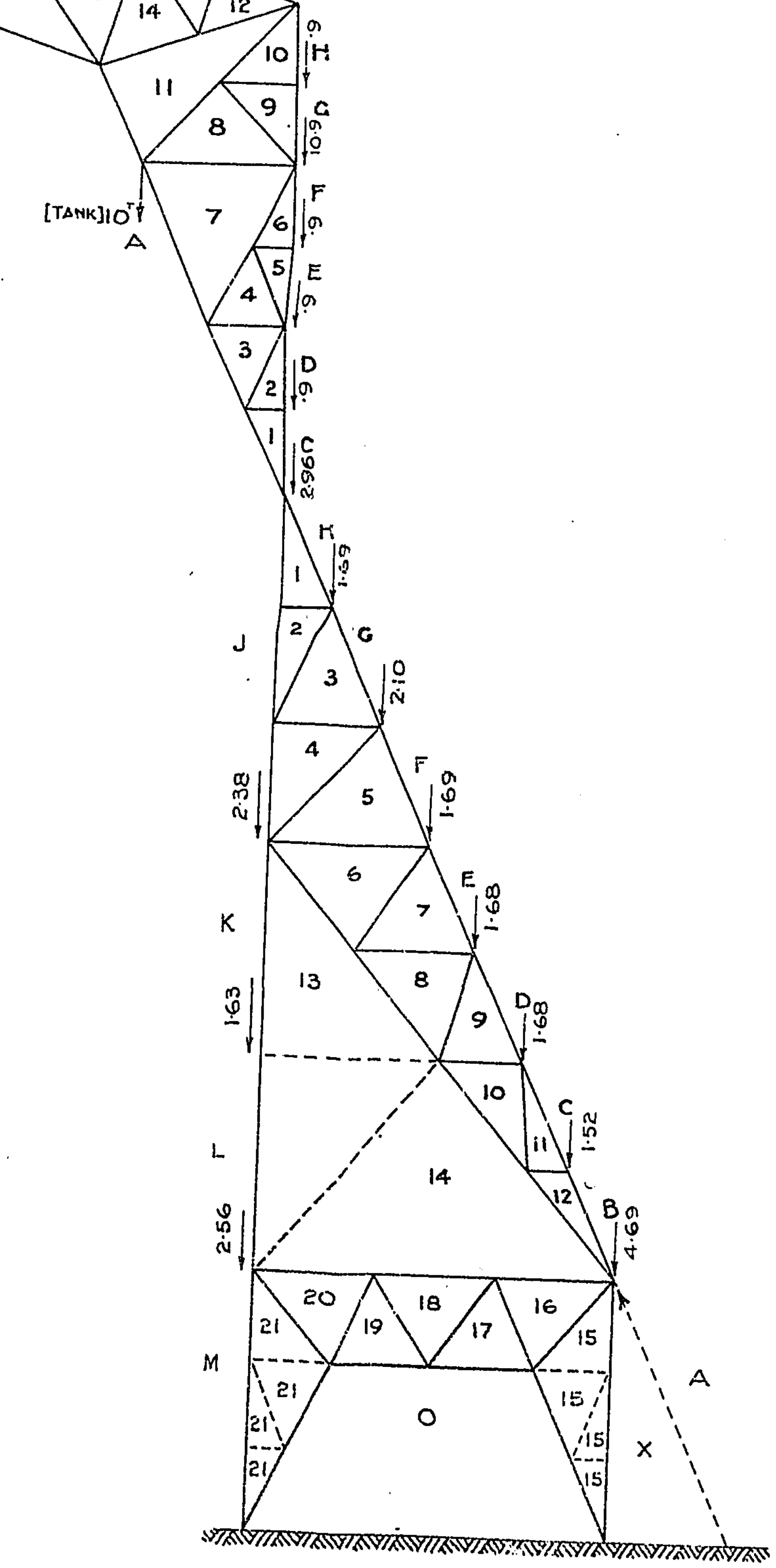


Fig. 12. Diagrammatic Section of "Premier" Horizontal Engine. The pressure of piston on cylinder is represented by P. and W. Note compartment for catching sludge thrown from piston, and separate compartment for lubricating oil.

