WORK OF R.E.
IN THE
EUROPEAN WAR, 1914-19

THE

WORK OF THE ROYAL ENGINEERS

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SUPPLY OF ENGINEER STORES AND EQUIPMENT.

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THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914–1918.

SUPPLY OF ENGINEER STORES AND MATERIAL.

INTRODUCTION.

IN order to gain a connected idea of the developments that were caused by the war in the production and distribution of "R.E. Stores" it is necessary in the beginning to have a clear understanding on two points. Firstly, what was the meaning of the expression "R.E. Stores," and secondly, what were the conditions of supply at the start of the war. Both these points require a good deal of explanation, which is not easily given in a few words.

No expression was more generally used or more widely interpreted in the field than this one of "R.E. Stores." To the fighting soldier it covered practically everything outside his arms, food, and clothing, an interpretation which was not very far from being correct. A more accurate name would have been "Army Technical Stores," for even before 1914 the Royal Engineers were responsible for providing the army with much technical equipment besides that actually used by the Corps, and it will be seen that this was very much the case in the early part of the war.

Under pre-war conditions every article of equipment or store that might be required by an army in the field was, after exhaustive enquiry and trial, allotted its place in the official "Vocabulary of Stores," and provision on a definitely laid down scale to the authorized units was arranged for. This included the technical equipment of R.E. units, *i.e.*, stores which they take to the seat of war in accordance with "Mobilization Store Tables," tools of various kinds, pontoon equipment, telegraph stores, and those required for printing, photographic and lithographic sections, together with others which need not be further specified. These were all classed "Ordnance Stores"; the pattern of each item was definitely fixed, and the Royal Army Ordnance Corps was responsible for establishing depôts whence they could be issued as demanded, either for first equipment or to meet the wastage of war. Unless it had its place in the vocabulary an article did not exist, to all practical military purposes. But war will not wait for vocabularies, and immediately the army took the field demands arose for articles both old and new which had no place in existing store tables. The machinery of the Ordnance

department was not designed to deal with the new conditions which gave rise to the R.E. stores organization ; which, on the other hand, was entirely a war growth, produced by and for the emergencies of active service. And so it came about that the R.E. were early regarded as the universal providers of everything that was not authorized equipment.

The numerous building and engineering stores that are needed for peace-time works form part of special contracts, all of which are included in certain items of army estimates. With a few exceptions these would normally be dealt with by the R.E. officer responsible for making the contract ; the principal exceptions being electrical and mechanical plant, and building stores in foreign stations. These questions were dealt with in the Fortifications and Works Directorate at the War Office by F.W. 4, under whom were three sub-branches, dealing with :—

(*a*) Electric Lights.
(*b*) R.E. Committee.
(*c*) Iron Structures.

Until submarine mining was taken overy by the Navy it formed an important part of the work of F.W. 4 (a)—thereafter it became convenient to give F.W. 4 (a) the duty of design, provision and inspection of all articles of authorized R.E. equipment, in addition to the special electrical duties.

As regards the work of F.W. 4 (c), there were obvious advantages in making contracts at home for the supply in bulk of various building stores to foreign stations, where they could not be as easily or cheaply obtained; and to equalize matters this work was entrusted to F.W. 4 (c) in addition to the usual mechanical duties.

And so, after the outbreak of war, all the miscellaneous demands for stores that poured in from expeditionary forces went automatically to F.W. 4 (c), the head of which branch was commonly known as "Inspector of Iron Structures," or shortly I.I.S. These demands could normally be met from trade articles, which only needed adaptation to service conditions. On the other hand F.W. 4 (a) ("Inspector of Electric Lights") had to deal principally with inventions and designs of new equipment, that naturally went with the enormous development in the use of electricity.

The result was a very big expansion of the office of the D.F.W. F.W. 4 (a) grew into F.W. 9 (Chief Electrical Engineer), and F.W. 4 (c) into F.W. 8 (Chief Mechanical Engineer). An entirely new F.W. 4 branch was formed to deal with *personnel*, whilst a new stores branch, F.W. 5, was added for purposes of *liaison* between theatres of war and the War Office. These developments are fully described further on, but it seemed advisable to explain generally how the conditions, that existed in August, 1914, came about.

Finally we arrive at a consideration of the theatres of war themselves, and here no prior explanation is needed, for the story confines itself to the war period. As will be seen from Chapters 8 and 9, no special organization for supply or distribution of R.E. stores with an expeditionary force was contemplated. The development that took place in this respect provides certainly not the least interesting among war studies ; but few subjects need studying with more careful regard to all the attendant circumstances. Without this care the final picture will not be seen in true perspective.

PART I.

AT THE WAR OFFICE.

CHAPTER I.

WORK OF F.W. 8 (CHIEF MECHANICAL ENGINEER).

General Retrospect.—The peacetime strength of the Inspector of Iron Structures was two staff captains, two quartermasters, and 21 other ranks, and existing regulations contemplated that on mobilization, with the addition of one staff captain and three clerks, this strength would suffice to obtain and ship with promptitude and dispatch all that might be required by an army in the field. But immediately war broke out it was decided that the I.I.S. should purchase all plant and material for railways as well as "works"; later, when the new Waterways and Docks came into being, the duty of supplying them with barges, cranes, plant and machinery, was also laid on the shoulders of the I.I.S.; and again for the Royal Flying Corps the same officer was called upon to provide, and in many cases to design, special wagons, machines and tools suited to the needs of their auxiliary services, mechanical transport, aeroplane trailers, mobile and stationary workshops.

At the end of 1916 Transportation was constituted as a separate organization with responsibility for railways, light railways, roads, inland waterways, and docks; thereafter the duty of supply passed from the I.I.S. who had furnished them with £700,000 worth of stores.

About a year later the Royal Flying Corps had also evolved its own supply organization, up to which time the value of stores supplied by the I.I.S. was £1,500,000.

Developments of branch.—From the very start of the war the magnitude of his task was realized by the I.I.S., and also the necessity for directness of method if demands were to be met; so he at once got sanction to place all contracts, irrespective of their value, without prior reference to the Director of Army Contracts or the finance branches of the War Office, subject only to the concurrence of the Director of Fortifications and Works, and on the understanding that the Director of Army Contracts should be kept informed of all contracts thus entered into. By this direct method, as distinguished from the more leisurely peace-time procedure, many urgent demands

from France were able to be discussed with manufacturers on the telephone; when it was known what it was possible for them to supply, and that such was suitable for the service required, a verbal order was given at once, to be followed immediately by written confirmation. As a result of detailed enquiries into the stocks of engineering and railway plant and machinery available in England, it was possible to provide stock articles to meet urgent demands during the first weeks of the war, thus saving time which was of the utmost value. Steps were taken to augment the directing, inspection, and clerical staff which had been doubled by the end of 1914; yet it was impossible to make appreciable headway with various and novel demands pouring in from the Engineer-in-Chief and Director of Works, the Director of Railway Transport, the Inland Waterways and Docks, and the Royal Flying Corps. At the beginning of 1915 the branch was organized in four main supply sections, one for each of the services named with a common pool of accounts, clerical, and shipping staff, and draughtsmen. Later in the year the supply sections were reduced to three with two officers and technical and clerical staff in each, whilst the Inspector of Iron Structures, who supervised the whole, was aided by an experienced mechanical engineer as civil assistant. Whilst the volume of work continually increased with the opening of new theatres of war in Gallipoli and Egypt, and the intensification of the struggle on the Western front throughout 1915–16, lack of accommodation in the War Office precluded adequate increase and organization of staff. The adverse conditions under which business was carried on may be imagined from the fact that nine officers with four telephones were working 13 and 14 hours a day in a single room.

At the beginning of 1917 urgent and continued representations resulted in a new home being found at Adastral House, Blackfriars, for the branch which was henceforward to be known as the Mechanical Engineering and R.E. Store Branch, F.W. 8.

Experience had shown that in addition to other duties it was necessary to provide for storage in depôt and store accounting. The branch was therefore further reorganized in two main sections:—

(*a*) Design, purchase and inspection;
(*b*) Shipping, store accounting; with a general correspondence section.

Each of the main sections was again subdivided in such a way that every demand was dealt with by a specially experienced officer whether on the purchase side or later, when the article was ready, on the shipping side.

As time passed on difficulties in ensuring the supply of raw materials and steel became greater, and labour was increasingly

scarce, particularly during 1918; but the organization had proved sound, and by the addition of sub-sections each in charge of carefully selected officers, it was possible just to keep pace with the work. In the middle of 1917 the soundness of the organization of the branch was put to a searching test by the Surveyor-General of Supply who regarded the existence of this separate supply branch as anomalous.

The Surveyor-General's representative, after careful study of the methods of work at headquarters, at the stores and docks, and at the receiving depôts in France, stated emphatically that the operations of the branch should be excluded from the general organization under the Surveyor-General, and further that it was the first department he had seen which carried its transactions through from the supplier to the army in the field.

At the end of 1917 it was decided that the demands of the American armies in France for all kinds of military supplies and stores purchased in England were to be handled by the War Office. In the C.M.E.'s branch the increase of staff required to meet this fresh call was estimated at 15 officers and 42 clerks; the existing strength at that time being 34 officers and 101 other ranks.

Shipping.—In peace time shipping formed no part of the duties of the I.I.S., but on the outbreak of war the Director of Works in France made urgent representations that this officer should take steps to ship his stores complete and with promptitude after arrival at the port of dispatch in England. The port of Southampton was selected and a senior quartermaster R.E. was posted there to supervise. The very heavy troop traffic at this port, and its distance from London, made effective control from headquarters difficult, and the embarkation of R.E. stores liable to great delay. Accordingly arrangements were made to utilize the South-West India Docks in London, and the Engineer shipping organization opened there on the 1st January, 1915. At these docks the shipping officer could keep in touch with contractors, railway companies, the Port of London Authority (who took over the stores from the railways and obtained receipts from the Admiralty stevedores), the Naval Transport officer who loaded the vessels, and the consignees overseas, so that a continuous check was exercised on consignments right away from the contractors' works to the depôt in France. The R.E. shipping officer could also get rapid information from Headquarters as to the relative urgency of consignments overseas, and was thus in a better position to select the goods to be called forward by rail. The railway facilities at these docks were greatly increased, consequently deliveries of cargo to ship and to shed were speeded up, and during the first half of 1915 ships required for R.E. stores were plentiful. But times changed, demands from all departments increased rapidly, whilst shipping became scarcer, and it was necessary continually to press the Ministry of Shipping to provide adequate tonnage. There ensued a period of

considerable anxiety, but in December, 1915, a definite agreement had been reached that a fleet of ten vessels was regularly required to carry Engineer stores to France. This number was not always forthcoming, and the uncertainty in regard to the vessels to be expected called for the exercise of the greatest care and ingenuity on the part of the shipping staff in the War Office and at the docks, so that best possible use should be made of the allotted tonnage. In addition to shipments from South-West India Docks a regular service of vessels ran from Liverpool with corrugated iron, and from Rochester with cement. These were supplemented later by services from Newport, Grimsby, and Southampton. When the Liverpool and Newport services had to be given up in 1917 owing to submarine activity it was most fortunate that the port of Richborough was available, and the tonnage of Engineer stores sent by that route was mainly limited by the capacity of the port and the fact that priority had of necessity to be given to ammunition and guns by barge and train ferry.

In January, 1915, 10,000 dead weight tons of R.E. stores were shipped to France from South-West India Docks alone, and in January, 1917, this had increased to no less than 55,457 tons. Thereafter the tonnage fluctuated according to shipping difficulties and the tactical situation, but for many months during the latter part of the war it exceeded 40,000 tons per month, the figure for October, 1918, being over 46,000 tons. To collect these quantities from contractors' works all over the country, to pilot them through the congested railways to various ports, and to dovetail into a shipping programme month by month was, needless to say, no small task. As many as 22 vessels in addition to a number of barges were exclusively employed on the service to France, and the total quantity so shipped to the Western front alone between August, 1914, and March, 1919, amounted to 1,817,242 shipping tons. Whilst the Western front claimed the greater share of attention, shipments to other theatres of war were also made in vessels carrying stores for other branches of the army. This procedure was not altogether satisfactory as consignments of Engineer stores were liable to go astray.

When the defence of the Suez Canal zone was taken in hand 41,000 tons of Engineer stores were sent to Egypt, and four vessels were specially allotted for the purpose. The total consignments sent to theatres other than France came to 200,215 shipping tons, to which must be added 21,528 shipping tons of Engineer stores for the United States armies. The latter were dispatched from the South-West India Docks under R.E. supervision, and tided over the period during which the United States army authorities were organizing their own system of transportation. The grand total of shipping tons dealt with by the branch or through its agency was 2,227,457.

Inspection and tests—A war of this magnitude, waged on many fronts and under the most varying conditions of terrain and climate, called for great modifications of accepted designs of engineering accessories, machinery and plant, together with the evolution of many novelties, the efficiency of which it was necessary to prove to demonstration under conditions reasonably similar to those which ruled in the field.

A suitable testing ground was temporarily acquired at Claygate near Surbiton in April, 1916, where exhaustive and instructive trials of various types of tunnelling machines, pipe pushers, trench diggers, light and heavy aerial ropeways were carried on throughout 1916–17–18. All the *personnel* employed in this work were unfit for service overseas: if they became fit again they were transferred to overseas drafts, whilst some who had become experts in the machines they had been handling were specially selected to operate them in the field. The trials disclosed weak points in various machines, which were steadily improved until at length each was ready for service in the field.

The monthly value of stores, plant and machinery ordered for the armies ranged from £74,500 in September, 1914, to £1,605,497 in October, 1918, the monthly average for the last year of the war being £1,241,802, so it will be easily understood how important it was to provide an adequate staff of experienced and reliable inspectors to watch manufacture throughout.

In order to keep pace with the ever-increasing demands the C.M.E. was compelled to place orders with contractors scattered all over the country. Many firms took up work to which they were quite unaccustomed in civil practice, and it was necessary to give them constant advice as to improved processes, as well as to design and to perfect special tools, machines, and jigs. These duties fell to the lot of the inspectors whose labours were unremitting, whilst continual travelling added to the strain.

In peace time the duty of inspection was carried out by three Military Mechanists who were supplemented by a few extra mechanists and by some civilian Inspectors and Examiners soon after the outbreak of war. By January, 1917, their numbers had increased to 11 military and 17 civilian Inspectors, and at the time of the Armistice 46 commissioned and 28 civilian Inspectors and Examiners were fully employed in supervising the multitude of orders under manufacture.

At the end of this chapter will be found graphs of the values of stores supplied quarterly and throughout the war. The grand total to the end of March, 1919, was close on £32,250,000, which gives ample proof of the heavy responsibilities of the Inspectors in watching, testing, encouraging, and hastening in the face of continually increasing difficulties in the materials and labour markets.

Nature of Stores sent to Western Front.—Demands for Engineer stores in war will necessarily depend upon the nature of the operations, the climate, and natural resources of the theatre of war and the vicissitudes of the campaign.

In the opening months of the campaign of 1914 an advance towards the Rhine was anticipated, and designs were made and orders placed for machinery and workshops for R.E. siege parks, workshops for the Air Force, full equipment of 2ft. 6in. gauge railways including internal combustion locomotives, rolling stock, locomotive and wagon repairing shops, girder and engineers workshops, together with permanent way and all plant and material required for operating these light railways ; but as soon as the opposing armies settled down into trenches the immediate call was for trench pumps, loophole plates, sap shields, wire entanglements, trench diggers and machinery for bored mines, together with road bridges of 60ft. and 30ft. span, and mechanical transport of all kinds for the Royal Flying Corps.

To keep fire and communication trenches dry became a matter of prime necessity, and the country was scoured for any pattern of hand pump, whilst power units of capacities varying from 2,000 to 9,000 gallons per hour against a low head were evolved and supplied.

To help the French railways in their difficulties caused by the German invasion the I.I.S. placed considerable orders in England for girder bridges and permanent way material. The total value of these orders was £92,528, and the French railway engineers expressed themselves entirely satisfied with the quality and workmanship, and conveyed their thanks for the punctual deliveries and for the efforts made to ease their difficulties.

In 1915, with the continuance of trench warfare conditions, splinter and bomb-proof shelters were demanded together with store buildings, horse shelters, and cover for many ammunition dumps. At the same time the development of new roads and maintenance of those existing called for the supply of thousands of tons of road metal (much of it from the Channel Islands) together with hundreds of thousands of gallons of tar, and many new bridges up to 85ft. span.

Simultaneously the rapid development of aerial warfare called for the supply of hundreds of sets of power plant for search beams to aid anti-aircraft guns.

Deep mining had now come into use, and in order to keep shelters and mines dry powerful motor pumps were required. The maximum weight of any part was laid down as 300 lbs., whilst the motors were to be driven by generating sets located in safe positions in rear. The ventilation of mine galleries was a serious matter, and to meet this need petrol and electrically-driven air pumps were designed and ordered. All the special stores required by Tunnelling companies, and generally demanded at the shortest notice, were provided by this branch.

In order to economize man-power in the digging of the network of trenches, trench excavators were asked for. Several patterns of mechanical excavators were tried in England, including one which dug two parallel trenches 4 feet apart. A machine was produced which did the work satisfactorily, but on trial overseas was condemned as being too heavy and cumbersome, and the matter was finally dropped.

The call for hand pumps for drainage of trenches continued unabated and by the end of December, 1915, over 15,000 pumps and 250 miles of hose were being manufactured, whilst a further demand was received for 150 miles of hose.

The demands for screw posts for entanglements, roofing felt, corrugated sheeting, structural steel-work, cement, stoves, and such special items as laundry machinery, showed that the armies were preparing for a protracted and bitter struggle.

Experience showed that the German bullet fired at close range would penetrate the standard loophole plate, which necessitated careful experiment with improved designs. The thickness was eventually increased from ·32 to ·4 in., which was accepted as the new standard. In December, 1915, 70,000 of these were delivered or under manufacture.

In 1916 the intensification of trench warfare and the increase in heavy artillery required the provision of deep dug-outs and shelters proof against the heaviest shells. To meet these conditions trials were carried out with several types of tunnelling machines. As these trials progressed, and the machines were improved, it became clear that the crux of the problem lay in the disposal of the soil excavated. No finality in this matter was reached, but some electrically driven machines went to the front to carry out offensive mining, whilst other types were called for for communication tunnels and deep dug-outs.

The necessity for destroying enemy trenches and their protecting entanglements brought pipe-forcing gear into prominence. Such machines were designed to force 3in. and 4in. pipes silently to a distance of 300 or 400 ft. at a depth of a few feet below the natural surface. The pipes were then filled with explosive which could be fired as desired. Communication trenches could be rapidly formed in this way; the explosion immediately creating a trench about 6ft. deep. Long and patient experiments were carried out and several outfits were forwarded to France, but their field of usefulness was always limited by the fact that the pipe could not be steered with any degree of certainty.

For the protection of signal cables a machine was asked for which would bury cable at least 12 in. deep, and after investigation ploughs capable of trenching 2 ft. in depth were supplied. The destructive effect of the enemy artillery fire in the Somme Battle caused opinion

in France to change, and later demands were for machines to cut a channel 8 ft. in depth. To meet this call deep trench excavating machines were ordered from the United States.

Water supply problems became pressing in 1916 and large orders for power-driven pumps poured in, culminating in November by which date nearly 800 sets had been supplied or ordered. Demands for water piping 4in. diameter and under had now reached 200 miles per month, and it became a matter of the utmost difficulty to secure adequate supplies within any reasonable time.

For roads, rollers in large numbers were demanded, which could only be found by requisitioning from local authorities in England with the aid of the Road Board and their staff. Inadequate supplies of road metal were reaching France owing to lack of shipping, and it was finally decided that F.W. 8 should supply quarrying machinery so that new quarries could be exploited in France. At the end of 1916, roads in rear of armies were taken over by the Director General of Movements and Railways, who thenceforward provided all stores and plant in connection with them, and so relieved the I.I.S. of this duty.

The destruction caused by continual bombardments made it necessary to provide extensively for hutting the armies in the autumn and winter. In June, 1916, corrugated steel sheets were already in very great demand for revetments, roofing, and temporary shelters for men, animals and stores, and by November the supply to meet these demands approached 14,000 tons per month.

During the year 1917 there was a great increase in the number of air-raids on England, and many anti-aircraft guns were installed both on the coast and around London. The C.M.E. was called on to provide large numbers of petrol electric and motor generating sets for use with searchlights in connection with these guns. At first engines, dynamos, and motor generating sets were freely commandeered from existing installations, and 60 cm. projectors were used with 8 K.W. 80 volt sets, but as the enemy operated at greater altitudes more powerful beams were required, and the later standard projector was 120 cm. with 24 K.W. 100 volt sets. So great was the call on manufacturers of electric plant and engines that these larger sets were by no means easy to supply, and entailed endless work and negotiation.

The successful advances during the year 1917 left the British armies in occupation of a tract utterly devoid of facilities for supply and shelter, whilst all means of communication had been scientifically wrecked. It is easy to understand that the Engineers were faced with a particularly heavy task throughout the year in meeting the varied requirements of the armies, and demands on England for Engineer stores, machinery and plant increased rapidly. At the same time it was decided to make the armies to some extent self-

supporting by cultivating the areas they had recovered, and yet further demands for agricultural machinery were submitted. These demands were met in the main by the Chief Mechanical Engineer.

Some idea may be obtained of the quantities and variety of the monthly demands from France alone by a perusal of the following list of the more important items going forward in February, 1917, which list, be it remembered, does not include any machinery or plant:

Cement—30,000 barrels	... 5455	tons
French wire entanglement—40,000 lengths ...	... 468	,,
Corrugated steel sheets—1,000,000	... 9500	,,
Roofing felt—50,000 rolls	... 1750	,,
Screw posts—400,000	... 1256	,,
Wire netting—20,000 rolls	... 560	,,
Wire weaving for trench boards—240,000 sq. ft.	... 91	,,
Steel shelters—5,000	... 3826	,,
Water piping—175 miles	... 2111	,,
Tanks—1,775	... 194	,,
Expanded metal sheets—20,000	... 352	,,
Rolled steel joists—26,000	... 8000	,,
Total weight	... 33563	,,

The remarkable increase in demands during this war may be gauged by comparion with the last year of the Boer War. Then the average monthly tonnage of all stores, supplies and ammunition imported into South Africa only totalled 20,000 tons.

Local production of timber, which was undertaken in France on a large scale early in 1917, brought urgent demands for heavy log saws which were met by requisitioning suitable plant in England, and by purchase of engines and saws capable of dealing with logs up to 48-in. in diameter. At the same time arrangements were made for the manufacture of additional suitable machinery.

The increasing weights of military vehicles and guns necessitated a reconsideration of the designs of road bridges already supplied, and to these was added the Inglis heavy type bridge. This type was designed and elaborated by Temp. Major C. E. Inglis, O.B.E., Professor of Engineering at Cambridge University, who was employed n the Chief Mechanical Engineer's branch. By the end of March, 1917, the Engineer-in-Chief, France, had demanded 188 bridges of spans varying from 16 ft. to 85 ft., and although at the time this programme was regarded in some quarters as being on too generous a scale, during the advance later in the year demand exceeded supply, and special efforts were called for to hasten deliveries from England.

The lack of shelter for the troops throughout the area of active operations has been referred to, whilst the increasing numbers of Labour Corps and other *personnel* on Lines of Communication demanded much additional housing. A type of bow hut on light steel framing had been designed in 1916 by Temp. Lt.-Col. P. E. Nissen, D.S.O., R.E., which became universally known as the Nissen hut. 27,000 of these were ordered in March, 1917, for early delivery in France, followed later in the year by a further demand for 20.000

The first demand had been complied with by the autumn of 1917, but shortage of steel delayed deliveries on the second order till well on in the winter, when the lack of accommodation was causing no little anxiety. Shortage of steel also caused trouble in complying with a demand for 53,000 stoves, but by dint of great exertions on the part of those responsible 43,000 had been shipped to France by the end of December.

The large amount of water supply plant ordered during 1916 has been mentioned, but it became clear that this would not suffice, and in June, 1917, 150 portable pumping sets were ordered together with 156 larger plants suitable for semi-permanent installations, and special steps were taken to expedite manufacture. In the absence of wells it became necessary to bore for water, in many places to a depth of 250–300 ft., and drilling plant was obtained from America where this class of work had been more highly developed than in England. Water from boreholes was brought to the surface by power-driven deep-well pumps and by air-lifts ; the latter called for a compactly designed compressor and engine carried on a lorry chassis so that the outfit could move from borehole to borehole. Water-purifying plant was also demanded by the armies, and in 1917 ten pumping installations were provided each capable of dealing with 6.000 gallons per hour. The crude water was treated with sulphate of alumina and soda, and sand filters completed the installation. In 1918 plants of double this capacity were sent out, but the water was purified by chlorination and dechlorination. Portable chlorinating plants were also supplied with a capacity of 1,200 gallons per hour, the whole designed to fit into a general service wagon.

Electric power was required for lighting both front and back areas, for mobile lighting sets for the Director of Signals, for searchlight sets for use with anti-aircraft guns, for X-ray sets at Casualty Clearing Stations, and for lighting mine galleries, whilst a large variety of motors were called for to operate machinery of all kinds.

Compliance with these various demands was rendered difficult through lack of co-ordination of standard pressures, but eventually separate standards were settled for the Signal branch, for lighting purposes, and for mining work.

To supplement an existing French installation at Havre a 1,500 K.W. 5,300-volt steam turbine driven set was secured in England in the autumn of 1916, and was erected in March of the following year.

During 1917 in addition to the above the Chief Mechanical Engineer supplied to the armies in France laundry and wood-working machinery, many machine tools, fire engines, destructors, disinfectors, gravity rollers, hot water apparatus, and various cranes.

Supply of trench fuel had been a difficulty early in 1917, and it was decided that charcoal from France and England must be supple-

mented by peat fuel manufactured in England. This entailed the erection of a special factory and the supply of much plant and electrically driven machinery for the excavating, carbonizing, and handling of the peat through the various processes until it emerged as a pressed briquette. At the end of the year the C.M.E. was called on to take charge of the building of the factory as well as the supply of all machinery and plant. Construction began in January, 1918, but owing to many difficulties and delays the fuel did not reach France before the end of the war, but was issued to Commands in England in order to determine its value as a substitute for coal at existing prices.

Throughout the earlier part of 1918 the C.M.E. was called on to maintain monthly deliveries at the existing high level, to be stored in depôt in England or shipped overseas as circumstances might demand. With a view to the coming winter 20,000 Nissen huts were demanded in February, followed by a further call in April for 15,000 to cover losses incurred during the retirement in the spring. Again in June 15,000 steel tents were asked for. Deliveries of huts were well up to programme, and tents were beginning to come forward, when the armistice was declared and steps were taken to cease manufacture.

In May it had been decided to provide special bridging equipment for tanks, and Major Inglis was detached to study these problems in company with officers of the Tank Corps. By September all details had been settled, manufacture was actually in progress, and spans had already been delivered to the Tank training school for experiment. In June the Field Marshal Commanding-in-Chief asked for a total of 1,018 girder road bridges varying in span from 21 ft. 6 in. to 120 ft., delivery to be completed by March, 1919. In face of the conditions prevailing in the labour market and the congestion of orders with manufacturers it was by no means easy to comply with this programme in the time allotted. All obstacles were, however, surmounted and by November substantial deliveries had been secured.

The retirement in the spring, and consequent re-grouping of troops, produced increased demands for water supply plant, and all England had tc be scoured to satisfy requirements either by purchase or manufacture. Similarly many workshop machines and tools were lost, and all sorts of types were secured to tide over the difficulty.

