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THE HUTTING PROBLEM IN THE WAR.

By THE LATE MAJOR-GENERAL SIR GEORGE SCOTT-MONCRIEFF,
K.C.B., K.C.M.G., C.I.E.

I.

DURING the war, as we all know, the peaceful countryside was invaded and disfigured by groups of unlovely huts, mostly of brown boards and black roofs, assembled either in clusters of a few, perhaps guarding some railway bridge or junction, or in far-spreading lines for thousands of men under training. Now, for the most part, these have disappeared, and the countryside has resumed the charm of rustic beauty which had been so rudely disturbed. Before the remembrance of the episode has passed away it may be interesting to record what was done, for the story is one of some interest.

II.

At the outbreak of war, the Works Branch of the Army had practically nothing to do, other than endeavouring to prepare preliminaries for possible eventualities. Operations in the field, so inseparably connected with military engineering, had not developed, and all requirements for home defence had already been considered.

But when Lord Kitchener's appeal for 100,000 men was made to the nation, it was evident that the New Army would require to be housed as well as fed, clothed and armed. There was actually enough barrack accommodation in the country, but much of it was in isolated garrisons, and it was a matter of primary necessity that the new troops should be quartered in brigades and divisions with ground suitable for training. By adding to existing training centres, such as Aldershot, Salisbury Plain, the Curragh, etc., a good deal could be done, but, withal, one division at least would have to be hutted in some new place, and many new hutments would have to be built to supplement the existing needs at the training grounds already existing. Moreover, three or four large remount depôts, each for 1,000 horses, with their attendant grooms, etc., were needed near the ports of Southampton, Bristol and Liverpool (these were subsequently largely increased), and at nearly all the principal defended ports on the South and East Coasts of Great Britain huts for coast defence troops were required. The order of urgency, however, was for the New Army first of all, and upon that enterprise all attention had to be concentrated. The order for construction of hutted camps was issued on the 12th August, 1914, and by the 14th complete working drawings for a typical hutted camp of a battalion of infantry at war strength, including 17 different designs (*i.e.*, men's huts, recreation rooms, lavatories, cooking huts, officers' quarters and mess, sergeants' mess, etc., etc.) were complete and received the sanction of the Army Council.

This rapid result, achieved by the energy and skill of Major B. H. O. Armstrong, R.E., and his chief assistant, Mr. J. D. Michel, and their small staff of draughtsmen working day and night, was remarkable. For it not only involved the completion, in every detail, of a large number of plans, but it meant the settlement of several very important sanitary and administrative problems, such as the provision of baths, the supply of water, the nature and amount of artificial light, and of interior space and ventilation, the arrangements for messing and cooking, and many other such matters. Indeed, so thoroughly was this done that the result was considered by Lord Kitchener to be unnecessarily good, and after the first camps were far advanced he gave orders to curtail a good deal of what he thought was unwarrantable luxury, in the shape of dining-rooms and drying-rooms, etc. Baths, however, were admitted to be a necessity always, both in this country and in the field, and this in itself was a matter of great sanitary importance and a new departure in military administration.

III.

A rapid result such as this preparation of the typical plans did not mature all at once. It was the outcome of long and careful consideration and of some experience. It may not be out of place here briefly to record what that experience was and how it had been considered in the preparation of the typical plans. During the South African War some additions to our existing training centres, especially for the increase of artillery in modern armies, had to be constructed. To avoid the expense and delay involved in the construction of permanent barracks, these additions were of a hut type, chiefly corrugated iron buildings, lined with wood. But it must be admitted that, though they were less costly than the type of permanent barracks then in vogue, they were in many respects very unsatisfactory, the saving in money being more than counterbalanced by the cost of maintenance and the general discomfort involved. The attention, therefore, of the War Office technical staff was directed to the possibility of so utilizing modern methods of engineering that a simple, inexpensive, and rapidly constructed type of building should be devised, of a reasonably comfortable nature, and yet free from one of the great objections to permanent barracks, namely, the great expense involved in alterations, or "re-appropriation," as it is officially termed, when, owing to exigencies of military service or the advance of sanitary science, buildings originally intended for one purpose have to be altered to suit some totally different requirement. From these considerations was evolved a type of steel and concrete construction which cost far less than the permanent and substantial buildings normally adopted, and the consideration of this type, involving, as it did, constant consultation with the Army Medical authorities and the Quartermaster-General's department, prepared the way for even more rapid and less substantial forms of habitation, to be adopted when the need arose.