CARDINGTON AIRSHIP SHED.







THREE PIN ARCH

Member	Dead Load	Snow To D.L.B.	Wind Windward To D.L.B.	Wind Leeward To D.L.B.	Max. Compn.	Max. Tension	Section
C 1	+18·4	− 1·1	+26·91	−10·5	45·31	—	2Ls 5. 4. 5/8"
D 2	+17·5	− 1·1	+26·91	−10·5	44·41	—	" "
E 5	+16·7	− 1·1	+26·91	−10·5	43·61	—	" "
F 6	+15·6	− 1·1	+26·91	−10·5	42·51	—	" "
G 9	+4·9	− 1·1	+21·0	−10·5	25·9	5·6	2Ls 5. 4. 3/8
H 10	+3·9	− 1·1	+21·0	−10·5	24·9	6·6	"
J 12	− 1·7	− 2·2	+26·47	−16·6	24·77	18·3	" "
K 13	− 1·9	− 2·3	+26·47	−16·6	24·57	18·5	" "
L 16	− 2·4	− 2·5	+26·47	−16·6	24·07	19·	" "
M 17	− 2·7	− 2·5	+26·47	−16·6	23·77	19·3	" "
N 20	+14·5	+ 3·1	+28·66	− 5·7	46·26	—	2Ls 5. 4. 5/8
O 21	+14·3	+ 3·	+28·66	− 5·7	45·96	—	" "
P 24	+14·8	+ 2·9	+28·66	− 5·7	46·36	—	" "
Q 25	+13·7	+ 2·8	+28·66	− 5·7	45·6	—	" "
R 28	+16·1	+ 4·3	+17·5	+ 6·1	37·9	—	2Ls 5. 4. 1/2
S 29	+16·0	+ 4·1	+17·5	+ 6·1	37·6	—	" "
T 32	+15·7	+ 4·	+17·5	+ 6·1	37·2	—	" "
U 33	+15·6	+ 3·9	+17·5	+ 6·1	37·0	—	" "
A 1	+26·4	+ 6·7	−21·9	+19·6	52·7	—	2Ls 6. 4. 3/4
A 3	+26·4	+ 6·7	−19·1	+19·6	52·7	—	" "
A 7	+26·4	+ 6·7	−13·7	+19·6	52·7	—	" "
A 11	+17·0	+ 6·7	− 8·2	+19·6	46·3	—	" "
A 18	+ 7·4	+ 3·4	−22·4	+21·7	32·5	15·0	2Ls 5. 4. 5/8
A 19	+ 7·2	+ 3·4	−22·4	+21·7	32·3	15·2	" "
A 26	− 2·9	− ·4	−17·9	+11·0	8·1	21·2	2Ls 5. 4. 3/8
A 27	− 2·9	− ·4	−17·9	+11·0	8·1	21·2	" "
A 31	− 4·8	− ·9	−13·6	+6·9	2·1	19·3	2Ls 3½. 3½. 3/8
A 33	− 5·4	− 1·3	−14·4	+6·9	1·5	21·1	" "
1. 2.	—	—	+2·5	—	2·5	—	2Ls 2½. 2½. 5/16
2. 3.	—	—	−2·7	—		2·7	" "
3. 4.	—	—	+4·0	—	4·0	—	" "
4. 5.	—	—	−2·7	—		2·7	" "
5. 6	—	—	+2·5	—	2·5	—	" "
6. 7.	—	—	−8·3	—		8·3	" "