Through the spring and summer of 1918 demands were received for complete plants for large electric power stations at Boulogne, Calais, Yvetot, and elsewhere. With the aid of the Ministry of Munitions all were arranged for. One plant had been ordered for the Russian Government, another for the Government of New South Wales, a third was purchased from a local authority in England, a fourth from a rubber mill, and a fifth from a colliery. Several

required overhaul and re-winding, together with the provision of boilers, water softening plant, transformers and switchboards, to meet the special conditions prevailing in France ; but all the sets had either been delivered or were approaching completion in November, 1918. With the declaration of the armistice the need for the majority of them disappeared, and their future disposal became a fresh problem.

The highly-developed use of camouflage during the war gave the branch much work. During three years thousands of fish-nets were supplied monthly together with many thousands of yards of canvas and coir screening. The problem of making fish-nets fireproof was solved fairly satisfactorily, but canvas, calico, and hessian presented many difficulties, and after months of experimenting a satisfactory process had been found in the autumn of 1918, when the demands from overseas ceased. The supply of suitable colouring materials opened out another large field of investigation and chemical research, and though suitable specifications were finally agreed upon the question of standard tints called for solution, more especially as the various artists demanded each his own tint. Here again standardization was on the point of settlement when the close of hostilities rendered further supplies unnecessary.

The work done is not in vain, for the results are recorded and specifications exist.

Stores for other Theatres of War.—Although the volume of orders for France was far greater than for any other theatre of war, very heavy work was entailed in complying with the demands from the farther distant and widely differing fields of hostilities.

Early in 1915 considerable quantities of defence stores were required in the Dardanelles. Supplies for immediate use were diverted from orders for France, and contracts were arranged for further deliveries. The shipment of these stores on vessels carrying consignments for other departments caused initial difficulties and delay, but in December two vessels sailed with full cargoes of engineering material (12,000 tons) followed in January, 1916, by three more carrying 18,000 tons. In October, 1915, it was decided to form a base depôt in Egypt containing Engineer stores for the whole of the Mediterranean forces. To this depot was transferred a great deal of the material of the Engineer siege park together with a complete outfit of 2ft. 6in. gauge railway originally provided for possible use in France, and later this proved of immense value in operations for the defence of the Suez Canal zone. Orders for these operations reached England at the end of 1915, when lists of stores required were immediately prepared and steps were taken to manufacture for early delivery. Demands for the forces in the Mediterranean (including Egypt) exceeded £1,000,000 in value during 1916, and included a number of internal combustion locomotives

(2ft. 6in. gauge) for Egypt, and short bi-cable ropeways for Gallipoli which eventually found their way to Salonica when the force in the Dardanelles was withdrawn. On the Palestine front during 1917 work was concentrated mainly on the improvement of communications, much railway work was done, and water was brought from Egypt through miles of piping. Roads were improved, new wells and powerful pumping plant were installed, whilst semi-permanent and temporary buildings of all kinds, including workshops, were erected. All this entailed heavy orders on the C.M.E. After the capture of Jerusalem in 1918 considerable quantities of cement, general building stores, and workshop machinery were sent forward from England, together with 12 large and many smaller power-driven pumps, and spares for several patterns of British made pumps captured from the enemy.

On the 7th April an Inglis rectangular bridge was demanded by cable to carry all classes of traffic across the Jordan ; details were settled by the interchange of telegrams, and a suitable bridge, completed with launching gear and all accessories, was tested in England at the end of May and reached Alexandria on the 1st July.

The final advance in September and October brought further demands for all kinds of Engineer stores, and the base in Egypt was still submitting various indents as late as December, 1918.

Throughout 1918 there had been great difficulty in securing shipments to Egypt, and these difficulties continued after November. Special measures were therefore required to keep up supplies in order to minimise inconvenience along the various Lines of Communication. Egypt was the base of supply not only for troops in that country, but to a certain extent for those on the Balkan front.

For the distribution of meat a cold store of 4,000 tons capacity was ordered at Port Said late in 1917. The refrigerating plant, valued at £20,000, was designed and manufactured under the orders of the C.M.E., and this plant with all necessary accessories had been shipped by April, 1918, and was in service in the month of August.

The force on the Salonica front had drawn most of its stores from the base depôt in Egypt, but in addition 25,000 tons weight were dispatched direct from England, and included a large outfit of rock drilling machinery for quarries, which was obtained only after considerable negotiation and labour.

During 1918 many stores were required for the improvement of living and sanitary conditions, and laundry machinery, destructors, disinfectors, and small electric sets for X-ray work were obtained in England and shipped direct.

When the Allied advance began on the whole Balkan front great difficulties of transportation by railway and by road were foreseen, and projects had been prepared for the erection of considerable lengths of ropeway in close consultation with this branch ; when

hostilities ceased the C.M.E. was supplying 50 miles of "general utility" ropeway in addition to a number of short lengths of a lighter type to be used for transporting stores across ravines, etc.

The question of providing cold storage at Salonica for army meat was raised in the spring of 1918, and was fully examined both in England and in Greece. An officer of the C.M.E.'s staff materially aided the local committee which examined the proposal, and after consideration of their report the scheme was finally vetoed, as events proved the store could not be provided in time to be of use, and any expenditure incurred would have been thrown away.

Out of the mass of business transacted for the various forces operating from the Mediterranean it has only been possible to refer to these few as illustrations of the varied requirements met by the Chief Mechanical Engineer's branch.

In 1916 demands came from East Africa for cement, hutting and building stores, and machinery. The total values ordered during this year amounted to £51,000.

From Mesopotamia came demands for hot water apparatus for hospitals, portable huts and bridges of spans up to 60 ft., whilst the port of Basrah was provided with a number of small independent electric power stations for lighting purposes, and with ice plants of 1-ton capacity for hospitals. These small installations soon proved unsatisfactory, and in the autumn of 1916 the War Office was called on to supply Basrah with a central power station of 1,000 K.W. capacity to provide current for lines throughout the port, for 7,000 fans in hospitals, and for the manufacture of 20 tons of ice per day. To ensure that the supply station should be at work in the spring of 1917 plant was acquired which was under manufacture in England for private concerns in India. Some spare plant was fortunately able to be purchased in India. The first consignment of boilers sent from England for the power station was lost at sea through enemy action. By strenuous exertions these were replaced in eight weeks, and the central supply station was operating in April, 1917.

After the Turkish armies were driven out of Baghdad irrigation was taken up in the valleys of the Tigris and Euphrates, for which the C.M.E. was called on to provide 8 powerful pumps and engines as a first instalment. A demand was also received for spare parts for some hundreds of pumps and engines of British manufacture which had been captured by the army, but little detailed information was forthcoming from the front beyond the names of makers. These lent their aid in tracing the original sales, and after several weeks of patient work a liberal outfit of suitable spares was ordered.

At the end of 1917 demands were received for hay balers, corn-crushing plant, ploughs, harrows, and rollers, all of which had been shipped by the end of the following spring.

Early in 1918 the port of Basrah was greatly improved, and in

connection with the shore facilities further demands for electric power plant continued to reach England. With the addition of a 500 K.W. plant obtained by negotiation the total capacity of the Basrah power house in June, 1918, was 1,700 K.W., but this expansion of power did not suffice, and soon after the additional plant had begun to work a requisition was received for a large turbine set to meet the increased requirements of docks and wharves. On receipt in Mesopotamia it was intended to transfer some of the existing plant from Basrah to Baghdad, where large railway workshops were being erected. The bulk of the plant required had been arranged for, and some delivered in England, when the armistice altered the whole situation, and the scheme was abandoned as a war measure.

For Lines of Communication small ice plants as well as many power plants (40–100 K.W.) were dispatched, and for farm, agricultural, and irrigation purposes a milling plant in nine small units, several dairy plants, many ploughs and harrows, and twelve oil-driven pumping sets with pumps varying from 6 in. to 20 in. were shipped as rapidly as they could be obtained.

To overcome difficulties of transportation on the mountainous road to the Caspian *viâ* Hamadan the manufacture of 50 miles of "general utility" ropeway was put in hand in August. This special military type of ropeway with its engines and all accessories was designed by officers of the C.M.E.'s staff for use in the Balkans. Owing to the sudden termination of the campaign this ropeway was no longer required at the front, but it was collected in England for possible future use in another theatre of war.

The camps that were established for the accommodation of refugees from Armenia and the Caucasus called for the supply of miles of piping, disinfectors, refuse destructors, and power plant for hospitals, all of which reached Basrah through the agency of F.W. 8.

The British force in Italy obtained the majority of its stores through the base depôts in France. In June, 1918, this force required a large pumping installation and applied to England for it, but, when the C.M.E. had ascertained that the requisite plant could not in the state of the market be delivered for some considerable time, it was found possible to divert suitable pumps, etc., recently delivered to the armies in France, and to replace these from England without undue inconvenience.

Again in September, 1918, shortly before the general advance of the Italian and British armies, an urgent demand reached England for 300 metres of Inglis rectangular bridge. To manufacture it in time was impossible, but orders then in hand for other fronts were drawn upon in consultation with the General Staff. In this way 540 running feet of this type of bridge were dispatched to Italy in the course of the next few weeks, and were in time to carry heavy traffic over the Monticano and Livenza.

Stores for American Army.—It has already been stated that the American armies in France depended on the War Office for such stores and supplies as were purchased in England. In accordance with this policy the C.M.E. was required to provide 1,200 Nissen bow and 500 hospital huts in August, 1917, and other orders followed in rapid succession for water piping, pumping plant, steam navvies, boring plant, workshop machinery, and a variety of electrically-driven plant, and yet another 1,000 huts. The majority of these demands required steel which was growing scarcer daily. To find the requisite quantities, to pilot the raw material to the manufacturer, and finally to spur the latter to work to his utmost capacity, entailed the exercise of tact, patience, and continual vigilance on the part of controlling and inspecting officers.

During 1918 business for the American armies steadily increased, and the complexity of the steel and labour positions made it very difficult to meet the demands with promptitude.

Inglis heavy rectangular and girder bridges of various spans were demanded, as well as some thousands of bow huts, water-softening plant, several units of baking machinery of an aggregate capacity of 1,500,000 rations per day, heavy saws and wood-working machinery, laundry plant, concrete mixers, pumps (steam and petrol driven), electric motors and generators of all sizes, and power plants of various capacities up to 600 K.W. If, for any cause, a demand could not be complied with in England in reasonable time early intimation was given to the American purchasing agent in London, who thereupon took steps to fill his demand from the United States.

The value of the orders for Engineer stores and plant for the American armies thus placed by the C.M.E. between August, 1917 and December, 1918, was £1,500,000.

Summary.—From time to time in the previous pages reference has been made to shortage of labour, lack of steel, shipping and manufacturing difficulties, which militated against the early supply of stores. Throughout 1918 these drawbacks made themselves felt increasingly, and in order to meet the needs of the situation an adequate sub-division of work was required in the C.M.E.'s headquarters organization, and special officers were appointed to deal with labour, steel, and the many other problems which threatened to retard the rate of manufacture in England and delivery overseas.

The following table gives in detail the organization of the branch as it existed at the beginning of 1919. From this it will be seen that the total staff was no less than 39 officers and 97 others, a remarkable and striking growth from the original 25 all ranks that formed the peace time strength of F.W. 4 (c).

Five graphs are also appended to show the value and tonnage of stores dealt with by the branch throughout the war.

Detailed Organization of F.W. 8 at the beginning of 1919.

F.W. 8. Deputy-Director of Fortifications and Works (Chief Mechanical Engineer), D.D.F.W. (b). 1 Officer.

Duties—Technical advice on mechanical engineering questions. Design, selection, purchase, and inspection of machinery, plant, structural and fortification steelwork, engineering stores and materials for Expeditionary Forces, Colonial Stations, United States Army, and special work of a similar nature for Home Forces.

F.W. 8 (a) 5 Officers, 11 others.

F.W. 8 (a)1 2 Officers, 7 others.

Duties—Huts, building, water supply and general engineering stores.

F.W. 8 (a)2 3 Officers, 8 others.

Duties—Constructional steelwork, bridges and fortification steelwork.

F.W. 8(a)3 1 Officer, 3 others.

Duties—Special plant and machinery.

F.W. 8 (a)4 2 Officers, 3 others.

Duties—Mining plant, ropeways, agricultural machinery, experimental plant and machinery—Claygate trial ground.

F.W. 8 (a)5 2 Officers, 3 others.

Duties—Electrical and pumping machinery.

F.W. 8 (a)6 3 Officers, 3 others.

Duties—Spare parts, machine tools, camouflage materials.

F.W. 8 (b) 1 Officer.

Duties—Finance, shipping and store accounting in connection with stores purchased by F.W. 8 (a). General administration of F.W. 8 and of Royal Engineer Stores Depôts and Royal Engineer Shipping Agency. All general questions.

F.W. 8 (b)1 7 Officers, 23 others.

Duties—Check and certification of contractors' bills, stores credits for stores and materials purchased by F.W. 8 (a) both for home and abroad.

F.W. 8 (b)2 7 Officers, 10 others.

Duties—Questions relating to railing and shipment of engineering stores to France. Programmes, records, statistics and returns.

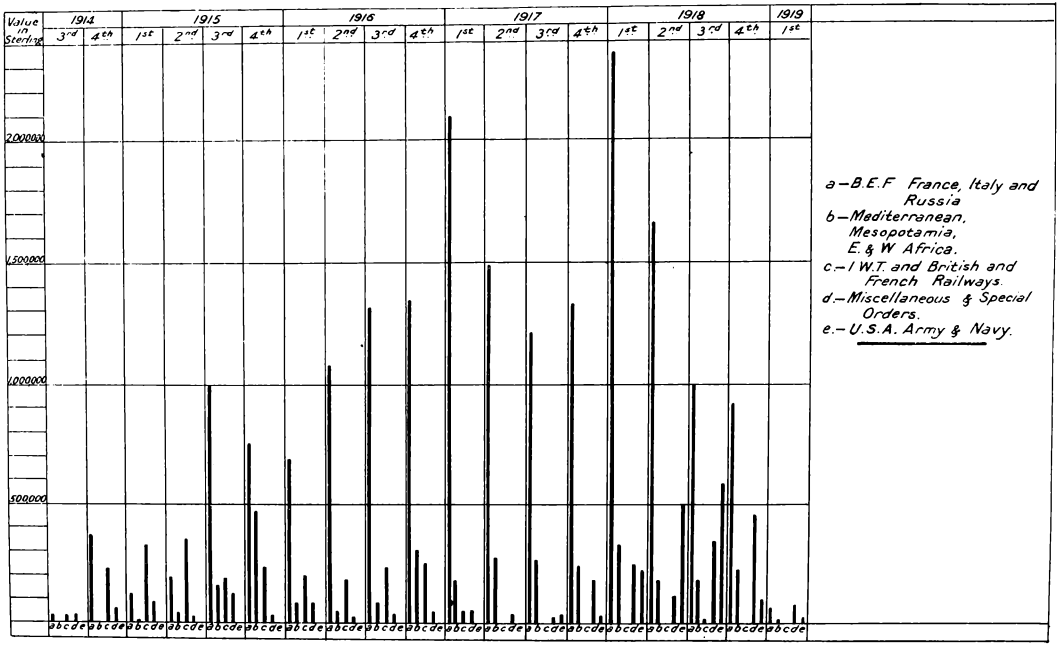
F.W. 8 (b)3 1 Officer, 3 others.

Duties—Questions relating to railing and shipment of engineering stores to all Expeditionary Forces, other than to France, and to Colonial Stations. Requisitions for freight, shipping estimates, records and statistics, also questions relating to transport of stores purchased by F.W. 8 (a) for U.S.A.

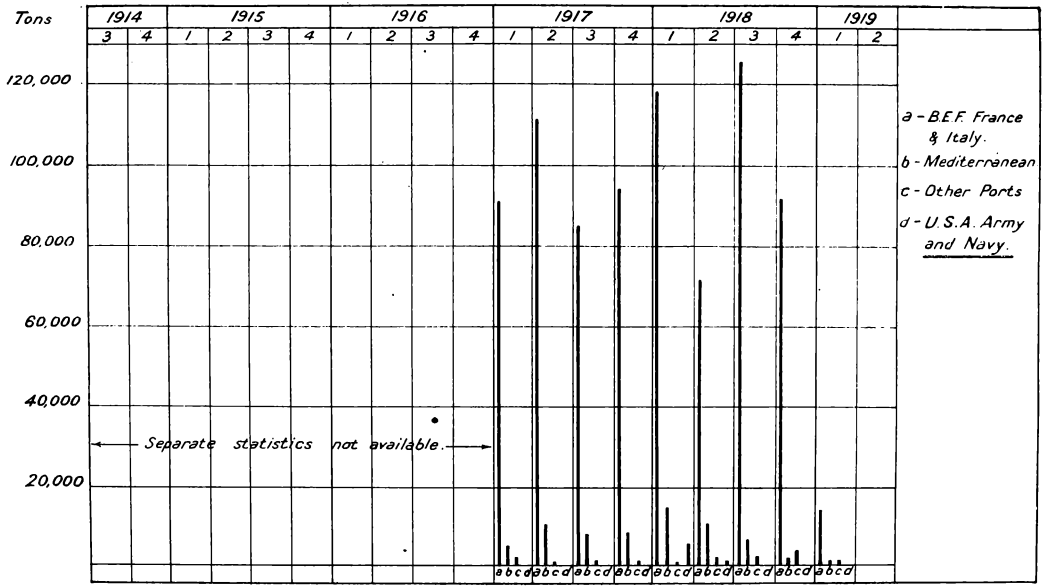
F W 8 (b)4 4 Officers, 23 Others.

Duties—General questions. Administrative and military supervision of A.I.R.E.M. Machinery and other office records. Disposal of unserviceable stores and machinery. Salvage questions. Preferential shipping treatment questions and Import Licences. Road Board accounts. Interior economy and general administration of F.W. 8.

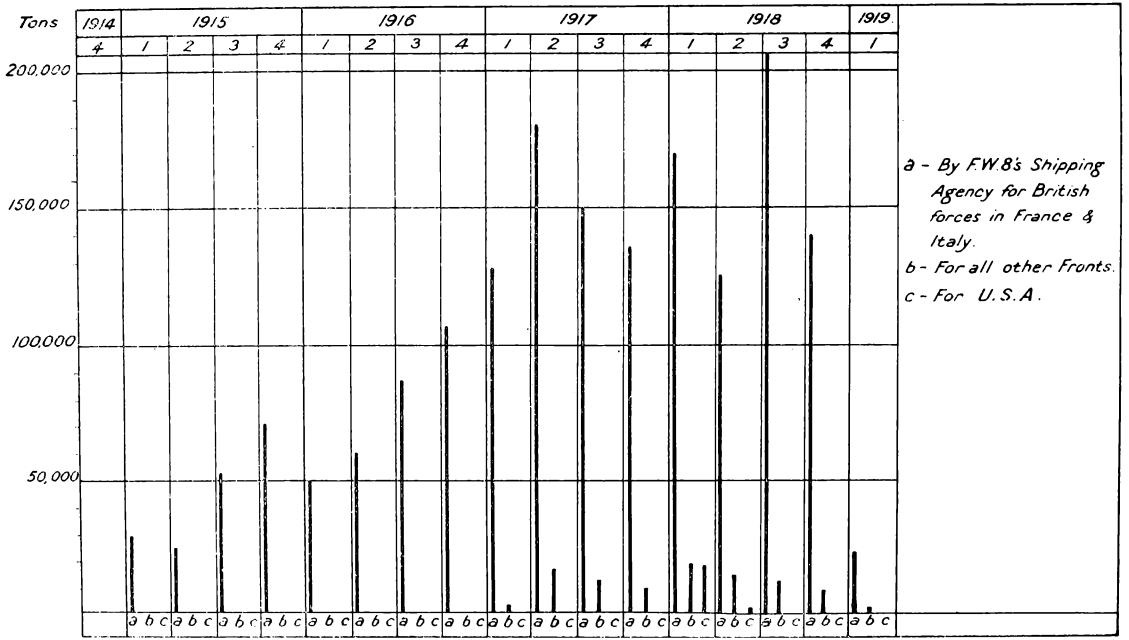
GRAPH—SHOWING QUARTERLY VALUE OF ENGINEER STORES ORDERED AND INSPECTED.



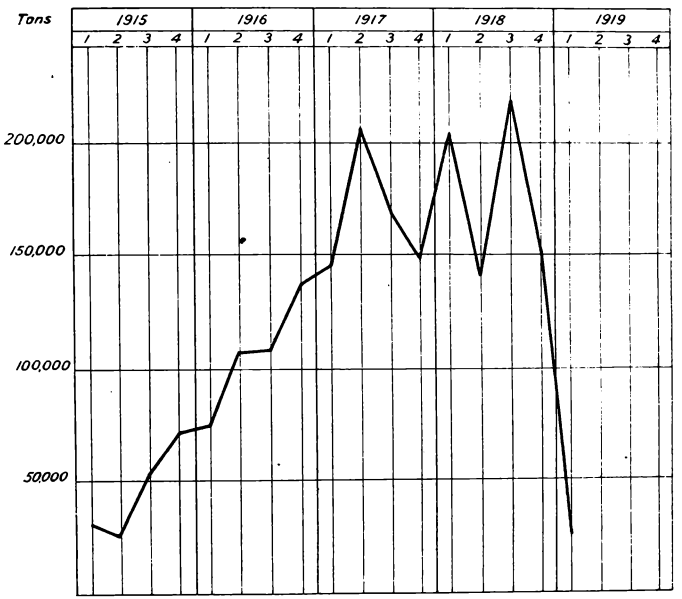
GRAPH—SHOWING QUARTERLY DEAD-WEIGHT TONNAGE SHIPPED OVERSEAS.



GRAPH—SHOWING QUARTERLY SHIPPING TONNAGE OF ENGINEER STORES.



GRAPH—SHOWING TOTAL QUARTERLY SHIPPING TONNAGE OF ENGINEER STORES TO ALL FRONTS.



CHAPTER 2.

WORK OF F.W. 9. (CHIEF ELECTRICAL ENGINEER)

Origin and Growth.—To understand the development of this branch it is desirable to add a few words to the account given in the introduction of pre-war conditions.

The original duties of the branch were confined to the control of submarine mining work, coast defence electric lighting, and the small amount of electrical work with which in those times the War Department was interested. In connection with this work there grew up at Woolwich an Inspection department dealing with technical stores, at first administered by officers of the branch who occasionally went to Woolwich, but eventually organized as a separate establishment controlled by the branch.

When submarine mining was taken over in 1905 by the Admiralty, and the work of the branch was consequently reduced, it became convenient to allot to it the responsibility for provision and inspection of all engineering technical "equipment" required by the army, in addition to dealing with all electrical work in which the War Department was interested. It is difficult to define what is comprised in the word "equipment"; roughly it may be taken to include the technical stores which are carried by any unit in the field, but not to include engineering works stores; but, as already explained, during the war the word was held to have a very broad definition.

In the years just prior to the war the branch, then known as F.W. 4 (a), was busily employed in developing coast defence lights, in installing electric lights in peace barracks, in equipping units, including Territorials, and in bringing up reserves of stores to the authorized scales. The total numbers employed, including the staff of the Inspection division, were 8 officers, 104 subordinates; but so little was the importance and extent of the work, which would fall to the branch, foreseen that it had been notified that the status of the head would be reduced to that of staff captain, a fate which had befallen his opposite number in F.W. 4 (c), Inspector of Iron Structures.

By the end of the war the numbers employed in F.W. 9 had actually reached 73 officers, 5,188 subordinates. It will be seen later that a very small proportion of these numbers was employed at the War Office. A feature of the work of this branch was the size of the outside establishments that grew up. The Inspection division

at Woolwich in particular had a remarkable expansion, and from it sprung the " Signals Experimental Establishment " and the " W.D. Signals Factories." The work of these three establishments is described in detail in Chapters 4, 5 and 6 respectively.

Development of Wireless.—The development of wireless telegraphy equipment was one of the great features of the war ; a development so extensive and progressive that its pre-war applications to military purposes may be said in comparison to be almost non-existent.

There are three matters of principle in which the war development was chiefly marked :—

(*a*) The use of small portable stations ; the lightest of which are adapted for man-pack transport for communication in forward areas.

(*b*) The use of so-called ' valves ' both for transmission and reception, and the consequent adoption of continuous wave systems of transmission employing these valves.

(*c*) The use of wireless telephony.

The principal types of apparatus designed during the war were :—

Spark Sets ;—the light motor set, and light sets for use in advanced areas.

Continuous Wave Sets ;—sets that could be carried by hand, larger C.W. sets for motor transport, long range C.W. sets for special purposes.

Searchlights. (*a*) *For Coast Defences.*—Before the war the searchlights installed in coast defences had been the special care of this branch, the head of which, as Inspector of Electric Lights, had visited each station once a year and had co-ordinated and criticised the practices carried out. Apart, therefore, from the provision of material for new stations, of which a number were formed, there was nothing requiring the special care of this office during the first years of the war ; and, owing to the pressure of other matters on the staff of the office, there was little touch maintained with the coast defence service.

The searchlights worked well throughout the war, and justified the attention which had been paid to them in peace time. It was only towards the end that developments took place in searchlight work, which promise to affect coast defence work generally in the future ; these will be described later on.

(*b*) *For Field Companies.*—In 1914 the Commander-in-Chief in France asked that all Field Companies should be provided with small searchlights. An oxy-acetylene portable set was adopted. The projector was 14 inches in diameter, capable of being run for 5 hours with each charge, and giving an effective range of observation under normal conditions of about 500 yards. The projector was

fitted with a signalling shutter, and the average range for daylight signalling was about 20 miles.

However, the conditions of trench warfare which supervened rendered these lights of but little use to Field Companies, and the lights were subsequently withdrawn from the companies and utilized on the L. of C. for lighting workshops, etc.

This confirms the decision arrived at some ten years ago, after considerable trials with field searchlights, that their use in the field for searching out works or lighting up the ground does not justify the transport and *personnel* they entail.

(*c*) *Anti-Aircraft.*—Prior to the outbreak of war practically nothing had been done in regard to provision of anti-aircraft searchlight equipment. A few experiments had been carried out at Chatham during the preceding year, which experiments were mainly based on the false assumption that the use of a projector of the coast defence pattern, that is to say, with the light reflected from a glass mirror, would not be practicable over a certain degree of elevation owing to the danger of breaking the mirror through pieces of molten carbon falling upon it. Experiments at Chatham were therefore mainly conducted with a projector fitted with a lighthouse type of lens.

Immediately on the outbreak of war, certain anti-aircraft lights were established by the Admiralty, mainly in London, and it was not until the autumn of 1914, when Zeppelin attacks were first made, that the question was seriously considered by the military authorities.

In the autumn of that year, the General Staff directorate circularized to the Commands in Great Britain asking whether any arrangements had been made locally to provide against anti-aircraft attack. The results showed that a total of about forty to fifty lights altogether had been installed, mainly 24inch in diameter. These 24inch lights (which included certain oxy-acetylene lights) had been almost entirely supplied by the Admiralty, and in a great many cases were manned by Naval ratings.

In December of that year a conference was held in the D.F.W.'s room, at which it was decided to make provision of searchlights to be used with anti-aircraft guns, which were just then being considered as a serious proposition. It was decided at this conference that fifty lights should be purchased in addition to those already existing. No definite recommendation was made as regards the size of these projectors, but it was decided by this branch to provide 60c.m. apparatus, largely on account of the comparative ease with which they could be procured as compared with the larger lights. Matters remained in this state until the summer of 1915, when a further conference was held and a further provision of 75 lights settled. A certain proportion of these were to be mounted on 3-ton lorries with generating plant.

About this time also the idea of mounting projectors on tram-cars in the vicinity of London was mooted, and a total of some twenty 60c.m. lights were actually so mounted, run by motor generators fixed to the trams. The arrangement proved perfectly satisfactory from the electrical point of view and these lights were a good deal used for a short time, but were subsequently abandoned.