On two occasions between the South African War and 1914 the need for such did arise, illustrating how the experience of peace does help in solving one of the problems of war.

IV.

The first occasion was in 1907, when, on the 14th January, an earthquake at Kingston, Jamaica, destroyed in a few seconds all the buildings in that town, and overthrew the substantial fortifications on the other side of its famous harbour at Port Royal. A telegram to the War Office asked that, at the very earliest possible date, a complete hospital for 80 beds should be prepared and sent to the colony. It is, perhaps, hardly necessary to say that a hospital for a given number of beds means a great deal more than the mere wards for sheltering that number of sick. The accessory buildings, the administration block, the rooms for medical stores, operating rooms, quarters for medical staff, nurses, etc., are often a more extensive problem than the actual wards. In this case, owing to the lack of labour in the colony and its occupation with other work, it was necessary to send with the hospital huts a sufficient number of skilled workmen to carry out the erection. So a company of Sappers was warned to be ready for embarkation, the officers in charge being instructed to watch the progress of the preparation at home so as to be ready to carry out the work with all speed on arrival. Meantime, some of the best experts in the London building trade prepared the huts from designs generally prepared by the War Office staff, and, by the beginning of April, less than three months after the earthquake, *the hospital was in actual use* in Jamaica, where the material had been all landed complete about a month previously. Later on, when the barracks, of steel and concrete, on earthquake-proof principles, had been rapidly erected, the medical authorities were asked whether they wished a new and more permanent hospital. Their answer, however, was that the hospital, which they had thus hastily received, was all that was required.

The second of the two instances occurred in 1912 in the building of the Flying School at Upavon on Salisbury Plain. In January of that year a site was selected by the Committee, of which Colonel Seely, M.P., was president, and which was then considering the formation of the Royal Flying Corps. This Committee selected the site for the school solely on aviation grounds, naturally. From an engineering point of view it had no advantages. It was far from any railway delivery, it had no water supply, still less had it any electric power. Materials for construction had all to be brought to the site. The buildings were of an unusual nature, for aeroplane sheds involve gigantic doors, and abnormal roofs. Large workshops, to admit full-sized aeroplanes, and much shafting, belting and miscellaneous tools, had to be thought out. Meteorological stations had to be provided, and these and many other requirements were still in the uncertain stage which always is inseparable from a new and gradually developing art, so that complete design and estimate of requirements was at first impossible. Even the number of officers was uncertain, so that their quarters and mess could only be tentatively built. With all these limitations, however, the work went on rapidly, was completed in six months, and the first class of instruction was started in August, 1912. We know now how vitally important even one month was at that stage of aerial warfare, and it is not pleasant to think of what might have happened if the construction of this school had followed the "leisurely trundle" of building operations normal in this country.

V.

Thus it happened that when Major Armstrong (to whom more than anyone the credit of the Flying School is due) got the word to produce hut designs in August, 1914, he did not lose a moment. Later on he produced the well-known "Armstrong hut" which, constructed in sections, was made in workshops and sent out ready-made to any proposed site and rapidly erected. But, at first there was no necessity for this, and, indeed, there was considerable advantage in utilizing local materials and labour. The huts were at first built of a wooden framework with corrugated iron on roofs and external sides, and with asbestos lining inside. This was the quickest and probably best form for a limited number of huts, and if only the first 100,000 men had been all that needed accommodation, no other sort would have been necessary. When, however, the numbers rose by hundreds of thousands, until the demands amounted to about a million, some other material was required. This point, however, will be considered later.

The reason why a type plan of a battalion hutment was so important is that it furnished a guide to any class of unit. The 17 plans which made up the whole typical set, could be used for any other unit. Thus, a brigade of artillery has a different strength in men and horses from a battalion of infantry, but the only difference involved was that more stables of the approved type, and fewer men's huts, were required, and the relative arrangement of the whole had to be somewhat altered. The same types of huts were used in all cases, and it is a tribute to Major Armstrong's foresight that practically the same types were used during the whole war, though details were frequently improved as a result of experience, and materials differed with local circumstances.