Member	Dead Load	Snow To D.L.B.	Wind Windward To D.L.B.	Wind Leeward To D.L.B.	Max Compn.	Max Tension	Section.
4. 7.	—	—	− 5·5	—	—	5·5	2Ls 2½. 2½. 5/16
7. 8.	—	—	+7·5	—	7·5	—	2Ls 4. 3. 5/16
8. 9.	—	—	− 1·8	—	—	1·8	2Ls 2½. 2½. 5/16
9. 10.	—	—	+ 2·5	—	2·5	—	" "
10. 11.	−4·75	—	− 9·0	—	—	13·75	2Ls 3. 3. 5/16
8. 11.	−4·75	—	− 7·1	—	—	11·85	" "
11. 12.	+5·0	+2·2	−18·5	+16·6	23·8	13·5	2Ls 4. 4. 1/2
11. 14.	+5·0	+2·5	−17·5	+16·6	24·1	12·5	" "
12. 13.	+ ·8	+ ·4	+ 1·3	—	2·5	—	2Ls 2½. 2½. 5/16
13. 14.	− ·7	− ·3	− 1·1	—	—	2·1	" "
14. 15.	+2·25	+ ·8	+ 2·6	—	5·65	—	2Ls 4. 3. 5/16
15. 16.	− ·7	− ·3	− 1·1	—	—	2·1	2Ls 2½. 2½. 5/16
16. 17.	+ ·8	+ ·4	+ 1·3	—	2·5	—	" "
17. 18.	+12·6	+3·9	+ 2·4	+6·9	23·4	—	2Ls 4. 3. 3/8
15. 18.	+13·2	+4·1	+ 3·3	+6·9	24·2	—	" "
18. 19.	− 1·0	—	—	—	—	1·0	2Ls 4. 3. 5/16
19. 20.	−9·6	−3·4	− ·2	−6·9	—	19·9	" "
19. 22.	−8·9	−3·1	+ ·9	−6·9	—	18·9	" "
20. 21.	+ ·8	+ ·4	+ 1·3	—	2·5	—	2Ls 2½. 2½. 5/16
21. 22.	− ·7	− ·3	− 1·1	—	—	2·1	" "
22. 23.	+2·25	+ ·8	+ 2·6	—	5·65	—	2Ls 4. 3. 5/16
23. 24.	− ·7	− ·3	− 1·1	—	—	2·1	2Ls 2½. 2½. 5/16
24. 25.	+ ·8	+ ·4	+ 1·3	—	2·5	—	" "
25. 26.	+2·6	+1·4	− 6·0	+6·9	10·9	3·4	2Ls 4. 3. 5/16
25. 26.	+ 3·2	+1·7	− 4·9	+6·9	11·8	1·7	" "
26. 27.	—	—	—	—	—	—	2Ls 4. 3. 5/16
27. 28.	− 1·3	− ·8	+ 8·1	−6·9	6·8	9·0	" "
27. 30.	− ·6	− ·5	+ 9·0	−6·9	8·4	8·0	" "
28. 29.	+ ·8	+ ·4	+ 1·3	—	2·5	—	2Ls 2½. 2½. 5/16
29. 30.	− ·7	− ·3	− 1·1	—	—	2·1	" "
30. 31.	+2·25	+ ·8	+ 2·6	—	5·65	—	2Ls 4. 3. 5/16
31. 32	− ·7	− ·3	− 1·1	—	—	2·1	2Ls 2½. 2½. 5/16
32. 33.	+ ·8	+ ·4	+ 1·3	—	2·5	—	" "