In December 1915 the question of further provision again arose, and the total requirements for home defence were given as five hundred, of which about three hundred had, at that time, either been provided or ordered.

In the spring of 1916, in consequence of a decision that the Field Marshal Commanding-in-Chief, Home Forces, was in future to be responsible for the anti-aircraft defence for the whole of Great Britain, the position was again reviewed and an estimate of requirements given by General Headquarters, Home Forces. This totalled 620 lights some of which were duplicated. Of these 620 lights a large majority were for use in connection with anti-aircraft guns, a small proportion being proposed for work in connection with defending aeroplanes. Approximately one quarter of the total was in connection with the defences of London. Later on a further sixty lights were approved for issue to the Royal Flying Corps.

Up to this date the only aircraft attacks on this country had been by air-ships and it was, as a matter of fact, found that the original recommendation to provide 60c.m. projectors was justified as far as defence against this type of attack was concerned.

In the summer of 1917, however, the first attack on this country was made by hostile aeroplanes, by day, and it was realized that night attacks by this type of machine were bound to follow shortly. Such experience as had been gained by the use of searchlights against aeroplanes, and by experiments with aeroplanes in the beam, made it fairly certain however that the 60c.m. projector was not sufficiently powerful as a defence against aeroplane attacks, and consideration of the provision of larger projectors was mooted by General Headquarters, Home Forces, in the early part of that year. The proposal was the substitution of approximately fifty of the 60c.m. lights by something considerably larger, and in this connection either 120 c.m. or 150 c.m. was proposed. Seven of the latter had already been ordered from France by the Royal Flying Corps.

In December 1917 a total of 660 lights for home defence was approved, of which 240 were to be 120c.m. projectors. This approval was subsequently extended to 660, 120c.m. projectors, and later to 800 of that size. Provision of these projectors and the corresponding engines or motor-generators was proceeded with, accordingly, and at the cessation of hostilities approximately 125 had been supplied and the replacement of the existing 60c.m. and 90c.m. lights was

proceeding, it being anticipated that this would be completed by March, 1919.

Anti-Aircraft Searchlights for France.—Issue of four 60c.m. lights to France was made with No. 50 Field Searchlight Company early in the war. Almost immediately on their arrival their use for purely anti-aircraft work was decided upon.

In the summer of 1915 two further sections of three lights each, equipped with 60 c.m. projectors, were sent, six more sections were reorganized on a two-light basis and nine more sections were equipped and sent out accordingly between June and October 1916. The necessity for larger lights against night aeroplane attacks was soon realized in France, and three sections were accordingly equipped with 90c.m. projectors and sent out.

In December 1916 the Commander-in-Chief in France asked that all future sections should be equipped with 90c.m. projectors and that sections already in that country should be re-equipped accordingly. The future proposed establishment was given in January, 1917, as forty-eight sections, eight of which should have mobile lights mounted in petrol-electric lorries.

In December, 1917, the establishment for France was increased to the following :—

90 projectors of 90c.m. some mobile, some fixed.
100 projectors of 120c.m. with petrol-electric lorries.
36 projectors of 120c.m. with petrol-electric lorries for Independent Force, Nancy.

These 286 lights were being formed into 95 sections of 3 lights each.

In October, 1918, it was further decided to send out eight lights with each of 5 R.A.F. Squadrons, making a further 40 lights. It was proposed to provide these by withdrawing projectors and engines from home defences, but this would have meant sending 60c.m. lights and fixed engines to France, which were considered unsuitable, and arrangements were, accordingly, made to issue 90c.m. projectors (obtained from the Navy), worked from standard A.S.C. lorries, equipped with the necessary dynamos, searchlights, etc.

At the time of the cessation of hostilities approximately 100 fixed and 100 mobile lights had been issued to France.

The duties of this branch were concerned with the provision of equipment only and not with the use of the lights ; no comment is therefore made on the value of lights in the field, a subject which is dealt with in another volume.

The branch was also very little in touch with the use of the anti-aircraft equipment at home, as it had been decided that the plant when issued was to be regarded as unit equipment, and as such was dealt with for installation and maintenance by the A.A. Defence Commanders and not by C.R.E.'s.

It became obvious after some time that this procedure was responsible for the slow progress in the development of the plant, as the providers were out of touch with the users, and to get over this disadvantage a Searchlight Committee was formed, consisting of representatives of France, G.H.Q. Great Britain, C.I.R.E.S. and this branch; representatives from the Admiralty and from the United States scientific department also attended. An experimental establishment, under the direction of the Officer Commanding the London Electrical Engineers, was also formed.

These arrangements proved very satisfactory, and resulted in an indication that there is room for considerable improvement and development of searchlight equipment both for coast defence and anti-aircraft work. Unfortunately, the matter was taken in hand too late to produce any large results for use in the war, but steps were taken to continue the work for future use.

The main experiments that were being dealt with were :—

(1).—The development of the Yorke control, by which it is possible to make use of a considerably increased current density in the arc with a consequent increased range of the beam.

(2).—Experiments to determine the best size and nature of carbons for use in searchlight work under various circumstances, and the voltage and amperage required.

(3).—To determine the nature of plant to be adopted in new installations of lights for coast defence.

(4).—To arrive at a reflector which will not break when high currents are being used.

(5).—To produce a satisfactory means of obscuring the light at will.

(6).—To obtain the best form of light projector for mobile lights.

Electric Light Fittings.—Very large quantities of electric light fittings and incandescent lamps were supplied to France and other war areas, as well as home services, for electric light installations in hospitals, huts, etc. For the first two years of the war, however, the quantities required were moderate, but in the latter part of 1916 they assumed very large dimensions. Some idea of the dimensions may be gathered from the following figures in respect of the quantities of power cables demanded by France :—

1st 6 months of 1916	...	...	...	yards	40,400
2nd ,, ,, ,,	...	...	...	,,	297,000
1st ,, ,, 1917	...	...	...	,,	550,000

Such a rapid increase without any prior intimation taxed all resources.

About 4½ million yards of power cable were provided in all.

Survey Stores.—Surveying instruments do not call for much com-

ment. The quantities were large in comparison with any previous experience, as the following provision indicates :—

Barometers	3,400
Clinometers	3,900
Levels	10,200
Sextants	3,250
Theodolites	700
Thermometers	20,000
Chains measuring	3,300
Compasses illuminating	350
Various instruments	6,200

Bridging Stores. (*a*) *Cavalry Equipment.*—On the mobilization of the Expeditionary Force the bridging equipment for Cavalry consisted of air bags and superstructure for the construction of rafts, or of a light foot bridge. In September, 1914, however, the Commander-in-Chief, France, reported that a boat equipment should be provided, suitable for the formation of a light bridge capable of taking any *horsed* vehicles with the cavalry.

Such a bridge had been contemplated prior to the war, and the matter was followed up and a collapsible boat equipment evolved. The first issue of these was made in 1915. The construction of the boats required men expert in that particular class of work, and these were found only after much difficulty. Efforts to get supplies from firms in America having experience of collapsible boat work met with no success, owing to necessary features in these boats which had no counterpart in commercial patterns. Concurrently steps were taken to obtain a steel pattern boat, and the latter was finally adopted as the service pattern.

However, in August, 1917, France asked for a further supply of the obsolete collapsible boats, for which a new service had arisen in getting men quickly across rivers by ferrying, under circumstances which did not permit of more elaborate methods. 230 sections were supplied and it was reported from France that no more would be required, as the supply had been required only to meet a temporary need. But in August 1918, in consequence of damage to bridges by aeroplane attack, further supplies of these boats were demanded. In all about 2,676 sections were provided.

For the cavalry light bridge equipment 125 steel boats were provided and 5,250 articles of superstructure.

(*b*) *Pontoons.*—The pre-war scale of pontoons provided for two bridging trains of 42 pontoons each and two pontoons per Field Co. Total pontoons 108.

During the war, 2,700 pontoons and 136,000 baulks, beams, chesses, transoms, etc., were provided. The trade for manufacture of pontoons had, practically, to be educated in the special processes

needed, and some energy was expended in finding manufacturers with facilities for building pontoons, including indoor accommodation which could be kept at a temperature essential to the process of fixing the canvas with rubber solution. A few steel pontoons were obtained, but there was a difficulty in getting pontoons made in steel sufficiently accurate for the two halves to fit closely enough to obviate any undue strain being developed in the bridge. The supply of these steel pontoons was therefore limited to enough for one train plus a few for instructional purposes.

Later on, an all-wood pontoon was designed and adopted as the service pattern.

Superstructure was a difficult problem as supplies depended upon large quantities of the highest quality Oregon and Kauri timber, This need was foreseen and the earliest possible steps taken to get supplies imported. There were many disappointments, but actually no delay in meeting demands from the armies. These demands were spasmodic, and the steps taken to accumulate a fairly good stock were justified ; *e.g.*, in October, 1916, Mesopotamia which had been fully equipped, cabled for an additional 300 pontoons complete with superstructure and spares to be sent out within three months. Nothing like that quantity could have been manufactured in the time. Late in the war France also sent a demand for an increase of 5 bridging trains in addition to about 200 pontoons for maintenance. The latter were issued, but the demand for equipment of 5 trains was cancelled in consequence of the armistice. Moderate supplies also had to be sent to Egypt, and supplies were also made for bridges contemplated at home in the event of operations here, in addition to issues made to various training centres where instruction in pontoon bridging was given.

Water Supply.—Arrangements for supply of pumps by F.W. 9 were limited to service patterns, other pumps of commercial pattern being dealt with by F.W. 8, but hose pipes for all patterns were provided by F.W. 9. The service patterns varied from the 60ft. lift and force pump to power driven pumps with an output of 3,600 gallons per hour. Over 32,000 pumps were supplied and 4,700,000 feet of hose of various sizes and material.

Sandbags.—Much was written and said during the war about shortage of sandbags ; but if ever such existed it was due to control exercised by the authorities in the field, for at no time was there any failure at the W.O. to comply with the demands received. Trench warfare, however, legitimately involved the use of such enormous numbers of bags that it became necessary to buy up all available supplies in this country suitable for the purpose, and to obtain supplies of some millions of bags from America and Canada pending arrangements being made for manufacture in India, and even then doubts were raised as to whether the available jute crop would suffice.

However, through the agency of Messrs. A. J. Henry and Co., one of the principal firms in the trade, who took up this agency on a fixed percentage basis, contracts were entered into with the mills in Calcutta, and regular monthly shipments followed. The estimated requirements at that time were about 10 millions a month, but as the British armies in France increased in strength and became responsible for longer lines, so requirements of bags increased, and the issues to France alone for one month rose to over 40 millions, the total for one year being 313 millions.

The control exercised under the arrangements made with the India mills no doubt resulted in a very large financial economy. A difference of only one farthing per bag on the one year's supply to France mentioned above would amount to over £326,000. The bags supplied were made of fairly low quality cloth, but it sufficed, and the price, delivered in this country, was at one time about 2½d. per bag, and at no time more than 3d.

The arrangement of supplies from India, however, involved storage of large quantities in this country to meet emergencies, and difficulties in regard to storage frequently arose. To meet the difficulties partially it was arranged with Messrs. Henry and Co. to build a store at their wharf at Greenwich, the store to be sufficient for 20 million bags, the site to be granted free of rent, and half the cost of the store to be paid by them on the condition that the building was to become their property 6 months after the war. As one of the conditions, they agreed to unload stock, and reload as required on payment of actual cost of labour. As the usual wharfage charges for bags going in and out amounted to about 4s. 6d. per ton each way, and the usual charges for bags in buildings to 6d. per ton per week, the arrangement with Messrs. Henry resulted in a considerable saving.

The need for sandbags enabled a considerable number of orders to be placed with the prisons and detention barracks, as the making up of these bags was found to be a useful means of utilizing unskilled labour.

The provision of sandbags during the war totalled up to about 1,300 millions—about 338,000 tons shipping weight, and at a cost of about £15,000,000.

Practically what amounted to a miniature sandbag was adopted for purposes of instruction in the use of hand grenades. These small bags were filled with sand, and a very small explosive charge and fuse. About 1½ millions of these were supplied to training centres.

Mining and Field Work Stores.—So far as F.W. 9 was concerned these did not form a very big item, as many new stores mostly of commercial patterns were dealt with by F.W. 8. But of the comparatively few service patterns of such stores which were dealt with, the quantities were fairly large, such as guncotton bags 123,000, mining bars 166,000, miners' hammers 223,000, picks, shovels, etc.,

235,000, gabions expanded metal 5,000,000, posts wire entanglement 10,000,000, and screw posts for wire entanglement 10,000,000.

Manufacture of both the gabions and posts gave trouble from time to time, from one cause or another, such as shortage of raw material, difficulties of transport, shortage of coal, etc., but supply was kept up to demand.

The provision of dynamo exploders was also a source of much trouble. Demands were very erratic, and contractors experienced much difficulty in making suitable instruments. Commercial patterns were useless for military requirements as they were incapable of giving the necessary current. For the greater period of the war these exploders were used mainly for firing mines, and the numbers required were not large and for a twelve-month had practically ceased, but a short time prior to the armistice unforeseen heavy demands arose, not only from our own armies but from the Americans, French and Belgians, for use in destruction of explosives placed by the enemy in areas which he had to retire from. By various means the manufacture was pushed up to a hundred a week, and would shortly have reached 300 a week. The cessation of hostilities, however, put an end to further requirements in the field. The experience shows that it is a store of which an ample reserve should be maintained. It is impossible to manufacture the instrument at short notice, and when the need for it does arise, it is an urgent one.

Sound detectors for use in mines were also supplied in considerable numbers during the period when mining in France and Belgium was active.

During the same period quantities of "breathing" apparatus were supplied for use by men entering mines in which poisonous gases existed.

Signal Service Equipment proved such a large item in the work of F.W. 9 during the war as to require a separate chapter.

A statement showing the approximate war provision of certain vocabulary stores is given at the end of the present chapter.

War Office Staff.—In August, 1914, the staff of the branch consisted of 3 officers and 6 subordinates. On mobilization 1 more officer was attached, and by August 1916 the number had been increased to 5. In view of later events it is obvious that this staff was quite inadequate for the situation which had to be met. There were great difficulties in finding officers or civilians available and qualified to deal with military technical equipment. Every trained officer was required with the troops, and men without military experience were not suited to organizing and arranging for technical stores. Certain results of this under-staffing must be referred to, amongst them the slow development of some of the equipment required in the field, and the delegation of electric power questions to Commands at home and to units in the field. There is no doubt also that the officers

who were available were so overwhelmed with work as to be unable to deal thoroughly with the matter in which they were engaged. More trained officers became available in 1917, by which time increase of staff in the War Office was being discountenanced for financial reasons, however, more increase was received and at the end of 1918 the numbers had reached 12 officers and 30 others.

The duties of the branch consisted primarily of controlling supply and issue of technical stores, preparing information for, and advising upon, contract matters. Contracts were actually placed by the Ministry of Munitions for electrical stores, and by the War Office Contract branch for others. In the last portion of the war it became necessary to 'chase' orders from this office, otherwise, in spite of priorities, War Department orders were liable to suffer in competition with those of the Admiralty and Air Ministry, both of which departments had a considerable staff of officers whose sole duty was to visit the manufacturers' works and push their orders through. Two staff captains of F.W.9 branch were fully employed on this work. These officers, in addition to ensuring that orders were not neglected, were able to give manufacturers much assistance by procuring parts which they were unable to obtain themselves, and thus prevented delays. This procedure, though a little irregular, was adopted with the cordial assent of the War Office Contract branches and P.C.10 of the Ministry of Munitions, which departments had not always the technical experts available for such work.

The taking over of factories under the Defence of the Realm Act threw considerable work on the branch, as it entailed many questions of compensation requiring technical consideration in conjunction with the Lands office. Questions concerning appointments, pay, and conditions of service of the employees at the Inspection Division, factories, signals experimental establishment, and searchlight experimental establishment also gave rise to a considerable amount of work.

The total amount of expenditure throughout the branch during the war may be put at £55,000,000; this is exclusive of about £1,000,000 for electrical machinery and other stores purchased by F.W.8 or Q.M.G.3, but administered by F.W.9.

The establishment of F.W.9 at the beginning of 1919 was as follows:—

Detailed Organization of F.W.9 at the beginning of 1919.

F.W.9.—Deputy Director of Fortifications and Works (Chief Electrical Engineer), D.D.F.W. (c). 1 officer.

F.W.9 (a).—5 Officers, 18 Others.

Duties—Telegraph and telephone equipment (except wireless). Pontooning, mining, water supply and survey stores. Administrative questions concerning Inspection Division, R.E. Stores,

War Department Signals Factories and Signals Experimental Establishment. Technical equipment for fortresses and districts, schools, and training centres. Miscellaneous questions.

F.W.9 (b).—3 Officers, 14 Others.

Duties—Technical advice on electrical questions, coast defence and anti-aircraft searchlights. Wireless telegraphy and telephony. Electric lighting and power supply. Fixed electrical communications. Technical matters concerning War Department Signal Factories and Signal Experimental Establishment.

F.W. 9 (c) and R.E. Committee.—3 Officers, 2 Others.

Duties—Royal Engineer Committee. Patterns and preparation of all Engineer Technical Stores (except Railway Stores). Patterns of Royal Engineer vehicles. Experiments in connection with Engineer Equipment and other stores, referred to the Royal Engineer Committee by branches concerned. Scales of Equipment, Regulations, and Mobilization Store Tables, and Scales of Reserves for Engineer field units (except Railway).

Statement showing approximate War Provision of certain Stores in Sections 28 and 29.

Belts, Lineman, Mark I.	108,100
,, ,, Safety	11,100
Poles, Telegraph, Iron	12,950
,, ,, Wood—17 feet, Mark II. ...	133,509
16 feet	69,262
15 feet	7,750
13 feet, light	345,157
13 feet, octagonal ...	169,743
8 feet	78,695
Brackets Insulator Bent Shank	148,800
Brackets Insulator Single	755,000
Insulators Ebonite	1,140,000
Insulators Porcelain	9,840,000
Pins Earth	113,500
Rods Stay	165,000
Suspenders Cable	270,000
Buckets Reel Cable No. 2	23,350
Climbers Pole, pairs	20,000
Mattocks Telegraph Equipment :—	
Heads	17,529
Helves	24,800
Cases	10,170
Sticks Crook :—	
Jointed ...	10,150
Straps securing	11,050
Long ...	5,300
Short ...	17,300
Long and Short :—	
Buckets	3,700
,, Straps securing ...	3,500
Wallets :—	
Lineman, pairs	3,700
Telephone equipment	4,100
Telegraph Sets various	11,000
Commutators Telegraph 6 line	3,180
Instruments Telegraph Sounder Translating ...	1,850
Keys Double Current	3,000
Relays Telegraph	2,520
Switches Single and Duplex	2,470
Transmitters Vibrating	5,600

Telephone Sets portable D. III.		103,105	
Spare Parts		1,386,000	
Telephone Sets portable Stevens pattern		12,700	120,000 Telephones
Spare Parts		105,000	
Telephone Sets portable C. II. & Trench		3,500	
Spare Parts		19,622	Includes 11,812 for Hand C. III.
Barrows Drum Universal		10,070	
Drums Cable and Reels		730,000	
Cells Electric and Batteries, units		4,500,000	
Vibrators Telegraph		7,900	
Lamps :—			
Bullseyes Field Telegraph		4,050	
Acetylene ,, ,,		1,750	
Spirit Tele. Mechanics		7,200	
Fullerphones		26,000	
Levels Field Service		8,900	
Theodolites		574	
Sextants Pocket		6,288	

Section 28A.

Lamps Electric Signalling		100,000
Projectors 120 c/m.		985
,, 90 c/m.		100
,, 60 c/m.		600
Reflectors 120 c/m.		1,336
,, 90 c/m.		431
,, 60 c/m.		1,062
Lamps 120 c/m.		940
,, 90 c/m.		317
,, 60 c/m.		800
Switchboards, 90/120 c/m.		1,515
,, 60 c/m.		697
Ammeters (all descriptions)		4,200
Voltmeters ,, ,,		5,100
Carbons 120 amps. pairs		580,000
,, 60 ,, ,,		297,000
,, various ,,		121,000
Wire Steel Hard enamelled, miles		82,500
Coils Resistance, 10,000 ohms.		520
,, ,, 100 ohms.		4,294
Galvanometers Detector Q. & I., etc.		12,600
Terminals Double E.L.		7,100
Terminals Electrical Instruments :—		
Single		840,864
Double		1,866,485
Cable Electric "A" yards		185,920
"B" ,,		244,166
"C" ,,		1,202,054
"D" miles		600,000
"E" yards		13,753,680
"J" ,,		4,943,050
"K" Single yards		63,360
"K" Twin ,,		72,075
"L" Single ,,		116,730
"L" Twin ,,		131,550
"L" Twin Cabtyre yards		777,850
"M" yards		23,800
"N" Single yards		100,500
"N" Twin ,,		10,500
Wire Electric "P" yards		1,338,000
"Q" ,,		532,300
"Q.21" miles		1,330
"S.11 Mk.III" yards		6,200,000
"S.11 taped" miles		8,860
"S.11 taped Twisted" miles		5,000
Wire Electric "T" yards		7,506,830
"U" ,,		6,718,430
"X, 1, 3 & 5" lbs.		932

Wire Electric "X, 11 & 31" ozs. troy	635
"W" lbs.	9,345
"WW" lbs.	12,637
"WE"	6,016
"Z" cwts.	7,589
Wire Electric Jointing and Binding, cwts. ...	177
,, ,, Stay, cwts.	1,500
Wire Electric Fermo, Eureka & Miscellaneous, lbs.	4,430
Wire Telegraph, tons	13,000
Pontoons complete (wood only)	2,662
Baulks	37,483
Beams Saddle	2,945½
Chesses	86,380
Ribands	7,346
Saddles Baulk Cut	664
Transoms Shore End	1,463
Boats Collapsible	169
Boats Steel	123
Baulks	3,254
Platforms chess	1,600
Transoms	412
Bags Guncotton	123,500
Bars mining	165,900
Blowers rotary	875
Hammers Miners	223,000
Picks Miners	86,000
Rammers Earth	55,500
Scrapers Earth	34,500
Shovels Miners	52,200
,, Ditching	6,500
Trucks Miners	4,080
Gabions Sheet	4,836,000
Posts Wire Entanglement	20,000,000
Sandbags	1,300,000,000
Hose Canvas 2½in. or 2in. bore :—	
100ft. lengths	1,300
50 ,, ,, ...	2,834
30 ,, ,, ...	55,550
20 ,, ,, ...	1,000
Hose prepared Canvas or Rubber, 2in. or 1½in. bore :—	
12ft. lengths	121,107
20,, ,, ...	46,816
Hose prepared Canvas :—	
4in.–10ft. lengths	1,234
Hose filling Water Carts :—	
2in. × 15ft. lengths	4,400
4in × 6ft. ,, ...	2,250
Hose Canvas (w/out Unions) :—	
1in. to 6in. bore, 100ft. lengths ...	3,130
Pumps Portable, 3,600 galls. ...	153
,, ,, 3,000 ,, ...	289
Pumps Deep Well :—	
100ft. 3in. bore ...	344
4in. ,, ...	42
Treble barrel	12
50ft. 3in. bore ...	54
Pumps Lift and Force	28,600
Water Main Field, miles	16
Engines Oil, 8 B.H.P....	45
Photo Plates, dozens ...	8,329
,, Paper ,, ...	33,600

CHAPTER 3.

SIGNAL STORES.

Pre-War Position.—The store position on the outbreak of the war as regards signal stores must be briefly described. It is of course known to all, that at that time the field army consisted of 1 cavalry division and 6 infantry divisions. The R.E. and R.A. units of those divisions were equipped with telephone stores, the signal units being equipped also with telegraph stores. There was no anticipation that other units would require telephone equipment, in fact some months prior to the war a question at to the provision of telephones for the Territorial R.A. units was met by a reply that under no circumstances were 2nd line troops likely to require such equipment.

The reserve of signal stores maintained prior to the war was small, but, except in one important instance (portable telephones), which will be referred to later, it was complete to the authorized scale.

The Signal Service however developed into one of vital importance to the success of the field operations, and in the earliest stages demands came, not only for supplies of such stores largely to increase the scales previously authorized for R.A. and R.E., but for supplies also to equip all fighting formations.

Five items of the large variety of stores required by the Signal Service will give some idea of how far in excess of anticipation requirements actually proved to be, *e.g.*

	Reserve provided for six months field requirements.	Quantity provided during the first two years.
Poles telegraph field	... 8,736	333,964
Insulators	... 7,776	1,330,000
Telegraph sets, duplex and simplex	... 27	2,500
Field Cable	... miles 2,292	165,000
Telephones portable	... 891	51,000 plus half a million spare parts.

Early War Developments.—The problem that developed in the early stages of the war, therefore, was not a light one. So far as the portable telephones were concerned, the difficulty was accentuated by the fact that the pattern of nstrument in use prior to the war had been condemned as unsuitable. A new pattern had been under consideration and was recommended for adoption in 1913. Approval was withheld, however, pending more extended trials, and therefore, when the war broke out, there was only one firm of contractors in

possession of tools, etc., for the manufacture of these instruments. Inevitably, therefore, in the earlier stages of the war it was quite impossible to provide telephones in anything like the quantity then urgently needed.

Field telephones are not akin to any patterns used in civil life, and the work involved in getting various contractors to start manufacture of a new pattern met with painfully slow results at the beginning.

Some little relief was gained by the use of wall and table telephones of obsolete patterns. The Post Office had a large stock of these taken over some years before from the National Telephone Company. Of course such improvised arrangements were by no means ideal, but nevertheless, in the emergency, they were useful.

The resources of the Post Office for telephone and telegraph stores were called upon from the first and the very large stocks, many of them, like the telephones, consisting of apparatus taken over from the National Telephone Company, were of incalculable benefit (*See end of this chapter*).

On 3rd October, 1914, Commander-in-Chief, France, put forward proposals for improving telephone communication between Batteries and Artillery Brigades and between the Brigades and Divisional Art. Commander. It was stated that the Divisional Signal Service was unable to cope with the communication work of the Artillery as well as that of the Infantry Brigades. It was suggested that a thin varnished wire should be provided, as the light cable in use for Artillery Brigade connections "is not satisfactory and wears out very quickly." It was also stated that R.A. officers express predilection for the Stevens pattern of telephone instrument.

Thin enamelled wire weighing 6lbs. a mile supplied on a small reel was obtained, but the opinion was expressed by this branch that such wire would not be found satisfactory. That opinion proved to be well founded. The use of this wire was not continued by the Artillery but was later on pressed for by Infantry Battalions. Its only advantage, however, was portability, and it was ultimately abandoned as a service store even by the Infantry.

As regards the Stevens telephone, it was pointed out that it had been tried and adversely reported on by the R.E. Committee and Army Signal School. The D.Mk.III. service pattern was superior, lighter and cheaper. A number of Stevens telephones were provided from time to time to meet urgent requirements, but the pattern was finally abandoned, and the D.Mk.III. pattern was eventually recognized as being an efficient and satisfactory instrument.

The Commander-in-Chief on 16th November, 1914, recorded that an expansion of Divisional Signal Cos. was likely to give the best results, the proposal to add Artillery communication to the Brigade Command being bad because it violated the principle that the fighting

man should be relieved of all communication in his rear. Sections were therefore added to Divisional Signal Cos. to provide for Artillery communication between Divisional Artillery commands and Brigades.

A scale of stores for telegraph lines was laid down in Mobilization Tables for Signal Services—to be provided if required on mobilization. It included 50 tons of 200lbs. iron wire, 1½ tons of copper wire, 2,500 poles and 15,000 insulators.

Immediately on mobilization the question of providing this material was taken up, but demands promptly came from France for 60 tons of copper wire, 9,000 permanent line poles, and similar proportions of accessory stores.

This was followed on 23rd November by a demand for another 60 tons of copper wire, 40,000 insulators, 2,500 *iron* telegraph poles, etc., followed in February by demands for 80 tons of bronze wire, 80,000 insulators, 4,500 iron telegraph poles and a large quantity of accessories. These orders were completed in April.

Meanwhile a statement was furnished of probable further requirements, including 20,000 telegraph poles, 50,000 pole arms, 178,000 insulators and 350 tons of 100lb. copper wire.

One of the earliest demands totalled up to about 7,000 tons of stores and was met within a few days. It was possible at that time to find fairly large quantities of commercial pattern stores in contractors' stocks, and so far as permanent line work was concerned commercial patterns of stores sufficed.

The foregoing remarks are an attempt to indicate the position in regard to Signal stores during the first months of the war, when demands were flowing in from all directions for work in France, for equipment of new units mobilizing at home, for training purposes, and for the requirements of the Mediterranean Expeditionary Force. As time went on the demands grew in magnitude and variety but, speaking generally, they were met without any serious delay.

Field Cable.—Field Cable was an item which became of first importance to the Signal Service, and was required in such enormous quantities as to tax all the resources of the country. The patterns in existence when the war commenced were not found in all respects suitable, and various changes were made in the composition of each pattern of cable, not only to reduce the electrical resistance and keep down the weight but also to provide for alternative gauges of wire, etc., so as to bring into use all available machines for wire drawing, stranding, and braiding. The manufacturing difficulties were constant; shortage of machines and factory facilities in the earlier stages were followed by shortage of material and labour.

Steps had to be taken to change the material for the braid from flax to cotton, because the quantity used in the cables was so large a proportion of the available supply as to seriously affect the aircraft service. However, despite the many difficulties, the output of field

cable was ultimately raised to over 7,000 miles of core a week. During the war a total of 600,000 miles of core of this class of cable was provided. 93 tons of steel wire per week were required for this.

The following issues of field cable were made to France alone :—

During the first year of the war	... ...	21,000 miles.
,, ,, second ,, ,, ,, ,,	... ...	50,000 ,,
,, ,, third ,, ,, ,, ,,	... ...	121,000 ,,
,, ,, fourth ,, ,, ,, ,,	... ...	245,000 ,,

Trench Cable.—Large quantities of cable were required in France of special types for burying. The patterns were designed by the engineering branch of the Post Office, and altogether about 53½ thousand miles were provided equivalent to 240,000 miles of core, at a cost of over £2,500,000.

Signalling Lamps.—Electric signalling lamps were another class of store which gave cause for anxiety for a considerable time. A pattern had been adopted before the war to replace gradually the old "Begbie" pattern in which the illuminant was oil. This electric lamp was supplied to most units early in the war, but proved to be unsuitable under trench warfare conditions. A lamp was found to be required in which the divergence of the beam was so small as to obviate signals being readable, except within narrow limits of its alignment. It was also required to be suitable for daylight signalling.

An officer of the R.A.S.C. (Lieut. Lucas) had designed a lamp to meet these requirements, and he was brought home to proceed with experiments and superintend manufacture. As soon as the pattern was sufficiently developed, an order was given to a firm at Birmingham which had made the pattern, and steps were taken to induce other firms to take up the manufacture. It was a difficult lamp to make, and the electric bulb fitting had to be within a gauge limit of about 3-1000ths of an inch to obtain the best results. The electric bulb had also to be of special design. Consequently progress at first was exceedingly slow, but the output was eventually raised to about 1,000 a week, and all services were equipped with this pattern.

Fullerphones.—This instrument was invented by Captain Fuller, who was sent to France (in January, 1916) with a rough made instrument to illustrate the principle of the invention. The Commander-in-Chief, France, asked that, subject to some alterations and additions, 1,000 of the instruments should be supplied. Captain Fuller was at once detailed to supervise the manufacture of samples, and drawings. The latter comprised 8 large sheets containing about 120 separate working drawings. On 17th March a contract was made with Siemens for delivery to commence in May, but the manufacturing difficulties were constant and on 15th July, by which date 500 should have been completed, the total number passed was only 31. The Post Office assisted by making about 2,500 in their shops, and

later on it was possible to complete the full numbers required in France, owing to the comparatively large numbers manufactured in the W.D. Signal factories.

Electric Cells.—Electric cells of various patterns were of course required in enormous numbers, and the strain upon contractors tended to the production of hurried work and somewhat naturally to articles below an acceptable standard. Constant supervision and pressure were needed to maintain the required supplies, which steadily increased in quantity. Practically all difficulties were eventually removed by Government assistance being given to Messrs. Siemens to increase their battery shops.

One curious form of trouble which arose at one time was due to the need for flour in the manufacture of dry cells. The Food Controller intimated that the use of flour for the purpose must be discontinued, and efforts were made to find a suitable substitute, without success however. Finally the Food Controller withdrew his veto.

Excluding those used for wireless apparatus about 5,000,000 cell units were provided during the war.

Switchboards Telephone.—Switchboards formed an important item, and for the most part the patterns were produced during the war to meet various conditions which arose. They were of buzzer, magneto and visual types varying in sizes from 5 lines to 200 lines, the small ones, of course, portable, and the larger ones so designed as to permit of their being dismantled and moved at very short notice. The total provision amounted to about 18,000.

Assistance rendered by the Post Office.—In June, 1915, a conference was held with representatives of the Post Office Department with a view to that department arranging for provision of such electrical stores, required by the armies, as were similar in pattern to those used by the Post Office.

This was to obviate competitive buying. It was agreed at the conference that all stores common to Post Office and army requirements should be provided by the Post Office, and further that the Post Office would act, in respect of these stores for the army, as an Army Ordnance department, and would arrange for storage and issue to the overseas bases on demands.

The Post Office also agreed to act as storeholders to the A.O.D. in respect of other stores as occasion arose, a considerable amount of P.O. store accommodation being available at Birmingham. As regards this portion of the arrangement large quantities of stores were provided for at Birmingham, such as wire entanglement posts and other heavy and bulky stores, but Birmingham proved to be a very bad centre owing to the constant railway traffic congestion there, and consequently the W.D. was not able to take such full advantage of the accommodation as would otherwise have been desirable.

As regards the electrical stores, in the first instance, most of the demands came through the Army Ordnance Department ; gradually, however, arrangements were made by which demands for nearly all stores supplied by the Post Office were sent direct by the Army Signals to D.F.W. and thence direct to the Controller of Post Office Stores, and an assistant from the Controller's office was appointed to act as *liaison* officer between that department and F.W. 9. By the latter arrangement a good deal of correspondence was saved, as this official attended at the War Office practically daily, and was able to give information at first hand on the numerous questions arising as to progress.

Numerous new patterns of instruments and trench cables were designed by the engineering branch of the Post Office to meet the army requirements, a list of which is appended ; and a representative of that branch, who was given a temporary commission and attached as adviser to the R.E. Inspection Division, made frequent visits to the Signal Service in France in order to make himself acquainted with new requirements and to put forward the D.A.S.' suggestions as to the proposed methods of meeting them.

The D.A.S. in France was at all times in direct communication with the D.A.S. Home Defence at the Post Office, and with the officials of the engineering and stores departments in regard to patterns of stores and progress with supplies. The extent of the assistance given by the Post Office to the armies is indicated by the statement of new stores designed and issues to the armies. The value of these stores amounted to over £6,000,000.

To that extent the War Office was relieved of the purchase, inspection, and issue of stores. It was most valuable assistance and all officials of the Post Office department endeavoured in every way possible to make it an efficient service.

Approximate quantities of issues made through the Post Office.

Poles and Line.	
Pole Arms	... 907,000
Bolts Arm	... 1,894,000
Binders	... 3,029,000
Brackets	... 537,000
Insulators	... 9,533,000
Rods stay	... 154,000
Spindles	... 7,188,000
Saddles	... 454,000
Wire.	
Bronze, tons	2,380
Copper ,, ...	5,440
Iron ,, ...	5,400
Cable.	
Trench, miles	53,465
Apparatus.	
Apparatus repairing wire	8,100
Telegraph	9,400
Telephone	91,300

General.

Cells, dry	...	...	2,022,000
Ratchets	...	...	12,500
Tongs, draw	...	...	13,300
Climbers pole	...	...	12,950

A LIST OF INSTRUMENTS AND APPARATUS DESIGNED OR ARRANGED BY THE ENGINEERING BRANCH OF THE G.P.O. FOR THE USE OF THE SIGNAL SERVICE.

Trench Switchboards.
Buzzer Switch-Units, 7 lines and 10 lines.
Magneto Switch-Units, 5 line and 10 line.
Switch-Unit with Visual Buzzer Call Indicator 8 lines.
Buzzer Switchboard with Visual Indicators, 12 lines.
Cordless Magneto Switchboards 5 line and 10 line.
Encased Magneto Switchboards 10 line.

Telephone Switchboards for Multiple Exchanges at Base Offices.
Modified type of 50 line floor pattern switchboard, with provision for multiple switching.

Switchboards for the Lines of Communication and larger Formations.
Many standard types of P.O. telephones switchboards were specially adapted for War use and fitted in combined stands and packing cases designed to facilitate transportation and rapid erection *in situ*. Several hundreds of these were supplied.

Trench Telephones.
Many forms specially designed for particular military purposes and existing patterns adapted.

Mobile Line-Testing Equipment for Divisional and Brigade Offices.
This equipment included the following items :—
Test Panels 12-line.
,, ,, 4-Transformer.
,, ,, 2-Transformer.
,, ,, galvo.
,, ,, P, 6-pair.

Test Frame, Portable, 160 Pairs and 80 Pairs.
Strips, Transformer Bracing, for
Protectors, Fuse and Test, No. 4002.
Protectors, Test No. 4001.
Test-Tablet, E.C. 1144.
Strips, Connection No. 50.
Transformer No. 6 (Double).
Plugs No. 218.
Plugs No. 112.

Lamp Signalling System for Observation of Fire of Anti-Aircraft Guns.
Items—Cases, lamp signalling, gun spotting.
Cases, press button, gun spotting.

Sound Ranging Apparatus.
Holders, Microphone (Marks 1, 2, 3, & 4).
Testboards, 40 Pair.
Instruments, Ranging, 6 slide.
Test-Boxes, 2, 4, 8 and 16 Pairs.
Cases, Microphone, Sound Ranging.
Containers, Air, Microphone.
Protectors, Test, No. 201.
Condenser 8 M.F. with Test Holes.
Flash Spotting Apparatus.
Switchboards, Flash and Buzzer, 4-line.
Switchboards, Flash and Buzzer, 6-line (Mark 1).
Switchboards, Flash and Buzzer, 6-line (Mark 2).
Press-key, Flash and Buzzer (Mark 1).
Press-key, Flash and Buzzer (Mark 2).

Lighting Set, Survey Post.
Jack No. 8 Double with Cord.
For Munitions and Stores Dumps in France.
20-Circuit Switchboards for Central Offices and special call points, providing continuous supervision of line insulation and automatic indication that call has been received.
Screening Buzzers.
Patrol Telegraph Sets.
Angle-Dividers.
Bell Set, Trench Mortar Battery.
Buzzer Sets, Trench Mortar Battery.
Distributing Cases, 40 Pairs.
Cross-Connecting Switch Cases, 40 Pairs.
Arm Grips.
Transmitter, Watch, with Press Button.
Insulating Blocks.
Telegraph Sets, Portable Central Battery.
Test Tablets 20 Wire, L. of C.
Transformers No. 6 Double.
Transmitters No. 20.
Test Set, Portable No. 1.
Muzzle Velocity Calibration Screens (Strips Connection No. 51).
Telephone Sets, Reporting. Telephone Sets, Receiving.
(Special for Secret Service in England).
Instruction Diagrams.
High Tension Fuses.
Test and Protector Case.
Ladder for Light Airline Work.
Search Coils.
Concentrating and Inter-Communicating Switchboards.
Concentration and Inter-Communication Switchboard for G.H.Q.
Drum Wire Z3.
Ear Pads No. 1.
Generator No. 20A.
Generator, Pedal Driven.
Gramophone Morse Records.
Headbands Nos. 1, 2 & 3.
Indicator, Buzzer Visual, Nos. 1A & 2A.
Indicator and Jack No. 1, and Indicator and Key No. 7.
Indicator and Key No. 6.
Keys 69F, 69FN, 72MB, 72MC, 73C.
Keys SC, Metal Frame.
Plug No. 301A.
Protector 40D.
Protectors, Fuse and Test No. 4002.
Protectors Test No. 4001.
Relay 171A.

CHAPTER 4.

INSPECTION DIVISION.

General.—The need for, and the work of, an Inspection Division are possibly less understood than in the case of any other branch.

The duties of an inspection branch are also among the most thankless of those connected with the provision and supply of stores. When the provision and contract branches have succeeded in getting orders placed, and the fighting forces have been anxiously waiting for some necessary article, the inspection branch may have to condemn the stores and so create another period of waiting. The natural result is to bring considerable moral pressure on the inspector to pass stores, and to support manufacturers in any dispute with the branch. This is particularly the case with the work of inspection of technical R.E. stores, since the vast majority of the stores are not of a purely military type but are closely akin to those used in civil life. The fact that conditions of active service, and the necessity for far greater interchangeability of parts, makes it imperative for the stores to have certain special attributes is lost sight of, and the opinion of the Inspector is frequently called in question by quoting against him the opinions of civil experts with civil experience of similar stores. There is a further stumbling block in the difficulty in getting first-hand information from the troops who actually use the stores. It frequently happens that stores are given up as worthless in the field for faults which are not due to faulty designing, but to the absence of some particular quality not normally to be found but easily obtainable in the article.

Duties.—Before the outbreak of war the duties of the Inspection Division, R.E. stores were generally as follows :—

1.—Preparation of drawings and specifications of stores forming part of the equipment of R.E. units and of stores of a similar nature used by other units, also of all electric light fittings and lamps used in the service.

2.—Inspection of such stores before they were handed over to the Army Ordnance Department or, in the case of electric light fittings, taken into store by the Division for issue to stations.

3.—Examination and grading of all such stores returned to Woolwich from outstations.

4.—Accounting for, storing and issuing electric light fittings and lamps.

5.—Fitting up and testing of the wagon wireless stations used in the service.

These duties were considerably added to during the course of war and, apart from the great expansion of all the above, new duties were undertaken, some of which are described below.

Many new stores were designed or improved in the Division, amongst which, excluding wireless and balloon propaganda gear, the following may be mentioned :—

Barrows Drum Universal.—Steel shafts designed and wheels improved.

Compasses Magnetic Pocket.—New dial and other improvements.

Compass Prismatic.—Automatic device for raising needle off pivot when closing.

Compasses Mirror.—Complete new type, designed.

Boards Artillery, rectangular and sector shaped.—Perfected from a crude sample.

Drums Cable "No. 5" and "Cart Mark IV".—"All metal" drum designed.

Light Bridging Equipment.—Capt. E. P. Sankey, R.E.'s design perfected and detailed design got out.

Steel Boats for Light Bridge.—Complete new design.

Pontoons.—Complete new design with double skin.

Boring and Jumping Bars.—Modernized and standardized.

Tapes Range Steel.—Designed.

Apparatus Laying Field Telephone Cable Portable.—Designed.

D. Mark III. Telephone sets.—Considerably altered and improved.

Telephones Hand and Receivers.—Cases and collars made interchangeable in transmitter and receiver and generally improved.

Potentiometer.—New pattern designed on a new principle.

Field Cables.—Frequently re-designed to suit manufacturing conditions and supplies of raw materials.

Cabtyre type of Cables.—Adapted to service needs.

Telephone Cords.—Re-designed by substituting tinsel for wire in conductor and adding helical wire reinforcement on ends.

Insulators Field.—New type designed to enable insulating materials other than ebonite to be used.

Cases for "D" Portable Telephone Sets.—Improved with a form of quick release strap instead of buckles.

Apparatus Illuminating Sights No. 2, 3, and 4.—Designed.

In addition to the above a large number of new stores were introduced for which the designs, though originated elsewhere, were completed and put into shape for manufacturing purposes, whilst manufacturers were given assistance and advice in producing suitable

types or adapting types to the increasing difficulties of production and dearth of raw materials.

Purchase of Timber.—The increase in difficulties of manufacture, and the strained situation as regards supply of raw materials, necessitated a constant watch being kept on the markets in order that proposals might be made as early as possible to deal with anticipated shortages. As an example of this the following instance may be cited. It became evident early in 1915 that a shortage in Oregon pine would occur. No other wood was so suitable for service pattern bridging equipment where size was limited by many considerations, and shape and design were governed by the necessity for complete interchangeability, whilst lightness was an absolute necessity. Authority was accordingly obtained to purchase stocks of prime clear Oregon pine for conversion into bridging superstruction as required; and some 60,000 cub. ft. were purchased at an average price of 3s. 10d. per cub. ft. This timber afterwards rose to 10s. per cub. ft. and much of the waste was actually resold at prices very considerably higher than the price for the original whole flitches. It was used not only for bridging stores, but for telegraph poles and many other stores for which suitable timber became difficult to obtain. The cost of bridging stores made from this timber was actually lower than the contract prices for these stores in peace time whilst, on the bridging stores made out of it up to the end of 1916, which consumed approximately half of the total, a saving of £3,650, or 23%, was made as compared with contract prices paid for these articles in 1915 in cases where the contractor supplied his own timber. A complete analysis of this transaction has not been made and would take a considerable time but, taking into account the value of waste sold, it is certain that more than the whole original cost of this timber was recovered in the shape of savings in the cost of articles made from it. It must be remembered that, at the time this deal was made, the idea of the War Department buying stocks of raw materials and making its own arrangements for their conversion was quite new.

Storage and issue of electrical stores.—In the direction of storing and issue of stores further duties were also undertaken. Owing to urgency the installation of electric light in the numerous hutted camps had been entrusted to various firms of consulting engineers, and consequently the equipment was not only not of recognized service pattern, but also was of very great variety. Further, as the shortage of raw materials and the difficulties of manufacture increased, it became necessary to use these to the best advantage and, wherever possible, to substitute cheaper and more easily manufactured articles for the service types, which were designed with a view to active service requirements, and were therefore, in many cases, unnecessarily elaborate or expensive for ordinary hut lighting. For a non-technical store branch such as the A.O.D. to do this

and to know what could be usefully substituted for the various service types of switches, cables, etc., was obviously impossible, and accordingly, early in 1918, the Division took over the accounting, storing, and issue of all electrical stores, other than plant, for hutted camps and barracks both in England and in the theatres of war. This was one of the most difficult tasks undertaken by the Division, since, the whole object being to take full advantage of the existing stocks and sources of supply, it was impossible to adopt a nomenclature which would be a guide to the subordinate staff employed in the storage and distribution of these stores, whose variety is extraordinary. Further the rate of wages was not sufficient to attract educated or highly trained men, and a complete staff had consequently to be trained for this work.

Wireless Experimental work.—Early in 1915 the rapidly increasing importance of aeroplane observation for artillery fire brought into prominence the use of wireless telegraphy for this purpose, and the Division gradually undertook the necessary trials and experimental work. The volume and importance of this work rapidly increased, and a separate sub-section was formed to deal with all wireless work. Many new instruments were designed, and the Division workshop was enlarged to enable experimental instruments to be turned out and a certain number of instruments to be made in small quantities for use overseas. Later factories were taken over and organized for this purpose, as described further on.

In September, 1915, wireless experimental and inspection works were formed into two separate sections under specially qualified officers, whilst the services of highly skilled civilian experts were also obtained.

In April, 1916, the wireless work was re-arranged and the Division shops were further enlarged and placed under a foreman examiner, whilst the experimental staff was further strengthened.

During all this time a certain amount of experimental work was also being carried out at the R.F.C. wireless establishment at Brooklands. This establishment was really intended for the instruction of wireless operators but, as so frequently occurs at such establishments, experimental work began to be undertaken there and a certain amount of overlapping took place. A R.F.C. wireless committee was formed in the summer of 1915 to try and co-ordinate the work, but these attempts were not entirely successful. Finally in the summer of 1916 it was definitely decided that all experimental work for wireless telegraphy in the R.F.C. should be carried out at Woolwich, and early in September, 1916, a technical R.F.C. officer was transferred from Brooklands to Woolwich.

During the summer of 1916 it was found that the situation of the dockyard greatly handicapped the experimental work, and it was decided to enclose a portion of Woolwich Common and to put up

huts and a permanent mast there to enable experiments to be carried out under more suitable conditions.

Until well into 1916 wireless work for the Signal Service made little progress. Except for direction finding and compass stations, which were obtained *en bloc* from the Marconi Company and installed and controlled by the Intelligence branch, comparatively little use was made of wireless on the ground, the original wagon and heavy lorry stations, and a light lorry type for the cavalry, being practically the only stations in use.

A certain amount of experimental work was carried out in France, but nothing very important appears to have resulted. By the early autumn of 1916, however, the difficulties which were being experienced in maintaining telegraphic and telephone communication under heavy shell fire resulted in the question of improved wireless communication coming to the fore, and experimental work for this purpose was taken seriously in hand.

At the end of September, 1916, it was considered that wireless experimental work had developed to such an extent, and become so important, that it could no longer be properly supervised as a branch of the Inspection Division, and it was decided to form a separate establishment under the name of the " Signals Experimental Establishment," on Woolwich Common in the enclosure and buildings which had been put up for this work.

In accordance with this decision the whole of the experimental officers and some 130 subordinate staff were transferred to this establishment, and the Inspection Division's direct responsibility for wireless experimental work ceased from September 29th, 1916.

During the time that the Division was responsible for the designs of wireless sets the following instruments and sets were produced :—

Amplifiers A. Mks. I, II, III.
Amplifiers B.
Batteries dry 600 v., 400 v., 200 v., 100 v., Mk. I.
Transmitters W.T. Aircraft 30 Watt Nos. 1 and 2 (developed from the Sterling Transmitter).
Transmitters W.T. Aircraft, continuous wave (Type " W ").
Tuners Aircraft Mk. I.
Tuners Heterodyne Mks. I, II, III.
Tuners Long Wave, Mk. III.
Tuners Short Wave, Mks. I, II, III.
Valves W.T. " White " Type.
W.T. Set Trench 130 Watt, Wilson Transmitter.
W.T. Set Trench C.W. Mk. I.
Mast and Aerial gear for 70ft., 30ft. and 15ft. steel masts.
W.T. Sets Service Lorry.
W.T. Sets Light Motor.
W.T. Sets Wagon, Mk. II.

In addition to these, experiments with Rouzet sets for aircraft were carried out and a number of sets obtained.

An account of the work of the "Signals Experimental Establishment" is given in the next chapter.

A.A. Defence Lights.—The first lights were mainly of the 60c.m. size, partly because this was the largest size of which there was any commercial pattern. All available types were secured and many were mounted, with their generating sets, switchboards, the necessary lengths of cable, etc., in the ordinary 3-ton lorry. All this mounting was done in the Division. Later a "Service type" of 60c.m. projector was designed in the Division, and still later a 120c.m. projector, whilst a large number of 90c.m. projectors were procured from the Navy, repaired and, where not already suitable for A.A. work, altered for that purpose. A large proportion of this work was done in the Division.

In addition to this, the demand for mobile lights as well as fixed ones for France began to be felt in the autumn of 1917, and developed rapidly into a very large affair. Before the war, two Tilling-Stevens petrol electric lorries had been fitted out in the Division as mobile coast defence lights. The projectors on these were altered to be suitable for anti-aircraft work, and after a considerable amount of work in England they were sent to France in March, 1916, with the 50th Searchlight company. These two formed the model for a large number of similar sets which were fitted up in the Division and dispatched to France, where they were understood to have proved very successful.

Field lighting sets.—Shortly before the outbreak of hostilities the General Staff had expressed a desire for a portable electric lighting outfit to allow of an Infantry Division staff office tents or premises being quickly lit electrically. A set was accordingly designed, consisting of a 1 K.W. direct-driven petrol set mounted in a 3-ton lorry. 36 lamps were provided; the main, feeder, and branch cables, of cabtyre sheathed twin cable, were all provided with a plug at one end and a socket at the other. The switch lamp-holders were provided with 12inch lengths of flexible cabtyre sheathed cable with a plug at the other end, and the shades had the shade carrier rings permanently fixed to them. A main switchboard was fixed in the lorry fitted with a socket for the main cable and two small sockets for portable lamps. A watertight main distribution 5-way fuzeboard of aluminium with open type fuses was provided, together with 5 watertight junction boxes of aluminium, each for one feeder and six branch cables. The main distribution board and junction boxes were all fitted with watertight sockets, and the whole arrangement was therefore extremely flexible and weatherproof and could be erected in a very short space of time. "Standard lamps" were provided, consisting of lengths of bamboo fitted with "drain cleaning

rod " screw plugs and sockets and a collapsible iron base, the lamp-holders being tied to the top of the rods as desired. These sets were extensively used and, for Corps and Armies, were increased to 3 K.W. sets supplying 60, 25 c.p. lamps. The apparatus was packed in Signal panniers.

Propaganda Balloons.—Various methods were tried from time to time for effecting distribution of propaganda in enemy countries. A number of experiments made by the Munitions Inventions Department resulted in a paper balloon of about 100 c.f. capacity, and in February, 1918, the Division undertook not only the inspection of the balloons but the whole organization of collecting, preparing for use, packing and dispatch to Charing Cross. It was early discovered that the balloons were not gas tight, nor were they suitable in many other respects. With the assistance of Messrs. Gamage, who were given the first contract for the balloons, further experiments with paper, dope, and paste, for making the joints were carried out. A satisfactory balloon was produced and large numbers were sent to France every week.

A section composed of women was organized to deal with the folding of propaganda, loading of releases, and packing. Some 80 to 90 girls were employed. Speed was naturally an essential as the great object was to keep the propaganda as up-to-date as possible, and consequently a very complete organization was required. The printing and actual preparation of the propaganda leaflets were arranged by M.I. 7. (B), the leaflets when printed being sent down to the Division at Woolwich, where they were dealt with as below.

At first each leaflet was folded in the form of a folded note, made into packets, punched, and attached to the releases. Later the folding was dropped as being unnecessary, a hole being merely punched in the corner of each sheet. The sheets were made up into bundles of $\frac{1}{4}$lb. and attached by means of " correspondence " tags, at intervals of $\frac{1}{2}$ inch, to the " release." The release consisted of a piece of tinder, such as is used in pipe lighters, having a wire threaded through it by means of which it was attached to the neck of the balloon, a free end of tinder of a given length being left at the top. To operate the release the free end was cut to a length varying with the strength of the wind and the distance from the starting point at which the first bundle of propaganda was required to drop. The tinder was lighted, and burnt down at the rate of 1 inch per 5 minutes. When the burning reached the first correspondence tag this latter was burnt through and allowed the first bundle of propaganda to drop, and so on for the other bundles. Several other patterns of releases were tried and some, besides that described above, were retained for special purposes. The balloons carried 4 lbs. of leaflets apiece. Special arrangements for speedy packing were made, and

the cases were sent to Charing Cross once a week, or, for a time, twice a week, in the Division lorries.

The Germans, who were of course the first to employ such methods, described ours as " English poison raining down from God's clear sky."

Various Experimental Work.—The Division also took part in experimental work in several other directions, from which stores of considerable use were evolved. For instance, the question of the screening of buzzer telephone sets from being overheard by " listening " sets, and of sound detecting apparatus for locating the direction and distance away of enemy land mining operations. Again, before the formation of an anti-aircraft searchlight experimental establishment at the headquarters of the London Electrical Engineers, all experimental work on and design for patterns of stores for A.A. searchlight defence was carried out by the Division.