NOTES

D.L.B. SIGNIFIES THAT THE WIND AND SNOW LOADS HAVE BEEN REDUCED TO DEAD LOAD BASIS

COMPRESSIVE FORCES +
TENSION FORCES −

ALL FORCES AND LOADS GIVEN IN TONS

TRESTLES

Member	Dead Load	Snow To D.L.B.	Wind Windward To D.L.B.	Wind Leeward To D.L.B.	Max. Compn.	Max Tension	Section
H. 1.	+24·5	+ 7·5	−33·0	+20·0	52·0	33·0	2[s 10. 3½. 23·5#
G. 3.	+25·5	+ 7·5	−36·8	+20·0	53·0	36·8	" "
F. 5.	+26·5	+ 7·5	−40·4	+20·0	54·0	40·4	" "
E. 7.	+29·5	+ 7·5	−37·5	+20·0	55·0	37·5	" "
D. 9.	+32·5	+ 7·5	−23·5	+20·0	64·5	28·0	" "
C. 11.	+35·5	+ 7·5	−15·0	+20·0	76·0	28·0	" "
B. 12.	+36·5	+ 7·5	−13·5	+20·0	78·5	28·0	" "
A. X.	—	—	−43·0	+20·0	20·0	43·0	" "
J. 1.	+ 5·0	− 2·0	+41·1	−11·4	46·1	13·4	" "
J. 2.	+ 5·0	− 2·0	+41·1	−11·4	46·1	13·4	" "
J. 4.	+ 5·5	− 2·0	+46·5	−11·4	52·0	13·4	"
K. 13.	+12·5	− 2·0	+70·5	−11·4	83·0	13·4	" "
L. 13.	+14·0	− 2·0	+70·5	−11·4	84·5	13·4	2[s 10. 3½. 23·5# PLUS
M. 21.	+ 6·4	− 2·0	+61·5	−11·4	57·9	13·4	1[9. 3. 19·73#
1. 2	—	—	—	—	—	—	2Ls 3. 3. 1/4
2. 3.	+ 1·0	—	+5·6	—	6·6	—	2Ls 3½. 3. 5/16
3. 4.	− ·5	—	− 2·1	—	—	2·6	2Ls 3. 3. 1/4
4. 5.	+ 1·5	—	+ 6·6	—	8·1	—	2Ls 4. 3. 5/16
5. 6.	+ 2·0	—	+11·4	—	13·4	—	2Ls 5. 3. 5/16
6. 7.	− 1·0	—	− 7·0	—	—	8·0	2Ls 3½. 3. 5/16
7. 8.	+ 1·5	—	+ 8·7	—	10·2	—	2Ls 4. 3. 5/16
8. 9.	− 1·0	—	− 6·5	—	—	6·5	2Ls 3½. 3. 5/16
9. 10.	+ 1·5	—	+ 6·6	—	8·1	—	" "

Member	Dead Load	Snow To D.L.B.	Wind Windward To D.L.B.	Wind Leeward To D.L.B.	Max. Compn.	Max. Tension	Section.
10. 11.	− 1·5	—	− 6·0	—	—	6·5	2Ls 3. 2½. 5/16
11. 12.	+ 1·0	—	+ 4·2	—	5·2	—	2Ls 3. 3. 1/4
6. 13.	− 4·0	—	−25·4	—	—	29·4	2[s 15. 4. 42#
8. 13.	− 5·0	—	−31·5	—	—	36·5	" "
10. 14.	− 6·5	—	−40·0	—	—	46·5	" "
12. 14.	− 8·0	—	−47·5	—	—	55·5	" "
14. 16.	—	—	+39·0	—	39·0	—	2Ls 5. 4. 1/2
14. 18.	—	—	+14·6	—	14·6	—	" "
14. 20.	—	—	− 9·3	—	—	9·3	" "
X. 15.	+10·0	—	−14·0	—	10·0	4·0	2[s 8. 3. 19·3
15. 16.	—	—	−13·3	—	—	13·3	2Ls 3½. 3½. 3/8
16. 17.	—	—	−20·0	—	—	20·0	2Ls 4. 4. 3/8
17. 18.	—	—	+23·0	—	23·0	—	" "
18. 19.	—	—	−23·0	—	—	23·0	" "
19. 20.	—	—	+20·0	—	20·0	—	2Ls 5. 4. 1/2
20. 21.	—	—	+13·5	—	13·5	—	2Ls 4. 4. 3/8
O. 15.	—	—	−30·5	—	—	30·5	" "
O. 17.	—	—	−15·0	—	—	15·0	" "
O. 19.	—	—	+15·0	—	15·0	—	" "
O. 21.	—	—	+31·5	—	31·5	—	2Ls 5. 4. 1/2
13. 14	—	—	—	—	—	—	" "
A. X.	—	—	—	—	—	—	" "
—	—	—	—	—	—	—	—

FIG. 4.