Factories.—When the requirements of wireless stores began to develop rapidly, early in 1915, it soon became evident that the Division shops would not be able to produce the numbers required. On the other hand it was not possible to give the work out to contractors, because the urgency was such that instruments had to be produced before detailed drawings and specifications could be prepared. Further, designs were necessarily subject to continual alteration, even when the instruments were in the shops in process of manufacture. To make a contract subject to such continual variations presented insuperable difficulties.

It was therefore evident that the only possible solution was to have a factory run directly by the War Department, by which means most of the above difficulties could be met. Actually five complete factories were taken over and run by the Inspection Division up to the end of 1917, when a separate organization was established under a Superintendent of Factories; thus relieving the Inspector of Stores of an enterprise which had altogether outgrown the resources of the Division. An account of these factories will be found in Chapter 6.

Personnel.—The difficulties of finding those with the peculiar qualifications required for inspection work have been referred to earlier. On mobilization the Division lost 37 employees, or nearly 40% of its staff. The war establishment was 4 officers and 165 subordinates, but it very early became evident that this would prove quite inadequate, and there was a progressive increase up to a maximum in October, 1918, of 30 officers and 1,620 subordinates, excluding the staff in factories.

This Division was one of the first, if not the first, W.D. office to introduce female clerks apart from typist *personnel*. The experiment was successful, and finally 104 were employed against 64 males, or 62% of the total. It is a high tribute to the care and accuracy of

the clerical staff that, in spite of the technical difficulties of accounting, only £950 worth of stores out of a total of £30,000,000 dealt with were not definitely accounted for on paper. Female examiners for lower grade examination work were first introduced in April, 1917, and in September, 1917, women began to be employed on high grade testing of wireless instruments.

Accommodation.—Throughout the war one of the principal troubles of the Division was lack of accommodation. Situated as it was in Woolwich Dockyard there were great difficulties in the way of any expansion. Stores when awaiting inspection take much more space than when in store, since goods from each contractor must not only be stacked separately, but each delivery from the same contractor must be kept distinct. Again stores must be stacked in such a way that they can be "turned over" easily by the examiner, whilst there must be space to stack them in heaps according to their grading after examination. The inevitable delays, and the lack of shelter for the huge deliveries, made it increasingly difficult to justify rejections, and gave manufacturers a good opportunity to disclaim responsibility for defects. A few extra stores sheds were taken over, and some built on the very limited space available, but it became absolutely necessary to look further afield; and after many difficulties a site was acquired at Southall in Middlesex, near a G.W. Railway siding, and having ample space for expansion. It was decided to put up a building here for the storage of electric lamps, fittings, and other E.L. stores for barracks and hutments, and also for their inspection. The building was started early in 1918, of reinforced concrete, with a wooden roof on specially designed large wood girders. Financial reasons caused part of the scheme to be abandoned, and labour troubles interfered with progress so that the building was not completed for occupation by the end of the war. Stores had, however, begun to be transferred there, and it was of considerable assistance even in its unfinished state. The store staff were moved to Southall in January, 1919.

Out-stations.—As the space in the Dockyard became more and more congested, and also as the excellent tendency to enter into running contracts grew, the amount of inspection carried out at manufacturers' works increased.

In September, 1915, a section was formed at Manchester and a foreman examiner, who had been many years in the Division, but had retired before the war, was brought back and put in charge.

In July, 1916, a sub-section was formed at Birmingham with a staff of 30. In January, 1917, this sub-section was made a separate section with a staff of 45 and a foreman examiner in charge.

In January, 1918, out-station work was completely reorganized as the work at Birmingham had spread too far. A section was formed with headquarters at Bradford, in charge of a foreman examiner,

to deal with inspection in Scotland, Ireland, and the North of England. A second section was formed with headquarters at Birmingham to deal with inspection in the Midlands, whilst the inspection in the South of England was dealt with from Woolwich. An officer was appointed to Birmingham, at first to supervise both out-sections, but, later, he was transferred to Bradford and another officer was appointed to Birmingham.

These sections did not deal with all types of stores, for instance cable inspection was still done by travelling examiners supervised from Woolwich. They dealt with all "general engineer stores" where resident examiners were kept at works, and with similar stores in their areas.

This scheme worked well and saved a good deal of transport, but, for various reasons, it would not have been economical to introduce it to the same extent that it could be practised by some munitions departments. In this Division it had to be more or less confined to stores of which factories were giving large outputs, and which only required to pass through the hands of one examiner; such as entanglement posts, barbed wire, gabions, pontoons, etc.; or to districts where a large number of firms were collected together in a comparatively small area—such as Birmingham.

Tables.—The four following tables give some instructive data as to the work of the Division.

On Table A the organization for work in November 1918 is shown.

On Table B the relations between value and cost of work done are illustrated. On this table the average number of inspection notes and average value of stores dealt with per head per week are tabulated, but much other work was done by the Division, while these figures were based on the whole strength. For instance, as will be seen from Table C, which gives some interesting statistics, the work of accounting and issue of stores for Division uses, and of electric lamps and fittings for issue to stations, involved an average of ·22 vouchers being dealt with per head per week; whilst through most of 1915 and 1916 between 1-8th and 1-10th of the strength of the Division was employed on experimental work.

Table D. gives some figures of the total number of some of the stores which passed through the Division. They represent only a few of the different stores dealt with. In round figures 650 different patterns of stores were inspected, varying from a paper balloon to a wireless telephone set, from a wrist-watch to a searchlight projector, from an incandescent lamp to a pontoon.

I.
Examn. Elec. Light Stores and Vote IX O Stores issued by Division.

II.
Examn. all General Eng. Stores and Scient. Insts.

	I.	II.
Inspectors.	1 Officer (I.O. 1.)	1 Officer (I.O. 2.)
Assistants to Inspectors.	1 Officer (A.I. 6.)	1 Officer (A.I. 12.)
Chief Foremen Examiners.	1 Other (C.F.E. 1.)	1 Other (C.F.E. 2.)
Chief Clerks Office Section.	1 Other (C.C.1.) (Office Section 1.) 1 Other (Southall) (C.C.1a.) (Office Section 1a.)	1 Other (C.C. 2.) (Office Section 2.)

Under I.:
- i, ia — 1 Officer (A.I.1.); 1 Officer (A.I.2.) (For Secondary batteries at Stations).
- ii — 1 Officer (A.I.3.)
- iii — 1 Officer (A.I.4.)

Under II.:
- iv, v — 1 Officer (A.I. 8.)
- vi — 1 Officer (A.I. 9.)
- vii — 1 Officer (A.I. 10.) (Stationed at Birmingham.)
- viii — 1 Officer (A.I. 11.) (Stationed at Bradford).

Heads of Outside Sections.
Foremen.
Assistant Foremen.
Assistant Forewomen.
Storeholders.

- i — Temp. Frmn. Exr. (F.E.i.)
- ia — Temp. Asst. Frmn. Exr. (F.E.ia.)
- ii — Temp. Frmn. Exr. (F.E.ii.)
- iii — Temp. Frmn. Exr. (F.E.iii.)
- iv — Temp. Frmn. Exr. (F.E. iv.) Asst. Forewoman.
- v — Temp. Frmn. Exr. (F.E.v.).
- vi — Temp. Frmn. Exr. (F.E. vi.)
- vii — Temp. Frmn. Exr. (F.E. vii.) (Stationed at Birmingham).
- viii — Temp. Frmn. Exr. (F.E. viii.) (Stationed at Bradford).

Period.	Value of Orders placed in £.			
	Total.	Average per week	Average per head per week	Aver per pect not
	£	£	£	£
1914 (whole year) ...	1228904	23633	141·5	14
1914 Pre-war (31 weeks) ...	450538	1466	15·3	1
1914 War Period (21 weeks) ...	1183851	56374	228·2	20
1915 (52 weeks)* ...	4300781	82707	124·9*	12
1916 (53 weeks)† ...	4406223	83136	102·7	11
1917 (52 weeks) ...	9730624	187128	201·4	22
1918 War Period (45 weeks)	9532864	211823	155·0	17
Total War Period ... (223 weeks) ...	29154343	126253	146·3	16
1918 Post War (7 weeks)	2856346	408050	252·6	31
1918 (whole year) ...	12388367	238238	172·5	19
Total for War Purposes (230 weeks) ...	32010689	139177	157·4	17
On 1. 8. 14.		950	10·0	1
1. 1. 15		69750	193·8	20
1. 1. 16		79300	94·4	9
1. 1 .17		123600	164·8	17
1. 1. 18		252300	236·9	28
9. 11. 18 Based on Average of last two months.		223000	141·6	18

TABLE C

INSPECTION DIVISION, R.E. STORES.

War Period—4. 8. 14 to 10. 11. 18.

Various Statistics.

Total number of orders dealt with	25,200
Total number of different contractors dealt with	1,150
Total value of orders placed for war purposes...	£32,011,000
Total value of orders dealt with	£29,155,000
Total number of Inspection notes received (approx. number of consignments)	177,350
Total number of examination orders from D.D.O.S. dealt with ...	6,350
Total number of issue vouchers for electric fittings, lamps and stores under A.C.I. 152 of 1918	12,750
Total number of receipt vouchers for electric fittings, lamps and stores under A.C.I. 152 of 1918	2,303
Total number of vouchers dealt with in Inspection Division store account	26,608
Maximum number of officers on staff	30
Maximum number of subordinate staff	1,620
Average number of subordinate staff per week	862·54
Average value of stores dealt with per head per week	£146·3
Average number of inspection notes dealt with per head per week ...	·92
Average number of examination orders dealt with per head per week	·03
Average number of issue vouchers for electric lamps, fittings, etc., dealt with per head per week	·07
Average number of receipt vouchers for electric lamps, fittings, etc., dealt with per head per week	·01
Average number of receipt and issue vouchers for Inspection Division stores dealt with per head per week	·14
Total pay of officers, including allowances	£28,400
Total wages of subordinate staff	£658,650
Number of specifications made or altered	870
Number of contract demands and enquiry forms dealt with ...	4,650

TABLE D.

INSPECTION DIVISION, R.E. STORES.

Numbers obtained of some of the principal stores dealt with.

Accumulator charging sets (portable)	590	
Ammeters and Voltmeters	22,600	
Apparatus Illuminating Sights and Aiming Points ...	190,000	
Balloons for Propaganda	35,700	
Bars Boring	174,000	
Barbed Wire—tons, 77,800 ; yards, 1,245,000,000 ; miles	707,500	
Batteries secondary, portable	28,000	
Baulks and Ribands, Bridging	31,700	
Boards distributing	14,000	
Bulbs 3·5 volt for Torches	1,655,000	
Cable field	786,000	miles
Cable and insulated electric wires, all kinds	925,000	miles
Carbons for searchlights	552,000	
Cells, secondary separate from batteries...	163,000	
Cells, dry, including those in battery units	19,825,000	
Chesses	86,700	
Cleats and Insulator Bobbins	5,385,000	
Compasses	423,000	
Dogs Railway	2,550,000	
Drums and Reels Cable	144,000	
Exploders	9,600	
Fittings for electric light and power	11,310,000	
Fullerphones	22,500	
Fuses, electric	163,200	
Gabions	4,235,500	
Hammers, Miners and Platelayers	160,000	

Hose, Canvas and Rubber (1,000 miles)	5,000,000	ft. run
Labels Line	6,100,000	
Lamps Electric, signalling, field	23,300	
Lamps Electric, signalling, daylight	72,500	
Lamps Electric, signalling, daylight, large	3,000	
Lamps Electric, incandescent	7,226,000	
Lampholders	763,200	
Lorries fitted with lighting or charging sets	200	
Lorries fitted with searchlight sets	222	
Mast Sections for W.T.	107,800	
Pickets, guy telegraph	169,000	
Pliers, side-cutting 8inch	553,000	pairs
Plugs and Sockets for electric light and power	98,000	
Poles Telegraph, light	800,000	
Pontoons	2,450	
Posts Wire entanglement angle steel	12,685,000	
Propaganda Leaflets made up into bundles for Balloons	20,600,000	
Propaganda Releases (tinder fitted with wire and paper tags)	25,000	
Projectors Searchlight	1,650	
Pumps	190,000	
Reflectors Searchlight	3,550	
Switchboards for Searchlights	2,150	
Switches electric	443,200	
Stays for W.T. Masts fitted up with runners, hooks, &c.	96,500	
Telephone sets portable D. Mk. III.	144,200	
Telephone Receivers, double, for Wireless telegraphy	83,800	
Torches, of sorts	607,000	
Tubing for electric light conduit	503,000	ft. run
Valves, for Wireless telegraphy	805,200	
Watches	152,000	
Wire iron, 14 s.w.g. for entanglements	13,000	tons
Wireless Telegraph Aeroplane Sets, Transmitters spark	5,140	
,, ,, ,, Telephone Transmitters	900	
,, ,, ,, Tuners Receiving	2,800	
,, ,, Field Spark Sets, Wilson	740	
,, ,, ,, 50 Watt D.C.	845	
,, ,, ,, Forward sets, A. and B.	2,300	
,, ,, Field C. W. Sets	5,300	
,, ,, Wagon sets } Fitted up as well as inspected	22	
,, ,, Lorry sets, heavy }	29	
,, ,, Lorry sets, light }	33	
,, ,, Pack sets	129	
,, ,, Tuners, short wave	7,150	
,, ,, Tuners, long wave	380	
,, ,, Direction-finding and special Marconi sets	58	

Chapter 5.

SIGNALS EXPERIMENTAL ESTABLISHMENT.

Pre-war conditions.—The precursor of the Signals Experimental Establishment was the "Wireless telegraph experimental section" at Aldershot, a minute organization which on outbreak of war was provided with :—

Firstly, a small staff well versed in all the leading wireless systems, and a knowledge of what was good and bad.

Secondly, a quantity of experimental apparatus and records.

Thirdly, service apparatus consisting of :—

(*a*) service 80ft. mast station, either horse or motor draft.

(*b*) service pack transport set (Marconi).

These were designed by the Aldershot experimental staff, under the ægis of the R.E. Committee, the pack set being got out in conjunction with the Marconi Company. The stations were intended to fulfil the then general staff requirements of wireless communication *i.e.*, Army to Cavalry Division and Cavalry Division to Cavalry Brigades.

These sets proved thoroughly serviceable, and both exist at the present time, but slightly modified.

As far as aircraft is concerned, some experience had been gained in working from and to airships, and in transmitting from aeroplanes.

Unfortunately continuity of work was broken on the outbreak of war, because the Aldershot establishment dissolved automatically on mobilization. It then devolved on the Inspection Division R.E. Stores, Woolwich, to fulfil future requirements of the service. The work done under the Inspection Division up to the formation of an independent experimental establishment has already been described.

Signals Experimental Establishment formed.—In September, 1916, a definite Signals Experimental Establishment was formed and a Chief Experimental Officer appointed ; the first necessity was to carry through the erection of shops, drawing offices, stores, garage, and offices ; after this, elaborations in the administration were carried out on the following lines :—

(*a*) Expt. number.—Numbers were allotted to every experiment.

(*b*) Reports.—Reports, at suitable intervals, were made on the progress of each experiment.

(*c*) Shop Orders.—Written shop orders with sketches were made out for all shop or drawing office work.

(*d*) Meetings.—The system of monthly committee meetings was more firmly established.

(*e*) Shop Officer.—A shop officer was appointed, also an officer to deal with pay, stores, and wages.

(*f*) Correspondence.—The correspondence was separated out from the C.I.R.E.S. files, an up-to-date filing system was adopted and a head clerk appointed.

(*g*) Visits to France.—Arrangements were made for new inventions or designs to be taken to France by the inventors, for discussion before proceeding to manufacture.

(*h*) Assistants.—Technical and laboratory assistants were definitely allotted to each experimental officer.

A definite procedure was laid down to cover the period from the inception of an idea to inspection of manufacturers first output. This period covers stages of research, construction of preliminary apparatus, manufacturers' criticisms, construction of samples, test and inspection of samples, making of working drawings, and final inspection of the first instrument produced by the manufacturers.

It was found best to test factory made apparatus at the front rather than S.E.E. apparatus, since the former represented bulk supply better than the latter, which were generally exceptionally carefully hand-made instruments.

Details of Experiments.

Of the more important and successful experimental work carried out the following might be mentioned :—

Nonspillable Accumulators Expt. 228.—All accumulators were rendered perfectly nonspillable ; this experiment was rapidly and well carried out by the exercise of good understanding and tolerance between the S.E.E. and manufacturers concerned.

C.W. Trench Set Mk. III. Expts. 104, 179, 233, 234, 260, 274.—Another successful experiment was the C.W Trench set Mk. III, which was used in large numbers for ranges of 3 miles up to 100 miles according to aerials used.

Close *liaison* with Signals in France alone enabled this instrument to be produced so as to fulfil Service requirements.

Valves. Expts. 152, 160, 236, 272.—Successful valves to cover all work, both sending and receiving, were designed and put on a manufacturing basis ; the impulse in the right direction, in this case, was primarily due to the French wireless service. There was some temptation to multiply types of valves for technical reasons ; this was wisely checked, but not in such a way as to prohibit legitimate introduction of necessary types.

H.T. Units. Expts. 261, 311. *120-Watt C.W. Semi-portable set. Expts.* 202, 213, 296.—Vibratory H.T. units, introduced by S.E.E., were progressively improved.

In February, 1918, an important set was designed, named the 120-watt C.W. semi-portable set to work up to ranges of 200 miles; this was produced in numbers at the S.E.E. (32 up to January, 1919).

The principle of making sets in portable cases for fitting into any vehicle or house was also introduced with this set.

Captured Apparatus. Expts. 269, 338.—All types of captured German apparatus were examined and reported on for materials used and for technical efficiency. Where possible ideas were taken from these sets.

120-watt Spark Trench Set. Expts. 258, 278.—One particular set evolved from notes of captured German apparatus was the new 120-watt spark trench set.

Vibratory converter. Expts. 137, 258, 311.—The main point of this set was the vibratory converter, which has now been improved on in the British model; this piece of apparatus is also invaluable for other purposes, in particular for providing high tension for valve sets.

It is interesting to note that this same instrument was being investigated in 1914 at Aldershot prior to the war. But for the break in continuity of research this particular instrument might have been adopted perhaps some three years earlier than it actually was.

C. Mk. III Amplifier. Expts. 110, 128, 230, 256.—Other important apparatus produced was the Amplifier C.Mk. III, for listening sets and magnifying Morse signals.

Forward B set. Expt. 187.—The forward B set for use in front line by unskilled personnel.

250-watt valve set. Expts. 299, 316.—The assembly of 250-watt valve sets for long range work in Ireland, Russia, and France.

Fullerphone. Expt. 224.—The development of the Fullerphone.

60-watt valve set. Expt. 314.—The 60-watt C.W. valve set designed on simplified lines for work between Divisions.

Testing Sets. Expts. 249, 250, 251, 252, 254, 264, 276, 282, 321.—In autumn 1917 the necessity for testing sets for each piece of apparatus arose, the object being to enable manufacturers or users to apply certain definite tests and so to discover whether the particular set was fulfilling all its functions correctly. The design of these testing sets was sometimes harder than the design of the sets which they were to test, because accurate setting and measurement was essential in their case.

Measuring Instruments. Expts. 245, 277, 295.—Besides these, many pieces of measuring apparatus were designed so as to standardize the methods of measurement as between C.E.O., C.I.R.E.S., and S.S.F.

Instructional Sets. Expts. 281, 531.—A further innovation, introduced in 1918, was the manufacture of instructional sets and wall diagrams. These sets were mounted on boards in skeleton form with coloured wiring easy to follow; they were made up for each piece of service apparatus.

Wavemeters. Expt. 284.—The question of wavemeters was placed on a sound basis by the introduction of one pattern throughout. This question was one of some difficulty requiring considerable forethought. The range of wave-lengths used is continually extending due to modern research and invention. Whereas in 1914 150 metres to 1,200 metres was thought satisfactory, in 1919 it was necessary to use 45 metres to 8,000 metres, with prospects of further extensions.

Sound ranging. Expt. 257.—An experiment on which much time and ingenuity was expended was the sound ranging experiment. The effect of this experiment was to enable cables to be dispensed with between the sound detecting apparatus and the recording apparatus in rear. The gear was not eventually adopted because it involved skilled *personnel* to maintain it.

Flying Corps Experiments Separated.

In April 1918 the Flying Corps experiments were separated from the Signals Experimental Establishment and transferred to Biggin Hill.

The most important experiments in this branch before separation were the following:—

Valve Transmitters and Receivers. Expt. (*See R.A.F. list*).—Design of various transmitters and receivers to adapt the valve to aeroplane use.

Aeroplane Telephony. 131*A to K*174.—The working out of the difficult problem of telephony between aeroplanes, which was successfully accomplished; telephony from aeroplane to ground had earlier proved a simple problem.

Fixed Aerials. Expt. 507.—Further, in response to pressure from overseas, attempts were made to eliminate the trailing aerial, but this met with little success.

Magneto disturbance. Expts. 184, 530.—A difficulty which had to be competed with in all aeroplane reception was disturbance from the magneto ignition of the engine.

Experiments in progress at end of War.

The more important experiments in hand at the beginning of 1919 were the following.

Fullerphone on lines. Expt. 337.—Application of Fullerphone principle to line telegraphy, an important innovation, giving a simpli-

fication of apparatus together with increased reliability of working over bad lines.

Semi-portable 500-Watt Valve. Set. Expt. 340.—The design of a more powerful portable valve set (500-Watt C.W. set) to work up to ranges of about 500 miles, to replace the mixed 250-Watt valve set then in use.

Compass and Intercept Stations. Expt. 327.—Standardization of compass stations, as used for accurately locating the position of wireless transmitting.

Aeroplane Compass error. Expt. 327.—The determination of aeroplane bearings, which required further research, since variations due to uncertain causes were found to arise.

Hammond Radio System. Expt. 342.—An American innovation making use of a new principle. Experiments showed that the greatest importance might be attached to the invention. It comprised a method of tuning to two frequencies, the effect being practically to eliminate jamming, enormously to increase the number of possible tunes available, and to render communication fairly secret.

A similar method was suggested by an officer in France; this was reported on by the S.E.E. during a *liaison* visit as a most promising idea, and the officer concerned was employed on working out the Hammond version of the idea at the S.E.E.

Field Wireless Telephone. Expt. 298.—A field wireless telephone working about 6 miles, with apparatus capable of being carried in the hand, and installed in a few minutes, was being introduced.

Dry Cell Research. Expt. 306.—Research into dry cell manufacture was in hand, and appeared to show that the life of dry cells may be much increased by good design; this is of importance owing to enormous quantities of these cells used.

500-Watt Spark Set. Expt. 317.—A spark station, 500-watt, was designed to replace the original pack W.T. set.

Speeding up manufacture.—The rapidly increasing demands from France made it necessary to organize design and manufacture, so that the interval between the completion of an approved sample and the supply in bulk to the service should be as short as possible. This was effected by keeping the closest possible *liaison* between the S.E.E. and the original factories, and more important still, by the adoption of standard piece parts and the elimination of all redundant parts, whereby design was simplified and draughtsmen's work reduced.

The system of manufacture that was evolved may be roughly arranged in the following chronological order:—

1.—Evolution of apparently satisfactory design to meet service requirements, watched in later stages by factory representatives for purpose of estimate, etc.

2.—Submission for trial and criticism in France.

3.—Correction of design accordingly

4.—Detailed examination by factory representatives.

5.—Preparation of drawings, commencement of S.E.E. hand reproduction and of samples for C.I.R.E.S. factory hand reproduction, etc.

6.—Preparation of technical specification, and decision as to tests required.

7.—Provision of complete drawings and specifications to factories and C.I.R.E.S.

In addition to the *liaison* with the factories, touch was kept with C.I.R.E.S., who eventually had to pass the instruments into the service, and the preparation of the final specification and provision of any special testing apparatus was thoroughly gone into so that all these branches, design, manufacture, and inspection should be working on exactly the same lines from the earliest possible moment.

Special work done at S.E.E.—In addition to the regular experimental work for the Signal Service, other work of a special nature, both for Army Intelligence and for the Royal Navy, was undertaken from time to time. This included some small portable C.W. transmitting sets with self-contained H.T. batteries.

Some special amplifiers for listening sets were also prepared. Several of both sets were manufactured, and in the latter case operators were trained in their use.

Secret telephones were also constructed, on the " wired wireless " principle, for superposing on ordinary circuits ; but these were only just completed when the armistice was signed.

Assistance was also afforded to the Royal Navy, both in connection with the anti-submarine work, Parkestone, and also in collaboration with R.N. Signal schools, Portsmouth.

Liaison with other establishments.—Close touch was kept with experimental and other establishments of other services and of the allied armies, both by correspondence and, where possible, by periodical visits.

It was especially close with the Royal Naval Signal schools, Portsmouth, and the Anti-Submarine depôt, Parkestone. Also naturally enough with the R.A.F. Depôt, Biggin Hill, an actual offshoot of the S.E.E.

Considerable assistance was received from the staff at Marconi House.

A very strong link between the various services was provided by the " Valve Production Committee." The extensive application of the valve in recent years, in almost all branches of wireless work, caused this committee to become in some ways a central bureau of information of what the services were doing, and its proceedings and investigations were the starting point of many interesting departures.

As regards allied armies cordial relations existed with the French, Belgian, and American services—*liaison* being especially close throughout with the French wireless service ; one of the latest examples of this was the taking to Paris of the S.E.E. standard wavemeter and its comparison with the French standard, giving the remarkable result of agreement within one per cent.

In order to further the scheme of general *liaison*, the practice was adopted in June, 1918, of publishing a monthly progress report, which gave a general outline of the condition of experiments in hand. This report was distributed to other services and to allied establishments, and their progress reports or occasional papers—as in the case of the French—were received by the S.E.E. When required, further detail was asked for or given.

This practice was extremely useful, as it tended to lessen the chance of overlap and encouraged co-operation.

Reference was made to the National Physical Laboratory in cases where authoritative decision was desirable on certain points, such as scientific measurements, properties of materials, etc.

Such matters as absolute wavelengths, standards of capacity, inductance and so forth were so referred, and reports on materials were ocasionally obtained to judge of suitability for instrument construction.

Appendices.—The following tables are appended.

Table E. War Establishment of R.E. Signals Experimental Establishment, 1918.

Table F. List of Experiments.

Table G. List of R.F.C. Experiments.

Table H. List of pamphlets issued by S.S.E.

R.E. SIGNALS EXPERIMENTAL ESTABLISHMENT, WOOLWICH.
WAR ESTABLISHMENT.

DETAIL.	PERSONNEL.								Civilian.		Total Military & Civilian.	REMARKS.
	Officers.	Warrant Officers.	Staff Sjts.	Sjts.	Corpls.	2nd Corpls.	Rank & File.	TOTAL	Men.	Women.		
Chief Exptl. Officer (Lt.-Col.)	1							1			1	(*a*) 5 Majors, 4 Capts., 3 Subalterns
Exptl. Officers (*a*)	12							12	2		14	(*b*) Subaltern.
Drawing Office	1(*b*)				1			2	11	15	28	(*c*) Mechanist Sjt.-Majors (W.O. Class 1).
Technical Staff		2(*c*)	2(*d*)		1		1	6	18	6	30	
Provision Store and Wages	1(*e*)						1	2	12	1	15	
Clerical Staff									1	6	7	(*d*) Mechanist Sjts.
Instrument Shop		1(*c*)	1(*d*)	1	1	1	32(*f*)	37	43	40	120	
Garage and Fitters' Shop ...				1	1		5(*g*)	7	14		21	(*e*) Lieutenant and Quartermaster.
Carpenters' Shop					1	1	8(*h*)	10	20		30	
Heating, Cleaning and Guard									16		16	(*f*) Includes 5 Lance Corporals.
Total excluding attd.	15	3	3	2	5	2	47	77	137	68	282	(*g*) Includes 1 Lance Corporal.
Attached—												(*h*) Includes 2 Lance Corporals.
Exptl. Officers General List (*i*)	2							2			2	(*i*) 1 Major, 1 Capt.
Total including attd. ...	17	3	3	2	5	2	47	79	137	68	284	

TABLE F.

SIGNALS EXPERIMENTS.

(NOTE.—Experiments which developed into Service Stores are marked *).

Exptl. No.		Description.
*100		Design of light Motor Set, Crossley Chassis, quenched spark, Wavelength 550 to 1,200 metres.
*101		Design of W/T Sets, field, 120-watt "Wilson " 350, 450, 550 metres.
*102		Design of W/T Sets, trench, 50-watt, spark, 350, 450, 550 metres.
103		Design of 550-watt spark set, 350, 450, 550 metres.
*104		C.W. Transmitter and Receiver, Type A. (W/T Sets, field, 30-watt C.W. Mk. I.)
*105		Tuner, S.W. Mk. III., 110 to 650 metres.
*106		Amplifier, Mk. I. (H.F.) and for R.F.C.
*107		Amplifier, Mk. II. (H.F.) and for R.F.C.
*108		Amplifier, Mk. III. (H.F.) and for R.F.C.
109		Amplifier, experimental.
*110		Amplifier Mk. I. (L.F.) and for R.F.C.
117		Transmitter for Tanks (Spark).
*118		Tuner, L.W. Mk. III., 250 to 5,000 metres.
*120		Design of C.O. Switch for Power Buzzer use.
*121		Hand-driven Trench Set Transmitter 350, 450, 550 metres.
122		Hand-driven Generator (Chain Drive).
123		Tuner for Earth Antennae, 350 to 550 metres.
*128		Amplifier Mk. II. (L.F.)
138		Lefroy Aston pocket Cipher wheel.
139		Rejector Circuits.
140		Lefroy's Vibrator Commutator System.
*141		Transformers for Valves.
142		High Speed W/T Transmission and Reception.
*143		Substitute for Perikon Detector (and for R.F.C.)
147		Power Buzzer experiments.
*148		Hand-driven Generator (Gear Drive).
149		W/T Sets, field, 120-watt, Wilson, W/T Sets, field, 50-watt, spark, } with hand-driven generator.
150		Power Buzzer experiments.
*152		General research on valves.
157		Amplifier, H.F. experimental.
158		Trials of N.P.L. Valve No. 2.
159		,, ,, N.P.L. Amplifier.
160		Experiments on Anode Tap for valves.
161		Grid potential experiments.
166		Permanite crystals, trials of.
*172		Amplifier, L.F. (C. Mk. II.)
173		Transmission, C.W. revised circuits (and for R.F.C.)
174		Alklum Accumulators, test of.

The above experiments were carried out prior to October, 1916.

	1916.	
*176	Nov.	Switchboard, telephone, for use with Buzzer Calls.
*177	,,	Jammers or Screening Buzzers for listening Sets.
178	,,	Valve Circuits, to determine best connections and details of transformers, chokes, resistances and condensers.
*179	,,	C/W Sets, field, 30-watt C.W. (Mk. II.)
*181	Dec.	Detectophone, design of.
187	,,	W/T Sets, Forward Spark, 20-watt " B " Mk. I., I*. II.
	1917.	
202	Feb.	Telephone (landline) Set, with Valves.
209	,,	Transmitter, 120-watt.
209a.	Mar.	(1918) Secret Telephones (Wired Wireless).
	1917.	
210	Mar.	Relay, reed, selective (Microphone pattern).
210a	,,	Relay, supersonic (Valves).
*211	May	Power Buzzer.
211a	,,	Power Buzzer, new make and break.
*213	Feb.	Receiver C.W. (For 120-watt Set, Exp. 202).
214a	May	Compass Set, experimental.

Exptl. No.	1918.	Description.
221	June	Indicator, Alphabetical (Visual Signalling).
*224	,,	Fullerphone, Mk. III.
225	,,	Tank Communication by C.W.
226	,,	W/T Sets, field, 50-watt, Spark (Experimental).
*227	July	Wavemeter Heterodyne, Mk. I., II.
*228	,,	Batteries, secondary, lead non-spillable.
229	,,	Amplifier L.F. Resistance type (Experimental).
*230	,,	Amplifier C. Mk. III.
*231	,,	Power Buzzer, Amplifier.
232	,,	Earth Current Signalling, elimination of X's., Experimental.
*233	,,	W/T Sets, field, 30-watt, C.W. Mk. III., Transmitter.
*234	,,	W/T Sets, field, 30-watt C.W. Mk. III., Receiver.
236	,,	Valves negative potential on grid, Experimental.
*237	,,	Valves, W/T type " R."
238	,,	Telephones, D. Mk. III., Test of permanent magnets.
*239	Aug.	Clapper Break for Coils.
*240	,,	Pins Earth W/T (power Buzzers).
241	Sept.	Secret Signalling with Lamps (Visual).
242	,,	Signalling Sets, Earth, H.F. (Trans. and Receiver).
243	,,	W/T Sets, field, " J " (for Jamming).
*244	,,	Testing Sets, W/T Sets, forward, spark, 20-watt B. Mk. I*, II. Two Units.
*245	,,	Wavemeter, Standard.
*246	,,	Insulating Waterproofing Solution.
247	,,	Waterproof Glue.
*248	,,	Valves W/T Type " B " Specification.
*249	,,	Testing Sets, Amplifier C. Mk. III. Three Units.
*250	,,	Testing Sets, Valves (Laboratory use).
*251	,,	Testing Sets, W/T Sets, field, 30-watt C.W. Mk. III., Trans.
*252	,,	Testing Sets, W/T Sets, field, 50-watt, spark.
*253	Oct.	Transformers Valve.
254	,,	Testing Sets, Aerial Inductance and Capacity.
255	,,	Relay for Buzzer Signals.
*256	,,	Amplifier, C. Mk. IV.
257	,,	Sound Ranging by Wireless.
*258	,,	W/T Sets, field, 120-watt, spark, Transmitter.
*259	,,	W/T Sets, field, 50-watt, spark, Mk. I*.
*260	Nov.	W/T Sets, trench, 30-watt, C.W. Mk. II. Alterations to aperiodic grid.
*261	,,	Unit H.T., W.Y., 30-watt, Mk. II.
*262	,,	W/T Sets, field, 30-watt C.W. Receiver Mk. IV.
263	,,	Relays, Valve.
*264	,,	Testing Sets, Valve Transformers.
265	,,	Receiver, C.W. Short Wave, 50 to 300 metres.
*267	Dec.	Batteries, secondary lead, non-spillable, 26 volts 13 amp Hrs. 18.1.18. changed to 28 volts, 13 amp Hrs.
*268	,	Masts, W. T. Steel, 15ft. Spikes foot (Swivelled socket).
269	,,	Tests and report on Selective German Trench Receiver.
270	,,	Scots Untappable Field Telegraph.
*271	,,	" D " III. Microphone attachment for Small Box Respirator.
272	,,	Small capacity valves for Short Waves.
	1918.	
*273	Jan.	Buzzer Sets, W/T Training.
*274	,,	W/T Sets, field, 30-watt C.W. Transmitter Mk. III*.
*275	,,	Relays, reed, selective, frequency 400 to 1,000.
*276	,,	Testing Sets, Amplifier, C. Mk. IV. (H.F. only).
*277	,,	Testing Sets, Capacity Bridge.
*278	,,	W/T Sets, field, 120-watt spark, Receiver.
*279	,,	Detector Valve.
*280	,,	W/T Sets, field, 30-watt C.W. Selector.
*281	,,	Sets instructional on Boards.
*282	,,	Testing Sets, Generator, C.W. valve, laboratory.
*283	,,	Unit H.T., W.T., 120-watt.
*284	,,	Wavemeters, 750–3,000 metres, 125–1,600 metres. 300–4,000 metres.
285	,,	W/T Sets, trench C.W. 60-watts, experimental.
*286	Feb.	Units, H.T., W.T., Rectifier, two valve.

Exptl. No.	1917.	Description.
287	Feb.	Substitute for Carborundum Crystal.
288	,,	Method of test for grid resistances.
289	,,	Signalling with Selenium Cell.
*290	,,	W/T Sets, field, 50-watt, Spark, Mk. I. & Mk. I*, Closed Circuit Inductance.
*291	,,	Batteries, secondary, lead, non-spillable, 10 volt 9 amp. Hrs.
292	,,	Generator H.T., D.C. Hand Drive.
293	,,	W/T Sets, light motor, spark. Re-design.
*294	,,	Specification for Coils.
*295	,,	Testing Sets, Inductance Bridge.
*296	,,	W/T Sets, field, 120-watt, C.W. Semi-portable type.)
297	,,	Allen Differential Microphone.
*298	,,	W/T Sets, field telephone.
*299	Mar.	C.W. Transmitting and Receiving Stations (Irish).
300	,,	Leitner Cell, test of.
301	,,	Microphone W/T (Major V. Smith).
302	April	American Pack Set, Test of.)
303	,,	" Jelle " paste for Accumulators, Test of.
304	,,	Amplifier L.F. Tuner, Experimental.
305	,,	Generator H.T. Hand Drive, Marconi, Test of.
306	Mar.	Dry Cell Investigation.
307	April	Motor Generator for C.W. Field Sets.
*308	May	Buzzer Inclined. Buzzer Horizontal.
*309	,,	Standard Inductances 500,000 cms.
309a	Dec.	Standard Fixed Inductances, Sets of.
310	May	Ultra Heterodyne. Experimental.
*311	,,	Unit, H.T., W.T., 50-watt and 100-watt.
312	,,	Wavelength Standards (Fixed).
313	,,	Amplifier F., experimental.
*314	,,	W/T Sets, field, 60-watt C.W. Receiver and Transmitter.
315	,,	Generators, D.C. Hand Drive, comparison of.
*316	,,	W/T Sets, 250-watt C.W.
*317	,,	W/T Sets, field, 500-watt, Spark.
318	,,	Rectifier, Villard Type.
319	,,	Earth Nets. (Substitute galv. Iron for Copper).
320	June	W/T Set, light motor, 120-watt, C.W. Beat Interference.
*321	,,	Testing Set, Acoustic Oscillator.
*322	,,	Adaptor and Socket 2-10 volt to 20 volt and 20 volt plug.
*323	,,	W/T Sets, field, 120-watt C.W. Rectifier.
324	,,	Sound producing attachment for Relay.
*325	,,	Tuner, medium wave (300–3,000 metres).
326	July	Loop Set, C.W.
*327	,,	Compass and Intercept Stations for Observation groups.
328	,,	Transmitting Station, C.W. 6-line.
329	,,	Transmission, spark, directional.
330	,,	Carborundum Crystal with steel point.
331	Aug.	Earth Current Set, 120-watt.
*332	,,	Cavalry, C.W. Set.
*333	,,	Tuner, long wave, Mk. IV.
*334	Sept.	Special Amplifier. (Intelligence).
335		W/T Sets field, 120-watt C.W. Telephone attachment.
336	,,	Amplifier, H.F. Tuned.
337	,,	Fullerphone principles applied to land lines.
338	,,	Variable Air condenser, German, report on.
339	Oct.	W/T Sets, field, 120-watt, Wilson re-design of Interrupter.
*340	,,	W/T Sets, 500-watt C.W.
341	,,	Buried metal search set.
342	Nov.	Hammond Radio System.
343	Dec.	Blythe Interference Eliminator.
344	,,	Condensers, standard, fixed, Sets of.

TABLE G.

R.F.C. EXPERIMENTS.

111	Transmitter C. W. Type " W " 1,000 to 1,200 metres.
112	Receiver C.W. Mk. I.
113	Receiver C.W. Mk. II.
114	Receiver C.W. Mk. III.
115	Station Tester, Mk. I. 110 to 1,400 metres.

Exptl. No.	Description.
116	Station Tester, Mk. II., 100 to 2,300 metres and for Signals.
119	Position Finder for S.W. (Aeroplane).
124	30 Watt Valve Type " A."
124a	,, ,, ,, ,, " B."
125	Fuses for protection of Valve Filaments.
126	Wind-driven 500-watt spark Transmitter, 300, 350, 400 metres.
127	Tuner S.W. Mk. IV., 100 to 300 metres.
129	Tuner Aircraft, Mk. I., 250 to 1,600 metres.
130	Tuner Aircraft for C.W. & Spark 200 to 1,600 metres, one unit.
131	Tuner Aircraft 800 to 1,000 metres.
131a	,, ,, 150 to 300 metres.
131b	,, ,, 200 to 1,200 metres, with reaction coil.
131c	,, ,, Mk. II. 800 to 1,000 metres.
131d	,, ,, ,, ,, ,, ,,
131e	,, ,, Experimental.
131h	,, ,, one unit.
131k	,, ,, Mk. III. two units.
132	,, ,, Mk. I. (Expt. 130) two units.
133	Transmitter, C. W. Type " W " 1,500 to 2,000 metres (exptl.)
134	,, C.W. Fixed Wavelength.
135	Generator, H.T., D.C., 600 to 1,000 volts.
136	Transformation of A.C. to D.C. by rectification.
137	Vibratory Transformer, D.C. to A.C. (and Signals).
137a	Tonic Train Experiments (and Signals).
144	Position Finder for C.W. long Range reception for Aircraft.
145	Transmitter, C.W. Aircraft, range 250 miles, 1,200 to 1,500 metres.
146	Transmitter, C.W. long range, ground to air.
153	Transmitting Valve, 80 watts.
154	Transmitting Valve, 160 watts.
155	Generators, H.T., D.C. wind-driven, 800 volts.
156	Receiver, heterodyne, Mk. IV., 1,200 to 2,000 metres.
162	Generator, A.C. wind-driven, 150 watt.
163	Windmills for Generators.
164	Receiver C.W. for Spotting.
165	Receiver, Type " P."
167	Tuner, S.W. Telefunken System.
168	Receiver Type " P2," for Crystal, Valve or heterodyne.
169	Chloride Accumulators, 4 and 14 volts, test of.
170	Induction Coil Contacts, Experimental.
171	Ediswan Dry Batteries, trials of.
174	Telephone, wireless, Aircraft, Mk. II. (Transmitter).

The above experiments were carried out prior to October, 1916.

	1916.	
180	Dec.	Reception of C.W. in Aeroplanes, Tuning by means of varying length of aerial.
182		Key, W/T, 5 amp. Aircraft.
183		Determination of Capacities and inductances of Aeroplanes and Aerials.
184		Elimination of Magnetic Disturbances in Aeroplane Reception.
185		Measurement of the Pull of an Aeroplane Aerial.
186		Practicability and possible advantages of Balanced capacity for Aeroplanes.

	1917.	
206	Feb.	Transmitter, W/T, Aircraft, 200 watt (spark).
207	,,	,, ,, ,, ,, ,, ,,
214	May	Compass Set, W/T Static.
500	June	Tuner S.W. Mk. V., Experimental.
501	July	Receiving Set, Aircraft, Visual.
502	Aug.	Transmitter, C.W. long distance, Aeroplane to Ground.
503	,,	Aerial Winches for Scout Machines.
504	,,	Spark Transmitter, spark rectification.
505	,,	Transmitter Aircraft, Tonic Train, Battery Supply.
506	,,	Transmitter Aircraft, Tonic Train, Alternator Supply.
507	Sept.	Telephony W/T between planes, fixed aerials.
508	,,	Batteries, Non-spillable, for Aircraft Use.
509	,,	Receiver, C.W. long distance.

Exptl. No.	1917.	Description.
510	Oct.	Oxygen Mask, fitted with Microphone Attachment.
511	,,	Tuner S.W. Mk. III.* for tropical use.
512	,,	Wireless Compass, vertical plane.
513	,,	Tuner Aircraft (first valve, no H.T.) Experimental.
514	,,	Transmitter, C.W. ground to Plane, range 35 miles.
515	Nov.	Battery Box, acid proof.
516		
517	,,	Testing Set, Telephone, Wireless, Aircraft Mk. II., Set Transmitting.
518	,,	Testing Set, Telephone, Wireless, Aircraft, Mk. II., Set Receiving.
519	,,	Transmitter C.W. Type " W," Re-design.
520	,,	Receiver, C.W. ground. Simple.
521	,,	Telephonic Intercommunication on planes.
522	,,	Relay, valve, C.W. for Aeroplane.
523		
524	Dec.	Amplifier, H.F. for Telephony.
525	,,	Transmitter, Aircraft, 250-watt C.W.
526	,,	Telephony, Wireless, ground to air, long range.
526a	,,	Telephony, Wireless, ground to air, medium range.
	1918.	
527	Jan.	Microphones and Head-receivers.
528		
529	,,	Tuner, Aircraft, H.F. (Marconi Co.) Report on.
530	,,	Magneto noise elimination.
531	Feb.	Instructional Sets on Boards.
		Telephone, Wireless Aircraft Mk. II., Set Transmitting.
		,, ,, ,, ,, Receiving.
		Tuner S.W. Mk. III.*
		Transmiitter W/T. Aircraft No. 1.
617	Mar.	Windmill for Telephone Wireless Aircraft Mk. II, on Handley-Page Machines.
618	,,	Telephone Control, Wireless.
619	,,	Davis high voltage accumulator, Test of.
620	,,	Variometer, Call up.

521, 527, 530, 617, 618, 620 were completed at Biggin Hill on formation of R.A.F.

TABLE H.

LIST OF S.E.E. PAMPHLETS.

No.	
1.	Power Buzzer.
2.	Amplifier, C. Mk. III.
3.	Telephone, Wireless, Aircraft Mk. II. Set Transmitting.
4.	Telephone, Wireless, Aircraft Mk. II. Set Receiving.
5.	Power Buzzer—Amplifier.
6.	Wavemeter Heterodyne
8.	W/T Sets, Field, C.W. Mk. III. Receiver Mk. III. Selector. Transmitters, Mks. III., III.*. Testing Set, W/T., Sets, Field, C.W. Mk. III. Transmitters, Mks. III., III.*
9.	Buzzer Sets, W/T Training.
10.	Amplifier, C. Mk. IV.
11.	W/T Sets, Field, C.W. Mk. III. Receiver Mk. IV.
12.	Unit H.T., W/T. 30-watt, Mk. I. Unit H.T., W/T. Rectifier, Two valve.
13.	Wavemeter, 750–3,000 metres, 125 to 1,600 metres, 300–400 metres.
14.	W/T Sets, Field, 120-watt C.W.
15.	W/T Sets, Field, 60-watt C.W.
16.	Unit H.T., W/T, 100-watt.
17.	Unit H.T., W/T, 50-watt.
18.	W/T Sets, Field, 120 watt, spark.

Chapter 6.

W.D. SIGNAL FACTORIES.

Work under Inspection Division.—In July 1915 it became apparent that, in order to meet the needs of wireless telegraphy services, it would be necessary to have a factory under the control of the War Office in which manufacture could proceed in conjunction and concurrently with experimental work and design, and especially in cases where secrecy was important.

The Sterling Telegraph Co. had a small factory in Soho in which wireless apparatus was being manufactured, but which for various reasons had failed to meet army requirements. It was therefore decided to take it over. It had an annual turnover of about £72,000.

In the following January, another factory run by the British Telegraph Instrument Co. at Teddington was taken over. It was occupied at the time with the manufacture of wireless apparatus in a small way, but hampered by want of capital and facilities for extension. The stock was valued at £2,750 and this with the freehold was purchased for £3,750. Adjoining premises were subsequently purchased and extension built.

The successful results obtained at the Soho factory with wireless apparatus, and the difficulties and delays in getting fullerphones, emphasized the advantages which would be gained by taking over a factory capable of dealing with telephone material.

Under the existing conditions full specifications and detailed drawings were essential before tenders could be obtained from contractors, and when, as frequently happens in the case of new patterns of apparatus, alterations were found necessary during the process of manufacture, there was considerable trouble in arranging terms with contractors

The International Electric Co., at Kilburn, employing 250 to 300 hands, was proposed. The company manufactured the Stevens pattern telephone. It was fairly well equipped, but supplies on W.D. contracts were unsatisfactory and deliveries slow, and in April 1916 it was accordingly taken over. For reasons similar to those in the case of the Kilburn factory, a factory at Cricklewood, in the occupation of the Phoenix Telephone Co., was taken over in February 1917, mainly for telephones and fullerphones. The company was well equipped for this work but had proved very unsatisfactory in regard to output, and the increasing army needs rendered it desirable that

the facilities of this factory should be brought under W.D. control. The few firms satisfactorily manufacturing this class of apparatus were already taxed to their utmost, and it was essential to take action that would ensure a still larger supply.

A few months later it was found necessary to take similar action in respect of the New Phonophore Co., at Southall. There were only two firms equipped for the manufacture of hand telephones, of which the New Phonophore Co. was one. We were to a large extent dependent on them for this class of work, but they had seriously failed to overcome the difficulties which had arisen in regard to labour and raw materials.

The results accruing from these factories being brought under W.D. control were very satisfactory in regard to the increased output which followed, and for a considerable time practically the whole output of fullerphones was obtained from these factories.

Requirements, however, continued to increase, and in July, 1917, it became apparent that still greater facilities would be needed in order to meet the wireless requirements of the army. Up to this point the factories had been administered by the Chief Inspector of Stores, but such a charge in addition to his very heavy duties as Chief Inspector was more than one individual could satisfactorily cope with.

Separate organization formed.—Steps were taken, therefore, to reorganize the factories, under the immediate supervision of an officer as Superintendent.

Premises at Raynes Park were organized as a machine shop for the production of piece parts; the Soho and Cricklewood factories were considerably enlarged by the acquisition of adjoining premises, and another factory at Southgate, engaged on wireless apparatus, was taken over as an alternative to allowing it to be closed by the owner, who was unable to carry on owing to labour difficulties.

At the same time an organization was set up in the factories to encourage and assist outside contractors in the manufacture of wireless apparatus for use in the field. The difficulty in getting such outside assistance was a real one, even wireless contractors, such as Marconi, being unable to take orders except under conditions involving parts of apparatus being manufactured in the W.D. factories.

Steps were also taken to train women for " assembly work " in anticipation of the shortage of skilled male labour. Later on, women were also trained for skilled lathe work.

A factory head-quarters staff was instituted; officers mainly from the Signal Service were engaged as works managers, and close co-ordination was provided for between the factories and the Signals Experimental Establishment at Woolwich.

Weekly conferences at the Soho factory were instituted at which

representatives of the R.E. Inspection Division, Signals Experimental Establishment, the factories, etc., attended to discuss with the C.E.O. the progress of work, the direction in which energy was most needed, and the steps necessary to meet the various requirements and cope with difficulties arising.

Obviously the organization, consisting as it did of factories situated in various parts of London, was far from being an ideal one, but the conditions which led to factories for telephone and wireless apparatus being run under War Office control was necessarily piecemeal, following to a great extent the failures of contractors to cope with the services required, and therefore the remedy essentially involved the acquisition of such facilities as existed in the way of accommodation and plant. Of course one large factory properly organized and equipped would have been more economical and have been run under more favourable conditions in almost every respect, but the provision of such a factory would have involved serious delay at a time when urgent action was needed, and, moreover, approval to such a factory in anticipation of requirements would have involved acceptance of the principle that the War Office should arrange for manufacture of articles in competition with commercial firms, which produced similar articles, and might be expected to meet military requirements. The failure of the trade to do this arose gradually, partly as a result of the withdrawal of skilled men for service in the field, shortage of raw material, and the constantly increasing pressure not only for larger supplies but for new designs to forestall or overcome the very rapid progress made during the war in the service of electrical signalling. The acquisition of the Signal factories was therefore essentially of the nature of a remedy for proved defects, and undoubtedly in that respect it proved successful. It enabled stores to be obtained in quantities which had been found impossible with the factories under trade control.

Prior to these factories being taken over the total expenditure (excluding Raynes Park which was taken over practically as an empty building) amounted to about £150,000 a year. In 1918, when the reorganization had been completed, the expenditure had risen to about £1,000,000 a year; the output of wireless instruments alone had reached 1,000 a week; and the facilities were sufficient to meet all anticipated army requirements for wireless and, in addition, the estimated requirements for aircraft.

Up to April, 1918, when a separate Air Ministry was formed, F.W. 9 was responsible for the provision of wireless apparatus for the Flying Corps as well as for the Signal Service, and even after the separation of the R.A.F. from the War Office this branch executed large " orders " in the W.D. factories of wireless apparatus for the Air Ministry. It should be recorded that in the autumn of 1918 the Minister of Munitions, after a visit to the front, called for an investi-

gation and report upon the supply of wireless apparatus to the Signal Service and the Air Force and upon the administration of the W.D. factories.

After an exhaustive enquiry the Minister's representative reported that the supply to the Signal Service was in a satisfactory state, that the factories were well organized and were capable of producing all the deficiencies of the Air Force as far as wireless equipment was concerned, and he recommended that the whole supply of wireless apparatus for both services should be placed in the hands of this branch.

The arrival of the armistice prevented any action in this direction being taken.

In November, 1918, steps were instituted to reduce the programme of manufacture with the object :—

(*a*) of gradual discharge of the *personnel*, and

(*b*) of producing in this process sufficient apparatus of the latest models to form a reserve for future mobilization.

At its maximum the factories employed 8 officers and 3,233 subordinates.

CHAPTER 7.

WORK OF F.W. 5.

Origin of branch.—In the first months of the war the Director of Works France found it necessary to detach a special officer to act as *liaison* between his headquarters overseas and the various home offices that were connected with the supply of stores. Early in 1915 this was made into a permanent appointment and Lt.-Col. D. Brady, who had previously been a Senior Works Officer in France, came on the strength of the Fortifications and Works directorate as head of a new branch henceforth to be known as F.W. 5.

The staff of this branch consisted of 1 assistant director, 1 staff captain, and 4 (for a time 5) ladies as clerks, the whole staff being accommodated in a single room.

The Director of Works put his requirements to F.W. 5, leaving it to him to discover who should actually meet the requirements.

The Engineer-in-Chief in France and senior Engineer officers of other expeditionary forces did not take long to discover that it saved a great deal of time for them to do the same thing. They were saved all the trouble of finding out where their demands should go, for they looked to F.W. 5 to get what was wanted whether from some branch of the War Office or from any other Government department. They were also saved much trouble in another way; when the exact things they required were unobtainable they could rely on F.W. 5 to know what would do as well, or nearly as well, as what they asked for.

Many of the demands could not have been complied with without great delay had it not been for the fact that F.W. 5 was kept informed, not only of what was wanted, but why it was wanted. This information was got partly by visits to France and partly by visits of officers from France to the War Office. Many of the senior R.E. officers in France and other places abroad made it their business to call at F.W. 5 office whenever they came home on leave or on duty, and the information they gave was extremely useful.

By degrees it came about that it was often possible to modify demands, sometimes increase them, and in the end the F.W. 5 interpretation of what was required was accepted as authoritative by departments in the War Office and other Government offices. This could not have come about without the accurate information that the visits from officers from expeditionary forces brought,

supplemented to some extent by personal visits of F.W. 5 to France. It is scarcely necessary to add that it could not have come about without the fullest assistance from the General Staff in the War Office in giving such information as affected the work.

By far the greatest number of articles required for the expeditionary forces could be got from some department in the War Office, and by degrees demands for them settled down into standing orders of definite quantities a month, but new demands were always coming in as conditions were always changing. There was still a residuum that no Government department could deal with, and it was the business of F.W. 5 to find some way of meeting them.

Contractors' and Workmen's Passes.—Contractors of many kinds had to be found for France and to a smaller extent for other expeditions. Their terms had to be settled and their journeys and journeys of their men, and the shipment of materials had to be arranged. At first the contractors and their men travelled to and fro without much restriction, but it soon became necessary for some good substitute for a passport that would also enable them to travel by routes closed to ordinary civilian traffic, so a system of workmen's passes commonly known as F.W. 5 pink passes was arranged. Details had to be settled and consent obtained from the Home Office, the French Government, G.H.Q. in France, the French military authorities, and the railways, but the whole matter was settled and the passes printed in little more than a fortnight. Alterations in the system were suggested from time to time as fresh Government departments took a hand in the business, but the system triumphed over all difficulties and objections. The Military Services Act introduced some unavoidable complications, as did the necessity for special precautions to keep out possible spies. Over 15,000 of these passes were issued during the war, many of them being re-issued over and over again, and in spite of the complications just mentioned no men were kept waiting, and no spies were ever known to have got to France on the passes. They were far more effective than passports, and towards the end of the war other departments asked for permission to use them. Similar passes, but of a yellowish colour, were issued for Belgian workmen sent to France by F.W. 5. The employment of Belgian labour was not a success, although at first pushed with enthusiasm.

Provision of Timber.—A very important duty of F.W. 5 was the provision of timber for the British armies.

Reference has been made in other sections to the difficulties that were met in arranging for supplies. Nearly the whole of the War Office work involved in administrating the Canadian Forestry Corps devolved on F.W. 5, who was also one of the original members of the timber Committee and worked in close touch with the timber Controller.

Geological Information.—Among the odd tasks that fell to F.W. 5

was the collection of geological information about Northern France and Belgium. The Director of the Geological Survey of England took immense pains to find out everything known, and also recommended a suitable officer as geological adviser at General Headquarters.

For the Dardanelles also F.W. 5 got all the available information, which did not amount to much, and also collected officers to go out as geologists. In addition a firm of oil drillers, Messrs. Thompson and Hunter, were engaged to drill for water. At the Dardanelles conditions were very unfavourable, but the firm later did valuable work near Salonica.

Mission to Serbia.—The arrangements for the engineering part of the British Adriatic mission, that went to the help of the Serbian army, fell to F.W. 5.

Defence of Suez Canal.—When the defence of the Suez Canal zone was taken in hand at the end of 1915 large requirements of engineering material became very urgent, and it fell to the lot of F.W. 5 to estimate what was wanted, and to see that it was sent out. Time was so short that the plan of defence could not be awaited, and F.W. 5 had to make his own plan and arrange for material to suit it. Although the scheme that was actually put into practice naturally differed in many points of detail the general requirements were fully met.

To get the large quantities of water pipes required then, and later on for Egypt, it was necessary to go to America, firstly because English makers could not supply in time, and secondly because the American pipes were stronger and less liable to damage. A special agent was authorized to purchase in America, and in spite of considerable shipping difficulties everything arrived in time.

Miscellaneous.—Various other services had to be carried out, which included the finding of special officers for camouflage work and for minor forestry operations in Greece. Towards the end of the war also F.W. 5 had much to do with the manufacture by the Ministry of Munitions of concrete pill-boxes and shelters. Most of the questions concerning engineering establishments for R.E. services of many kinds were referred to F.W. 5 throughout the war.

PART II.

IN THEATRE OF WAR

CHAPTER 8.

DIRECTOR OF WORKS, FRANCE.

Early Developments.—From the previous chapters it will be clear that, at the commencement of the campaign, there was no organized system of supply of engineering stores other than ordinary equipment. There was at first little demand for articles of R.E. supply by the armies, and entrenching tools, barbed wire, sandbags and explosives were held in small quantities on rail by the Ordnance Department at ammunition railheads.

As regards engineering stores, not of Ordnance supply, required on the Lines of Communication, they were obtained principally by local purchase, when not supplied by the contractors by whom at that time most of the work was carried out ; and were supplemented by demands sent by responsible Works officers to the D.F.W.

In October, 1914, a special purchase office was opened in Paris, and continued to operate throughout the war, although towards the end the stores available for purchase lessened very much.

On the 26th December, 1914, an Advanced R.E. Park was opened at Strazeele for the Second Army, which was administered by the Director of Works, the staff consisting of 1 Lieut. and Qr.Mr. in charge, 1 W.O., 1 ledgerkeeper, and 1 storeman, checkers being furnished from a detachment of the 29th A. P. Coy. R.E. at St. Omer. In March, 1915, a second R.E. Park was formed at Berguette for the First Army, and the administration of both the Advanced R.E. Parks was transferred from the L. of C. to armies, on 20th March, 1915.

The D. of W. collected information as to stores required, indented on the War Office, and arranged for their shipment to Boulogne, where an officer and small staff were placed to receive and transit forward the stores. The 32nd Advanced Park Co. R.E. was sent out to France in April 1915, and was stationed by the D.W. at Havre, with instructions to construct and organize a base workshop. Bridges for the army were sent from England and stored at Havre in charge of this company and tested by them. As the war went on a great deal of new bridge work was constructed in the Havre workshop. The 1st A.P. Co. R.E. was sent to France in March 1915, placed at the disposal of the D. of W. and stationed at Calais.

By July, 1915, it became obvious that further development was necessary in the system of the provision of engineering stores. The Director of Works therefore formed base depôts and shops at Havre and Calais, and appointed certain officers, whose specific duty it was to deal with questions that arose concerning the supply, transportation, and custody of stores, under the title of " Works Stores Officers," subsequently styled " R.E. Stores Officers." The stores staff at Boulogne continued to deal with the receipt and forwarding of R E. stores arriving at that port. A special staff officer (subsequently A.D.W.) was appointed on the D.W.'s staff to deal with the general organization of the system.

In general, the Engineer-in-Chief's office forecasted the requirements of armies monthly, and sent this forecast to the D. of W. The latter, after adding the stores estimated as required by works on L. of C., arranged for the provision of the stores, either by purchase in Paris or local purchase by R.E. stores officers, by manufacture at base workshops, or by indent on the War Office through F.W. 5.

At the end of 1915 it became apparent that large quantities of R.E. stores of all kinds (including timber) must be kept in stock, in order that stores required for a serious operation could be " rushed" to armies concerned within the period of time between the date at which preliminary preparation became permissible and the date on which concentration of ammunition and troops began, after which R.E. stores could not be handled by railways, etc. Also stores for winter hutting had to be accumulated on an average monthly tonnage to steady manufacture and shipping, although such stores were not required until the autumn.

Formation of Base Depôts.—For this reason, early in 1916 two base depôts were opened :—

One at Les Attaques, 3 miles S.E. of Calais.
One at Abancourt, on the Rouen–Amiens Railway.

The depôt at Les Attaques was situated between the Calais–St. Omer Canal and the railway, and branches from the railway were brought into the depôt. Wharves were constructed along the canal for the barges, and they discharged by decauville track direct to the appropriate stacks.

The requirements of the canal traffic, however, restricted very greatly the length of wharf permissible. To obviate this it would have been of great advantage to widen the canal on the depôt side, so that barges could lie alongside the wharves without restricting the canal traffic.

This depôt consisted originally of 50 acres, but was enlarged subsequently by 15 acres as the accumulation of R.E. stores increased, and eventually spread to the other side of this railway, where a large timber depôt was formed, 150 acres in extent. A plan of the depôt as existing in 1918 is given at the end of the volume.

At Abancourt there was no canal, but the depôt was situated close to an important railway junction, suitable for concentrating trainloads from Le Havre, Rouen and Dieppe. It consisted in April, 1916, of 32½ acres, and was expanded in May, 1917, to 163 acres.

Le Havre and Rouen became subsidiary stores depôts. That at Le Havre was necessary owing to the railways being unable to remove sufficiently quickly stores which arrived at that port, and which had to be sent there owing to the congestion of other ports.

Rouen had become the principal port of the D.W. for the reception and storage of timber from overseas. In November, 1915, a wharf for R.E. stores was constructed by contract, and a local depôt established for general R.E. stores with a " brouettage " service.

In general these depôts were fed :—

Les Attaques, from the ports of Calais and Dunkirk and to a small extent from Boulogne.

Abancourt, from Havre and Rouen, and occasionally from Dieppe and Fécamp.

In turn, they normally supplied :—

Les Attaques to three Northern Armies and Lines of Communication (North).

Abancourt to two Southern Armies and Lines of Communication (South).

Base Workshops.—The base workshops developed concurrently with the development of the base depôts.

It has already been stated that a base workshop was created at Havre in 1915. This was developed into a considerable factory for the manufacture of bridge work and as a repair shop for machinery. Spare parts for machinery installed in works on L. of C. and in army areas were held by this shop.

At Rouen and Abancourt shops were opened for the conversion of timber into trench stores and for hut construction. In September, 1918, the factory was concentrated at Abancourt. Similarly, a factory for timber articles and metal working shops was opened at Les Attaques in January, 1916. The latter eventually undertook manufacture of steel bridge work for the armies on a considerable scale.

The woodworking shops at Abancourt and Les Attaques developed very much, and in 1918 were each converting from 3,000 to 4,000 standards of timber monthly into articles required by the armies. Particulars of the workshop at Les Attaques, together with some figures as to output in July 1918, are given in Tables J and K.

Table L gives a list of standard articles manufactured at the base workshops with a typical month's output when full development had been obtained, and Table M gives a summary of actual quantities supplied to armies in the period June to August 1918.

Personnel.—It is here convenient to deal briefly with the expansion of *personnel* caused by the continually increasing work that was thrown on the base depôts and base workshops.

During 1916 the 1st Co. R.E. was converted from an Advanced Park Co. to a Base Park Co., increasing the *personnel* from 4 officers and 150 other ranks to 9 officers and 227 other ranks.

By the end of 1915 the increasing demand for checkers, storekeepers, yardmen, etc. had become acute, and it was obvious that stores work could not be carried out efficiently with the "P.B." men (unfit Infantry details) who had been provided for this work.

A proposal made in February, 1916, by the O.C. 1st A.P. Co. was approved, to raise stores sections consisting of specially selected P.B. men. Six sections each of 3 officers and 97 o.r. were eventually raised.

On 20th July 1916 the D. of W. reorganized all stores officers and *personnel* into two groups, a Northern group and a Southern group. The officers in charge were styled Chief Works Stores Officer (North) and (South), their headquarters being at Les Attaques and Abancourt respectively.

In February, 1917, a revised establishment was approved to deal with stores, consisting of:—

D.D. Works, A.D. Works } at D W.'s headquarters.
C.R.E.S O. (North) at Les Attaques.
C.R.E.S.O. (South) at Abancourt.

The 24th Co. R.E. was re-converted into a Base Park Co. and transferred to the southern section (Rouen and Abancourt).

Area Employment Artizan Cos. were raised of 270 o r. each, and one was allotted to the northern and southern groups respectively.

Two additional stores sections were raised and sent to form depôts in the region of Albert, into which the Salvage Corps might collect serviceable Engineer stores salved from the Somme battlefield.

At Les Attaques the scarcity of labour was still felt, and 300 French labourers were recruited.

Eventually prisoners of war formed into companies were employed. These worked under their own N.C.O.'s and proved very satisfactory, the average daily task being $5\frac{1}{2}$ tons per man.

From experience the Director of Engineering Stores evolved the following formula from which the necessary labour in a stores depôt could be estimated:—

$$\frac{3}{6} \times \frac{\text{tons received} + \text{tons dispatched}}{2} + 10\% = \text{No. of labour.}$$

Discharge of Shipping at Ports.—The rapid discharge of shipping had in 1916 constituted one of the principal troubles of R.E. stores

officers. The requisite labour constantly did not synchronize with the trucks and barges available. The lack of co-ordination was greatly felt.

In December, 1916, the newly formed D.G.T. organization took over the whole responsibility of receiving stores discharged from ships and of transporting into R.E. depôts.

Checking and Accounting.—Under the conditions that were in force to ensure rapid discharge, it became evident that any attempt to check cargoes out of ships did not justify by its results the employment of the large *personnel* essential to obtain even approximately accurate results. The system adopted therefore was checking in and out of depôts only. Experience proved that a skilled central staff at the depôt was able to reconcile receipts with the manifests of ships with a surprisingly small percentage of error.

In the depôts a system was adopted of tally cards for each store. Stores were maintained in groups under group storekeepers, who were responsible to the chief storekeeper of the depôt.

Stocktaking officers were attached to chief store accountants, to whom was assigned the duty of taking stock continuously, choosing, so far as possible, items of which the stock was for the moment low. The stock so counted was checked by them with stocks as recorded on the chief storekeepers' tally cards and with the ledger remains, any discrepancies found being adjusted as laid down in Regulations for Engineer Services.

Stone Supply for Roads.—By 1915 the upkeep of the roads behind the armies became a matter of serious concern. The maintenance was under the French department of " Ponts et Chaussées," but the stone used before the war for the upkeep of roads in the north of France was no longer available as the quarries were in areas in occupation by the enemy.

It became necessary for the British to provide stone, and the Director of Works arranged for the importation of road metal and soling.

About November, 1915, 10,000 tons of road metal was supplied from the Penlen quarries, Cornwall, landed at Boulogne and handed over to the Ponts et Chaussées. This was followed by an importation of 15,000 tons of grey granite from Guernsey, part of which was landed at Boulogne and part at Calais and Dunkirk.

A fleet of 12 small ships was chartered to bring stone from Guernsey, and this stone was handled chiefly at Dunkirk by a staff provided by the Works Directorate and dispatched to army areas.

Three vessels were sent to Le Treport, and landed about 200 tons per day on an average. These vessels were unloaded by the R.T.O. and the stone dispatched to the Ponts et Chaussées. In 1915 quarries at Marquise were opened by the Director of Works, which provided limestone, road metal, and soling of fairly good quality,

but rather too soft to resist the very heavy traffic. The development of the supply of this stone is described under " Quarries " in a separate history of the Works Directorate.

During 1915 the D. of W. was providing about 350 tons of granite road metal from quarries near Caen, obtained through French quarry contractors.

In December, 1915, the average daily supply of stone was approximately :—

1,000	tons per diem from	the Marquise quarries.
350	,, , ,, ,,	Caen quarries.
1,000	,, ,, ,, ,,	Guernsey, landed at Dunkirk and Le Treport.
2,350	tons per diem.	

During 1916 the amount of stone imported from Guernsey decreased gradually, as the ships were required by the Admiralty.

The import of stone (200 tons average per diem) into Treport continued, however, until the supply of stone was taken over by the Roads Directorate.

The increase of traffic, and the destruction of roads through increased intensity of shell fire during 1916, made the demand for stone for repair and maintenance of roads in army areas more and more urgent.

In October 1916 the average daily supply of stone was :—

860	tons from	Channel Islands.
420	,, ,,	Caen.
70	,, ,,	Audrehem.
1,900	,, ,,	Marquise.
3,250	total tons per diem.	

The importation of stone from abroad had had to be restricted for want of ships, but the output of stone from Marquise quarries was increased until at the end of November 1916 they were providing over 2,000 tons of road metal and soling per diem.

On the 1st December, 1916, the quarries at Marquise were handed over to the newly formed Roads Directorate, and subsequently the provision of stone ceased to be a function of the Works Directorate.

Timber.—By 1915 the demand for timber by armies had greatly increased ; in February, 1915, the D. of W. began to purchase all available timber from stocks held by timber merchants in France. Rouen being the centre of the timber trade, the D. of W. appointed a special officer, under the Senior Works Officer, Rouen, to conduct operations. Timber was chiefly obtained from Rouen itself, from Nantes and also Havre. Smaller quantities were purchased at Calais and Boulogne.

In August, 1915, the Director of Works arranged for a supply of timber to be imported from England through the War Office, at a rate of 350,000 ft. cube per month, two months' supply being sent out the first month. Of this, 31,000 ft. cube was to be of good (British) quality for " works " ; about 204,000 ft. cube of Canadian or American spruce, or inferior British quality for " trench work " ; and 4,700 ft. cube of 3rd quality (British) in long lengths for light ' bridge work." The scantlings ranged from 3 in. x 3 in. to 9 in. x 3 in.

This timber was unloaded principally at Rouen where a timber yard was established, but the larger ships had to be partly unloaded at Havre, and when lightened were sent on to Rouen. So far as possible timber unloaded at Havre was sent direct to armies.

In November, 1915, the Director of Works entered into a contract with Foden, by which a supply of logs and rough planks was imported, at the rate of 9,000 tons per month, landed at Dunkirk and dispatched by barge to Les Attaques.

In October, 1915, the Director of Works commenced forestry operations (described in history of Works Directorate), and 18,000 tons per month were produced, the depôt being Abancourt ; this timber being principally consumed by the Third and Fourth (later also by the Fifth) Armies and by L. of C. (South). In March 1917 a Directorate of Forestry was formed which took over the control of the whole provision of the timber required by the B.E.F.

In 1917 the consumption of timber by armies and L. of C. had risen so greatly that the issues of timber from R.E. depôts averaged 51,000 tons monthly.

Hutting and Miscellaneous Stores for the Armies.—The magnitude of the task that was involved in supplying the demands of the army can be best appreciated from the examination of a few statistics.

On Table N is given an abstract of hutting stores during the year 1917.

Tables O and P give the total tonnage of stores received and issued during 1917.

It will be seen that in both cases timber accounted for rather more than half the total tonnage.

During the first three months of 1918 complete trains of R.E. stores were dispatched from bases to armies as follows :—

January	...	...	...	...	185 trains.
February	...	...	...	...	195 ,,
March	...	...	...	...	198 ,,

There were great difficulties in the way of foreseeing requirements so as to avoid large accumulations in France and England, whilst being prepared to meet unexpected demands when they should occur. A good example is provided by the case of barbed wire. Up to the end of 1917 average issues never exceeded 1,600 tons monthly. In

January, 1918, demands rose to 3,000 tons, and in April actually reached 10,000. Average supplies to the Armies during the months April–July were 6,000 tons, so that more than a normal year's supply was consumed in three months, and even then only accounted for 60% of actual demands. The retirement in March and April, 1918, entailed considerable losses on the British right, but these were no greater than could have been expected, and were nothing like the losses of the enemy in his retreat. Most of the abandoned British dumps were recovered later in 1918 together with additions ; proving that, with the exception of timber, engineer store dumps can for the most part be neither moved nor destroyed in a retreat. No real embarrassment was caused to the stores branch as regards normal stores, the most serious items being destroyed bridges, pumping plants, and encampments.

Supply of Material and Stores to L. of C.—In 1914 most of the work on the L. of C. was carried out by contractors, French and British, and materials and stores for each work were principally obtained by the contractors to whom the work had been specifically entrusted. Other stores and some machinery required were obtained by local purchase, and S.W.O.'s were authorized by the D.W. to indent direct on the War Office for such stores and material and machinery as could not be obtained locally, or which were not of Ordnance supply. These demands were sent direct to F.W. 5.

This system obtained until the 29th June, 1917, by which time the demands had increased very greatly, partly owing to increase in the work on L. of C., and partly owing to the difficulty of obtaining stores by local purchase in France, and to difficulties experienced by contractors in obtaining stores in England.

With regard to timber, however, by the end of 1915 it had become necessary to regulate the supply to prevent competition, and on 4th December, 1915, Senior Works Officers were forbidden to purchase imported timber, or to use French timber except when included in French contracts under 25,000 fcs.

On the 30th September, 1916, the purchase in France of any materials procurable of British manufacture was restricted to purchases not exceeding 10,000 fcs. ; this did not apply to the purchase of bricks and other articles not suitable to transport, or to articles provided by a contractor as part of a general building contract.

On 19th November, 1916, instructions were issued to Senior Works Officers to submit monthly estimates of timber required by them through their D.D Ws. to the D. of W. for supply from British army stocks.

On 2nd January, 1917, a further restriction was introduced that British contractors might only use imported timber if bought by them under special license for the use of the British army.

As regards stone, this was first obtained by Senior Works Officers from convenient local quarries under contract, but, owing to the demands by the armies, all stone obtainable from the Marquise, Necy, Invcheille quarries, etc. was reserved, and Works Officers were instructed to put in their demands for stone monthly to the Director of Works, who allotted them stone as the exigencies of the armies permitted. On the 1st December, 1916, all the quarries in France were taken over by the newly formed Directorate of Roads and indents for stone required on L. of C. were submitted by D.D.Ws. to the D.W , and by him to the Director of Roads.

By the middle of 1917 it became necessary to control centrally the supply of all kinds of engineering stores and material, and on the 29th June, 1917, the system was abolished under which works officers could demand stores and machinery direct from F.W. 5.

Stores were divided into groups :—

1. Timber.
2. Stores used by the armies.
3. Stores used on L. of C. only.
4. Machinery.

For (1) and (2) consolidated indents were submitted monthly by the D.D.Ws. to the D.D.W. Stores, in the D. of W.'s Office. Allotments were made by the D.D.W. Stores to the D D.Ws. who in turn made allotments to the various C.R.Es. (Senior Works Officers) in their district. The latter submitted their demands according to this allotment to the C.R.E.S.O. (N) and to the R.E.S.O. Rouen, respectively, who arranged for the dispatch of stores.

Demands by C.R.Es. for machinery were forwarded by the D.D.Ws. to the D.D.W. Stores as occasion arose, and either supplied from base depôts or obtained in England through F.W. 5.

The supply of such classes of stores as were not used by armies was arranged for by D.D.Ws., and for convenience the stores were stocked by the C.R.E.S.O. (N) or by the R.E.S.O. Rouen, and allotted to C.R.Es. on their demand on D.D.Ws. This system obtained, with certain modifications throughout the war.

In January, 1917, the control of the disposal of engineering stores was taken over by the Engineer-in-Chief, who decided the allotments to be made monthly for works on L. of C.

On the 1st July, 1918, a separate Directorate of Stores was formed under the Quartermaster General, but the new organization did not affect the system by which the works officers on L. of C. received their stores.

On Table Q is given a statement of the issues of R.E. stores in the Rouen district from 1915 to 1919. This may be taken as typical of the issues in a first class L. of C. district.

C.R.Es. Workshops on L. of C.—At an early period of the war

workshops were established by Senior Works Officers at the stations where important work was being carried out and especially at their headquarters. These workshops increased in importance as maintenance work became more serious, and as more and more work was carried out by direct labour. Machine tools were installed, driven by steam or by electricity according to circumstances. The equipment of these shops varied according to the work, to the skilled labour available, and to the importance attached by the C.R.Es. to the shops.

By D.W.'s circular memorandum No. 283, dated 29th October, 1917, these workshops were regularized, and an equipment of machine tools laid down.

It was stated that the primary object of C.R.E.'s workshops was to execute work connected with Engineer services carried out by the Works Directorate, and not in order to manufacture articles for stock, nor to execute work for other directorates.

TABLE J.

LES ATTAQUES.—BASE WORKSHOPS (WOOD-WORKING).

1.—*Personnel Employed.*

Officers	3		
British Military Artizans ...	132		
P. of W. Artizans	272		
French Civilian Artizans ...	18	Total Artizans ...	422
P. of W. Labour ...	383		
French Civilian Labour	4	Total Labour ...	387

2.—*Floor Area.*

(a) *Covered Space.*

	Square Feet.
Saw Mills	27,000
Wood Machine Shop ...	6,300
Joiners' Shop	9,900
Nailing Sheds	17,000
Tool and Nail Stores ...	3,400
Total Covered Area	63,600 square feet.

(b) *Yard Space.*

Area for Stacking Timber ...	125,000 square feet	Including Sidings.
Area for Manufactured material	168,000 ,, ,,	
Total Uncovered Area	293,000	

3.—*Machinery Installed.*

Twelve Mills, comprising :—

Band Saws ...	8
Blower...	1
Boring Machines ...	2
Circular Saws ...	... 36
Fan Exhaust	... 1
General Joiner ...	... 1
Grinding Machines ...	... 2
Gulletting Machines ...	... 3
Hearth	... 1
Log Saw	... 1
Morticing Machines ...	... 2
Planers	... 3

3.—*Machinery Installed (cont.).*

Pendulum Saws	7
Picket Sharpening Machines	1
Thicknessing Machines ...	2
Vertical Spindle	1
Saw Sharpening Machines ...	3
Total Machines	75

4.—*Prime Movers and Motors.*

Portable Steam Engine, 70 B.H.P.	1
,, ,, (Marshall) 32 B.H.P.	1
Ransome Portable Steam Engines 8 H.P.	4
,, ,, ,, ,, 10 H.P.	1
Ruston Proctor Portable Steam Engine, 10 H.P. ...	1
23 Motors, D.C. & A.C., H.P. installed	130

Total H.P. installed, 284.

METAL WORKING SHOPS.

1.—*Personnel Employed.*

Officers	1		
British Military Artizans	58		
P.O.W. Artizans	340		
French Civilian Artizans	5	Total Artizans ...	403
P.O.W. Labour ...	67		
French Civilian Labour	8	Total Labour	75

2.—*Shops.*

Name of Shop.	Area in Square Feet.	No. of Machines.	Total H.P. of Motors or Prime Movers.
Generating Station	830	3	112
Machine Shop	8,250	37	32
Fitting and Erecting Shop ...	6,455	12	13½
Blacksmiths' Shop	4,545	26*	22
Pattern Makers	3,640	5	5
Foundry, Iron	9,007	7	20
,, Brass	280	1	—
Coremaking Room	280	1	—
Fettling Room	2,352	6	—
Platers' Shop...	5,340	21	91½
Electricians' Shop	4,050	1	30
Instrument Shop	100	1	—
Tool Smithy	360	8	36
Offices, Store Sheds, Erecting Sheds, etc.	20,325	—	—
Total	65,814	129	

*Includes 18 Hearths.

3.—*Horse Power Installed.*

Engines	20 H.P.
D.C. Motors ...	93½ ,,
A.C. Motors ...	369½ ,,
Total	483 H.P.

Kilowatt Hours consumed (A.C. Motors only) ... ... 3,312 per diem.
Hours worked ... ... 16 ,, ,,

4.—*Summary of Machines.*

	No.	Description.
Blowers—Sturtevant ...	5	1½ to 12 H.P.
Compressors—Air	1	Ingersoll. 100 Cubic Feet of air per min. 100lbs. press.

Cranes.		
Gantry Crane ...	1	2ton, 23ft. span.
,, ,, ...	1	3ton, 17ft. 9in. span.
Crane	1	5ton, hand.
Cupolas	1	10tons capacity, 2ft. 6in. diameter.
	1	3 ,, ,, 1ft. 6in. ,,
	1	2½ ,, ,, 1ft. 4in. ,,
Drilling Machines	4	Sensitive up to ½in.
	2	Vertical up to 1¼in.
	6	,, ,, ,, 2in. and 2½in.
	2	Pillar up to 2½in.
	4	Radial ,, ,, 2½in.
	1	Hand ,, ,, 1¼in.
Furnaces.		
Oil, nuffle ...	1	One burner.
Halls Monometer	1	Oil fired and blower to 150lbs. crucible.
Forge.		
Rivet heating ...	1	
Grinders	4	3 double ended and 1 30in. single ended.
Generating Station	2	4-cylinder high speed vertical petrol engine. 1-32 B.H.P. 1-40 B.H.P.
	2	D.C. Generators. 1-18 K.W. 1-24 K.W.
Hammers.		
Pneumatic	1	2cwt.
Steam ...	1	3cwt. Vertical boiler, 100 sq. lbs.
Lathes.		
S.C. & S. ...	5	6in. to 9½in. gap.
,, ...	1	15in. gap.
,, ...	1	27½in. gap. 6ft. oin. C/S.
Machines.		
Bolt and Nut making	1	⅜in. to 1in. bolts.
Milling Machines	2	Table 2ft. 10in. × 10in. 20in. feed
Miscellaneous.		
Hand drills, hand shearing machines, small moulding machines, fettling wheels, etc.	15	
Motors	5	D.C.
	9	A.C.
Planing Machines.		
Metal	1	6ft. 6in. stroke.
	1	3ft. 4in. ,,
Punching and Shearing Machines	1	Double, up to ⅞in. plate.
	1	,, 13in. blade.
Saws.		
Band	1	Small, for Patternmakers.
Hack	6	7in. and 8in.
Screwing Machines	1	⅝in. bolts up to 4in. diam. pipes.
	1	⅜in. bolts to 1½in.
	1	1¼in. bolts to ⅜in.
	1	4in. to 8in. pipes.
Shaping Machines... ...	3	12in.–14in. (2 box table).
Smiths Hearths ...	21	19—3ft. 6in. diameter. 8in. uptake, and 3 smaller.

TABLE K.

OUTPUT DURING THE MONTH OF JULY (WOOD-WORKING SHOPS).

1918.

Article.	No. Manufactured.
Ablution Benches	289
Artillery Bridges	270
Bridging Stores, various	200
Bridges	3
Crosses	4,747
Camp Boards	2,400
Calais Trucks	162
Forms	585
Gas Frames, A, B, and C.	2,426
Infantry Bridges	1,187
Latrines, 1 seat, 2 seat and 5	1,656
Lifting Bars	200
Mining Frames	22,629
Marquee Hospital Floors	251
Notice Boards	3,984
Revetting Hurdles	27,607
Sausage Hutting—Roofs	6,234
,, ,, Sides	8,022
,, ,, Trusses	3,746
Scantlings, Timber converted to	FR. 1,000,000
Stay Blocks	3,860
Tables and Trestles	953
Trench Boards	82,344
Trench Frames, small	28,407
Telegraph Arms	13,624
Tank Covers	48
Van Ness Trucks (Woodwork)	87
Water Troughs	194
Windlasses	100
Equivalent to conversion of 2,045 Standards of Timber.	
Consumption of Nails	Cwts. 840

OUTPUT OF METAL WORKING SHOPS DURING MONTH OF JULY, 1918

Article.	No.
Belt Pumps	6
Bridges, emergency Portal Type	2
,, 30ft. R.S.J. Spans	18
,, Parts for	104
Cast Iron Collars	42
Cast Iron Moulds	100
Culverts, cleats for	1,824
Coupling Links	200
Decauville Trucks	162
Fire Bar Sets	Sets 41
Hook Bolts	1,500
Half Block Moulds	100
Incinerator Covers	47
Manhole Covers	8
Nissen Ovens	132
Pile Drivers (15cwts.)	3
Spanners	160
Sheet Iron Pipes	380
Steel Rods	88,000
" S " Clips	68,200
Sledgers (Ironwork)	60
Tip Trucks	10
Van Ness Trucks (Ironwork)	87
Water Bottle Fillers	25
" Z " Irons	500
Equivalent to consumption of :—	
Wrought Iron and Mild Steel ...	410 tons
Cast Iron	60 tons

REPAIRS TO MACHINERY.

The following machines were repaired in Metal Working Shops.

Cranes	1
Portable Steam Engines ...	7
Band Saws	1
Oil Engines...	5
Lathes	2
Thicknessing Machines ...	1
Saw Sharpeners	2
Planing Machines ...	4
Drilling Machines ...	5
Screwing Machines ...	1
Steam Hammer	1
Air Compressors	11
Hunters Boring Gear ...	1
Differential Blocks ...	6
Pumps	2
Shafting in Mills	3
Pendulum Saws	4

TABLE L

ENGINEERING STORES.

A Typical Month's Output.

August 1918.

Description.	Unit.	North.	South.	Total.
Trench Boards	No.	150,000	50,000	200,000
Trench Frames, small	,,	30,000	10,000	40,000
Revetting Hurdles	,,	25,000	20,000	45,000
Sausage Hutting	F.R.	12,000	6,000	18,000
Box Latrines, 1 seat	No.	400	1,000	1,400
,, ,, 2 seats	,,	600	700	1,300
,, ,, 5 ,, ...	,,	600	1,000	1,600
Squatter Latrines	,,		150	150
Water Troughs	,,	300	250	550
Notice Boards, tin	,,	1,900	8,000	9900
,, ,, wood, 18in. × 12in. ...	,,	1,900	3,000	4,900
,, ,, wood, 24in. × 18in. ...	,,	1,900	2,500	4,400
,, ,, wood, 24in. × 9in. ...	,,	1,900	3,000	4,900
Tables, 6ft.	,,	250		250
Forms, 6ft.	,,	400		400
Artillery Bridges	,,	400	150	550
Infantry Bridges	,,	1,200	150	1,350
Anti-Gas Frames, Type A.	,,	1,000	1,500	2,500
,, ,, ,, ,, B.	,,	500	250	750
,, ,, ,, ,, C.	,,	500	250	750
Frames for 2,300 gallon tanks	,,	50	70	120
M.G. Tables	,,	400	200	600
Ablution Benches	,,	400	800	1,200
Nissen Ovens	,,		40	40
Water Bottle Fillers	,,	100	30	130
C.I. Culverts	F.R.		40	40
Mining Frames	No.	62,500	60,000	122,500
Crosses, small	,,	3,913	1,290	5,203
,, medium	,,	16,827	6,880	23,707
,, large	,,		240	240
Jewish Memorials	,,		425	425
Indian Snakes	,,		110	110
Pegs, letter, large	,,		300	300
Plot Boards	,,	400		400
British Cemetery Boards	,,	400	199	599
Peg Boxes	,,		13	13

ENGINEERING STORES.

Issues to Armies during June, July, August, 1918.

Description.	Unit.	North. I., II., V. Armies.				South. III., IV. Armies.				Totals.
		June.	July.	August.	Total.	June.	July.	August.	Total.	
Trench Boards	No.	72,858	60,950	132,693	266,501	36,442	20,233	99,171	155,846	422,347
Trench Frames, small	,,	22,531	26,550	37,970	87,051	3,934	910	1,901	6,745	93,796
Revetting Hurdles	,,	35,940	25,102	29,069	90,111	4,578	10,196	10,378	25,152	115,263
Sausage Hutting	F.R.	4,600	6,800	4,980	16,380	4,552	7,400	4,992	16,944	33,324
Box Latrines, 1 seat ...	No.	424	446	890	1,760	914	789	748	2,451	4,211
,, ,, 2 ,, ...	,,	427	450	905	1,782	555	828	730	2,113	3,895
,, ,, 5 ,, ...	,,	444	450	500	1,394	1,099	638	846	2,583	3,977
Squatter Latrines	,,						125	61	186	186
Water Troughs	,,	197	192	125	514	236	106	37	379	893
Notice Boards, tin	,,	8,208	8,000	3,450	19,658	10,415	8,780	1,100	20,295	39,953
,, ,, wood, 18in. × 12in.	,,	2,865	2,885	2,980	8,730	1,654	1,692	1,216	4,562	13,292
,, ,, ,, 24in. × 18in.	,,	1,684	2,740	1,890	6,314	2,251	1,820	916	4,987	11,301
,, ,, ,, 24in. × 9in.	,,	2,478	1,500	3,150	7,128	1,440	1,211	841	3,492	10,620
Tables, 6ft.	,,	344	440	595	1,379	270	177	107	554	1,933
Forms, 6ft.	,,	688	880	1,175	2,743	490	284	15	789	3,532
Artillery Bridges	,,	290	250	146	686	341	84	329	754	1,440
Infantry Bridges	,,	749	600	350	1,699	293	110	88	491	2,190
Anti-Gas Frames, Type A. ...	,,	218	150	130	498	2,371	1,300	411	4,082	4,580
,, ,, ,, B. ...	,,	134	100	100	334	303	317	256	876	1,210
,, ,, ,, C. ...	,,	174	140	100	414	648	332	156	1,136	1,550
Frames for 2,300 gallon tanks...	,,	18	46	20	84	61	57	56	174	258
M.G. Tables	,,		60	67	127	447	100	74	621	748
Ablution Benches	,,	211	364	250	825	611	717	724	2,052	2,877
Nissen Ovens	,,	43	66	56	165		39	40	79	244
Water Bottle Fillers	,,	98	25	15	138		45	55	100	238
Mining Frames	,,	19,035	18,090	32,020	69,145	56,058	41,349	22,357	119,764	188,909
Trucks, Van, Ness	,,	30	87	85	202					202
,, Calais, Push	,,	191	266	132	589					589

TABLE N.

hower Baths.	Stoves.	Tar.	Pitch.	Sheet Iron.	Fire-bricks.	Fireclay.	Remarks.
No.	No.	Brls.	Brls.	Sheets.	No.	Cwts.	
94	8320	135	15	22700	5400	10	
54	3000	180	—	6800	—	—	
33	1450	340	11	5900	3000	50	
202	670	250	9	2500	11400	20	
30	350	220	5	100	1200	10	
78	110	400	8	200	6000	500	
102	670	350	10	1800	17000	90	
110	1910	785	75	1800	21000	200	
161	15610	1630	77	8900	50500	600	
145	15650	2840	295	15500	100000	450	
150	11400	2030	350	28800	175000	450	
150	9200	2670	225	15000	195000	650	
110	5700	1000	90	9200	47000	250	

TABLE O.

RECEIPTS, 1917, IN TONS.

	Timber.	Stores Imports.	Purchased in France.	TOTAL.
January	60,000	32,000	12,000	104,000
February	39,000	32,000	12,000	83,000
March	49,500	38,000	7,000	94,500
April	53,000	31,000	7,000	91,000
May	60,000	47,000	7,000	114,000
June	43,000	47,000	7,000	97,000
July	68,000	40,000	7,000	115,000
August	56,000	29,000	10,000	95,000
September	83,000	27,000	12,000	122,000
October	73,000	26,000	19,000	118,000
November	63,000	34,000	20,000	117,000
December	40,000	35,000	20,000	95,000
TOTALS	687,500	418,000	140,000	1,245,500

TABLE P.

ISSUES, 1917, IN TONS.

	TIMBER.			Stores.	TOTAL.
	Sawn.	Forest.	Total.		
January	28,000	11,600	39,600	43,000	82,600
February	35,500	11,200	46,700	28,000	74,700
March	34,500	32,000	66,500	39,000	105,500
April	20,000	38,000	58,000	31,000	89,000
May	18,000	29,000	47,000	48 000	95,000
June	15,000	26,000	41,000	36,500	77,500
July	24,500	31,000	55,500	44,000	99,500
August	23,000	33,000	56,000	52,500	108,500
September ...	33,500	35,000	68,500	72,000	140,500
October	21,500	40,500	62,000	75,500	137,500
November	29,500	39,000	68,500	71,500	140,000
December	25,000	28,000	53,000	74,250	127,250
TOTALS	308,000	354,000	662,300	615,520	1,277,550

RECORD OF ISSUES—R.E. STORES—ROUEN.

Description.	1914	1915		1916		1917		1918		Totals.
	August to 31. 12. 14	1st ½ year.	2nd ½ year.	1st ½ year.	2nd ½ year.	1st ½ year.	2nd ½ year.	1st ½ year.	2nd ½ year.	
Cement ... ... Tons	NO LEDGER ACCOUNT	89	500	595	1750	1135	867	2087	725	7748
Iron Corr. (All sizes) Sheets		17733	12494	17298	12857	16150	99265	75074	92780	343651
Roofing Felt ... Rolls		2045	1283	741	523	2882	8539	4537	5801	26351
Decauville Track F.R.		*Nil*	*Nil*	7037	9414	5656	12695	13716	10000	58518
Firebricks... ... No.		*Nil*	*Nil*	*Nil*	22447	34311	29311	37851	47767	171687
Fireclay ... ... Lbs.		*Nil*	8425	15768	43372	55760	35255	32206	44934	235720
Glass ... ... F.S.		1019	5022	10384	19998	19938	33483	31560	45917	167321
Ridging ... ... F.R.		*Nil*	*Nil*	2639	*Nil*	594	13724	15398	14650	47205
Windows ... ... No.		*Nil*	5	375	1145	1890	2977	1239	1976	9607
Stoves (all sizes) ... No.		1177	1121	1105	1110	353	2057	811	2165	9899
Ranges (all sizes) ... No.		383	85	76	89	134	136	71	138	1112
Asbestos Sheets ... No.		279	400	352	883	491	2012	927	920	6264
Baths ... ... No.		116	9	13	7	28	29	37	76	255
Bolts and Nuts (all sizes) No.		3169	5444	9475	42598	73022	205664	120108	132935	592415
Cisterns (all sizes) ... No.		226	109	330	54	344	125	148	134	1470
Piping W.I. (all sizes) F.R.		29614	14366	37423	34481	4152	94213	53536	71739	339524
Bricks Common ... No.		35993	177180	177614	312982	306570	117647	169273	93442	1390701
Pipes, Drain (all sizes) No.		1410	5735	6192	5421	8717	10803	9743	3923	52034
Lamps, E.L. (all c.ps.) No.		1486	6473	10652	14348	15192	27719	34054	33762	143686
Cleats ... ... No.		*Nil*	21310	27668	49763	40994	63933	96358	54600	354626
Switches ... ... No.		115	1686	2073	3023	2404	6640	4009	3583	23533

TIMBER.

During the period July, 1917, to December, 1917 ... ... 450 standards sawn timber
" " " March, 1918, to August, 1918 ... ... 661 " " " 1194 tons poles
" " " Sept., 1918, to March, 1919 ... ... 862 " " " 1156 tons poles

Quantities as shown were used.

CHAPTER 9.

WORK AT GENERAL HEADQUARTERS AND AT HEADQUARTERS OF FORMATIONS.

Early Conditions.—In the original expeditionary force the duties of the senior R.E. officers were advisory only; the only one empowered to incur expenditure on a larger scale than incidental expenses met from imprest was the Director of Works.

It very soon became necessary to regularize expenditure on stores and other services outside the sphere of the D.W., and in time the appointments of Engineer-in-Chief, and Chief Engineers Armies and Corps, were approved, these officers being granted the financial powers of a Director. Further to define the powers and procedure of C.R.Es. and other officers a pamphlet entitled "Administration of R.E. Works in the Field" was drawn up for, and issued by, the Quartermaster General in January, 1916. In the following year, after much discussion, amendments to Field Service Regulations Part II. were published in which the status of the Engineer-in-Chief was defined. The points affecting R.E. stores were:—

(*a*) The E-in-C. to be responsible for provision (*i.e.* estimates) and allotments of stores.

(*b*) The D.W. under the instructions of the E-in-C., to be responsible for provision (*i.e.* supply) and distribution to armies.

Thus the Engineer-in-Chief had a dual function in safeguarding the interests of the fighting formations and in controlling the operations of the D.W. in respect of supply of stores.

In forwarding these amendments to the War Office, G.H.Q. France pointed out that it might become desirable at some later date to divorce the provision of stores entirely from the D.W.

Stores Estimates at G.H.Q.—As soon as the supply of R.E. stores had settled down to a regular system the procedure became as follows:—

The staff of the Engineer-in-Chief received monthly—

(*a*) Estimate of stores required in the ensuing month by each army.

(*b*) Stock lists of stores in base depôts.

(*c*) Information from the D.W. as to the armies which it was best to supply from each of the base depôts.

On this information the E-in-C. made allotments to each army for the ensuing month, sending copies to the base concerned and to the D.W. C.Es. Armies informed depôts concerned as to destination to which they wished stores sent, and the depôt arranged transportation trucks and dispatch of the stores up to the total of allotment *in train loads* to destination named during course of month.

Constant alterations in demands naturally occurred during active months, and all such were communicated by Chief Engineers to the Assistant Engineer-in-Chief (Stores), who acted as *liaison* officer between the armies, (or users) and the D.W. (provider). Only as regards allotments already made could formations deal direct with bases.

The retirement in March, 1918, made a new system inevitable for the provision of stores to Third and Fifth Armies. A special *liaison* officer from the Works Directorate was attached to the E-in-C. with powers to decide on the spot all questions of supply. Monthly estimates and allotments were given up, and weekly stock sheets and demands instituted, which remained in force until June, when it became possible to resume the normal system.

Soon after the formation of the Engineering Stores directorate in the summer of 1918 another modification was made in the E-in-C.'s office The war had arrived at an abnormal stage, in which both production and distribution had reached the absolute maximum—the normal system of monthly army estimates was therefore no longer of value, and was given up. The E-in-C. continued to receive army stock sheets, and E.S. depôt stock lists ; he also had complete statistics of demands, allotments, and consumption in previous years, and was in the best position to get any information as to the future tactical employment of armies. It was very simple, therefore, to work out the most suitable allotment of principal stores to armies for the ensuing month, and armies then indented direct on the bases in accordance with their actual requirements.

The total issues of principal stores to armies in 1916, 1917, and 1918 are given on Table R.

System in Armies, Corps, and Divisions.—The system in armies and lower formations was naturally very similar to that at G.H.Q. as regards stock sheets and estimates ; armies received them from Corps, Corps from Divisions, and in many cases Divisions asked for them from Brigades or Field Companies. From 1916 onwards Divisions were so constantly on the move that C.R.Es. found it often impossible to make any useful estimate of stores required for ensuing month, and it was partly with a view to relieving them that the final abandonment of monthly estimates was decided on at G H.Q. Stock sheets of course were always necessary, and constituted the only means that the responsible R.E officer had of accounting for stores received and issued. From time to time attempts were made

TABLE R.

ISSUES OF PRINCIPAL STORES TO ARMIES.

STORE.		1916.	1917.	Jan. to June, 1918.	July to Dec. 1918.
Cement.	Brls. ..	172900	302400	122529	76283
Coir Screening.	Rolls ..		7210	1570	2203
Corr. Iron.	Bdls. ..	392030	709800	172225	119839
Roofing Felt.	Rolls ..	195000	439500	109202	102826
Joists.	No. ..	181700	137200	53021	50300
Rails.	No. ..	192900	82900	29826	13804
Screwposts.	No. ..	2153800	3698900	3365980	1749335
Shelters, large.	No. ..	9919	24170	10448	7160
,, small.	No. ..	9541	21000	9640	9460
Willesden Canvas.	Rolls ..		1810	505	887
Wire Entanglement.	Bdls. ..		44310	11244	23162
Wire Netting.	Rolls ..	169600	183100	55279	82678
Wire Weaving.	Rolls ..		17210	19315	5917
Revetting Hurdles.	No. ..		166500	99573	95385
Trench Boards.	No. ..		2200100	924321	510500
Trench Frames.	No. ..		193200	110962	97850
Trench Scoops.	No. ..		38700	4650	7050
Piping. 6in.	Miles ..		47	$4\frac{1}{2}$	$1\frac{3}{4}$
,, 4in.	Miles ..	291	703	$58\frac{1}{4}$	$117\frac{1}{4}$
,, 2in.	Miles ..	$162\frac{1}{2}$	407	$47\frac{1}{2}$	$56\frac{1}{4}$
,, $1\frac{1}{2}$in.	Miles ..	$95\frac{1}{2}$	220	$26\frac{1}{4}$	$15\frac{3}{4}$
,, 1in.	Miles ..	85	193	$19\frac{1}{4}$	$16\frac{3}{4}$
Tanks, 1600 gall.	No. ..	508	974	76	82
,, 400 ,,	No. ..	1587	3645	738	788
,, 200 ,,	No. ..	1758	5045	821	896
,, 100 ,,	No. ..	2321	6660	1657	1284
,, 50 ,,	No. ..	2999	7175	1781	1337
Pumps, Superior	No. ..		9870	1405	2324
,, Inferior	No. ..		5340	2700	850
Picks.	No. ..	537425	751200	489200	198892
Shovels.	No. ..	1019887	1560600	978000	460078
Sandbags.	No. ..	288932492	308763900	88820200	43041850
X.P.M.	Sheets ..	1122503	1254400	1080300	388738
Barbed Wire	Tons ..	15295	17170	34800	14098
Plain Wire.	Coils ..	75201	56250	110700	$16757\frac{1}{4}$
Posts. W.E.	No. ..	1411379	2255300	2542800	1237510
Nails.	Lbs. ..	9574840	17087700		

by certain administrative and audit branches to turn C.Es. and C.R.Es. into store accountants, but this would have been so obviously to the detriment of the fighting services that it was always successfully resisted. At the same time very strict orders were issued through all the branches of the Corps to ensure the most careful supervision and economical use of stores, and there is every reason to believe that this was effected far more thoroughly than would have been possible if the time of executive officers had been taken up by a more elaborate system of paper accounting.

Every Chief Engineer found it necessary at a very early stage to tell off an officer whose sole duty was the control of R.E. stores, and this presented especial difficulties in the case of Divisions, where a C.R.E. had only one assistant—namely an Adjutant. At least three-quarters of the Adjutant's time was taken up in most cases

with ' stores ' duties ; in fact he rarely had time for any other work at all, a state of affairs too unsatisfactory to require further comment.

Transport of Stores.—A further difficulty that was always pressing was how to get road transport. In quiet times lorries could be obtained in reasonable numbers by C.Es. and C.R.Es. through the ' Q ' Staff ; but as soon as active operations began, and the need for stores became greater, the supply of lorries grew less, and sometimes ceased altogether.

No mechanical transport was permanently at disposal of Chief Engineers except a few special heavy bridge trailers, and in some cases the lorries and trailers of M.T. Pontoon Parks ; but these latter were R.A.S.C. units, and as such directly under the control of the Director of Transport. C.R.Es. of Divisions had an infallible standby in the three pontoon wagons with each Field Company, strong and handy vehicles which did inestimably useful work. The opposition put up by every C.R.E. to all attempts to withdraw bridging equipment from Divisional Engineers was mainly due, not to any affection for the pontoons, but to utter impossibility of replacing the pontoon wagons in the forward carriage of stores. The following table gives the weight and dimensions of R.E. stores in everyday use, from which lorry and wagon loads could be calculated :

Article.	Weight.	Dimensions.
Sandbags, a bale of 250 ..	95lbs.	2ft. 6in. × 1ft. 6in. × 10in.
Corrugated Iron Sheets, a bundle of ...	205lbs.	6ft. × 2ft. 3in. × 2in.
,, ,, One sheet ...	11lbs.	6ft. × 2ft. 10in.
A coil of barbed wire ...	28lbs. 6ozs.	Average 110 yards
,, ,, plain wire ...	169lbs. 5ozs.	
,, ,, French entanglement ...	78lbs. 5ozs.	
Wire netting, a roll ...	48lbs. 5ozs.	
X.P.M. Sheet, one ...	7lbs. 5ozs.	6ft. 6in. × 2ft. 8in.
,, a crate (average) ...	264lbs.	6ft. 10in × 3ft. 3in. × 10in.
Angle Iron Picket, 6ft. ...	12lbs. 1oz.	6ft.
,, ,, ,, 3ft. 6in. ...	8lbs.	
Screw Post, long ...	8lbs.	5ft. 3in.
Tarred paper, one roll ...	76lbs.	3ft.
Canvas rotproof, one roll ...	130lbs.	5ft.—129yds.
,, cover, 30ft. × 30ft. ...	212lbs.	
Cement, large cask ...	422lbs.	
,, small ,, ...	330lbs.	
,, bag (average) ...	244lbs.	
Decauville 60cm. track (light) 5m. lengths ...	154lbs.	16ft.—5in.
Decauville 60cm. track (light) 2½m. lengths ...	73lbs.	8ft.
Curved steel shelter, sections of ...	48½lbs.	
Loophole plates ...	49½lbs.	2ft. × 1ft. 3in.
Steel rails, per foot, average ...	21 1lbs.	
,, girder, 9ft. ...	103lbs.	9ft. × 5in. × 3in.
4in. Flanged pipe ...	143lbs.	17ft.
4in. Screwed pipe ...	132lbs.	15ft. 6in.
2in. Galvanized iron pipe ...	59lbs.	18ft.
1½in. ,, ,, ,, ...	50½lbs.	16ft.
1in. ,, ,, ,, ...	28½lbs.	19ft.
1,600 gallon plate tank, complete with bolts, etc. ...	2,591lbs.	
A square of boarding : per inch thickness ...	300lbs.	

Army, etc., R.E. Parks and Dumps.—The formation of the first two Advanced R.E. Parks has been referred to. The general principles regulating issues from these parks were :—

(*a*) That tools were to be issued for work only, and on no account were units to make use of the park for replacing equipment.

(*b*) That no stores were to be issued except on the authority of a C.R.E. Division, or C.E. Corps.

These parks were accounting units, and vouchers were passed for all stores received and issued.

As the size of the army increased more parks were formed till there were at last 12 in operation. These were allotted to Armies by the E.-in-C. in accordance with tactical requirements.

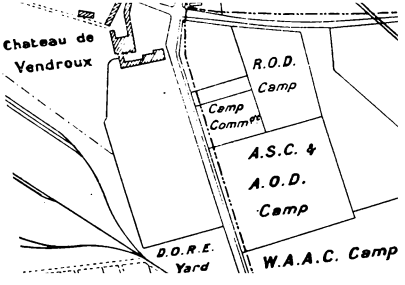
The Army parks were necessarily sited at some distance from the front, and quite early in the war it became the custom to form Corps parks or dumps, sited near railhead on the broad gauge system, and to which all ordinary bulk stores were sent direct from the base. In this case the army park only received special small or valuable stores and tools, and stores such as explosives, machinery, water supply equipment, etc., which the C.E. retained under his own control.

Similarly C.R.Es. Divisions established Divisional R.E. dumps, which would normally be at the head of the light railway system. In a few areas such as the coal mining district north of Lens, where there existed a network of broad gauge lines, it was possible to forward trucks of stores right through from the base to a Divisional dump without transhipment. This was certainly done for a considerable time on the I. Corps front to Les Brebis and Philosophe, but the cases were exceptional.

The actual system of demands and deliveries varied in formations, but it was a sound and generally accepted axiom that every unit ought to be responsible for delivery forward ; *i.e.*, the C.E. army would keep Corps yards supplied ; the C.E. Corps would deliver to Divisional dumps ; the C.R.E. Division to the Field Companies, and the Field Companies to the limits of mechanical or horse transport, from which points carrying parties had to be provided by the users. At each stage the forwarding authority would have to obtain the loading parties, whilst the receiving authority was responsible for unloading, and where necessary transhipping.

Mining Stores and Machinery.—Two classes of stores, *viz.*, machinery and mining stores, require separate notice. The demand for the latter arose on the formation of Tunnelling companies in the spring of 1915. Stores were largely experimental and of constantly changing types, and rapidity of supply was essential in order to keep pace with the formation of units ; in February, 1916, the responsibility for the provision of special mining stores was transferred to the Inspector

of Mines, who continued to control them to the end of the war. Special arrangements for the supply of machinery were unnecessary till the middle of 1915 when the demand for stores made itself felt; these were for about a year supplied almost entirely from French sources, after which it was necessary to import from England. Very few power driven pumps were supplied prior to the autumn of 1915, at which time small petrol pumps for trenches were first supplied. These did not prove of much use for trenches, but subsequently the best types were invaluable for water supply. A considerable quantity of low lift pumping plant was sent out at this time for use by Land Drainage Companies. The first large demand for pumping machinery was sent to the War Office in the last week of 1915 in connection with the preparations for the concentration of troops for the battle of the Somme. From that time on the provision of machinery expanded enormously. A special spare parts store was opened at Havre, but the multiplicity of types and lack of standardization in manufacture made the maintenance of spares an almost hopeless task. Fuller information on this subject is given in the volume dealing with "Machinery, Workshops and Electricity." Mining stores are described in the volume on "Military Mining," whilst questions referring to transport and storage of R.E. stores generally are further dealt with in the volume entitled "Forward Communications."


Chateau de
Vendroux
R.O.D.
Camp
Camp
Comm^ds
A.S.C. &
A.O.D.
Camp
D.O.R.E.
Yard
W.A.A.C. Camp

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