The hut for the rank and file, which may be said to be the nucleus of the whole, was a small one only, for 24 men and 1 N.C.O. The reason for not having a larger one was mainly on the ground of discipline, the underlying idea being that 24 entirely raw soldiers would be more easily ruled by 1 N.C.O. than a greater number, say 50 or 100. In addition to this, and also to the fact that a small building is more easily fitted to the irregularities of ground than a large one, there was always the possibility of re-appropriation; experience having shown that military policy is by no means a constant, and that a building designed for, say, a recreation room, may be required shortly as a barrack store, or divided up into officers' quarters. And finally, the risk of fire has to be remembered, and a small building is more easily isolated in event of a conflagration, and, of course, more easily evacuated, than a large one. For these reasons the huts were small, relatively. Our American allies were surprised at this. They had built their huts for 100 men in two floors. Possibly this may have been cheaper, possibly it was more convenient and it enabled a larger number of men to be housed to the acre than our plan did. But it is doubtful whether it was a better plan, for the reasons above given.

Major Armstrong also planned his type grouping so that down the centre of his battalion camp came the accessories, recreation room, dining-rooms, sergeants' mess, kitchens, officers' mess. On either side came groups of men's huts and of officers' huts. The underlying idea was that the former (accessory buildings) should be erected, complete, first, and that the men and officers should sleep in tents, with boarded floors. The winter was coming, the materials and labour problems were gigantic. It would be better to ensure warmth and comfort to the men in their dining-rooms, etc., until they actually had to sleep, rather than, by grasping at completeness, fail to give even a reasonable amount of warmth and shelter. As it was primarily a question of health, it was referred to the medical authorities, and the Army Council, after hearing their views, pronounced against the proposal, and ordered that every endeavour should be made to provide sleeping accommodation concurrently with the accessory arrangements, and not, as was intended at first, build the huts to replace the tents as, and when, circumstances admitted, afterwards. This was tried, but it proved an impossible task. Later experience proved that men might quite well have lived in tents all winter, provided they had warm shelter to occupy until night came on. It is feared that the attempt to give them more, proved to be a cause of intense discomfort for thousands during the winter of 1914-15.

VI.

Although the typical hut scheme was the same for all places, it is obvious that every place differed in respect of roads, drainage, water supply, and in most cases artificial lighting. These problems, which, in some cases, were of great difficulty, had to be solved in each case from the local conditions. It was decided that, wherever possible, local water supply and sewerage systems should be utilized, but, of course, in many cases this was impossible. If a local gas or electric light supply existed, it was also to be used, but if none was available, then an electric power station, with oil-engine, dynamos and accumulator, was to be built, and a scale of lighting for the various buildings was worked out. This subject was one that was not hastily decided, for there were many matters to be taken into account, and it was not finally settled until some weeks after the first plans were sanctioned. As regards sewage disposal, where no public facilities existed, it was decided that all liquid refuse should be treated in filter beds and thoroughly purified before discharge into some water course. Soak pits were not to be used in England, though in France afterwards they were largely in vogue. Solid refuse was burnt in incinerators, the best pattern of which, however, was not settled until after a good deal of experiment. In the case of large camps for, say, 10,000 men and more, it was found, later on, that a regular water-borne system of sewage was the most satisfactory. As the hutting programme developed, during the first 12 months of the war, these problems of water, electricity, and sewage became enormous, and it was found desirable to have at the headquarters of each military command a specialist in each of these engineering subjects, whose responsibility was limited to the proper working of his own branch of each of the foregoing. These gentlemen were usually civil engineers over military age, or who had returned wounded from the front.

VII.

Thus it will be understood that the hutting problem, as it presented itself to the War Office authorities in the early months of the war, was more an engineering than an architectural one. Complaints were freely made, from influential quarters, too, that, with the immense programme of hut building, no advantage was taken of the services of the many members of the architectural profession who were out of work. It will, however, be understood that the architectural problem, *i.e.*, the designing of the actual buildings, was practically complete with the preparation of the type plans. That nothing more was wanted is proved by the fact that four of the large divisional camps at Clipstone (Notts), Puckridge (Staffs), Oswestry (Salop), and Rhyl (Flintshire) were entrusted to the Barrack Construction Directorate of the War Office (since abolished), whose permanent operations were at a standstill. This directorate, wholly under the control of professional architects, and with a free hand to accept or reject any designs prepared by another directorate, had handed over to it the whole of Major Armstrong's type plans. As the architects concerned did not make even a suggestion of alteration in design, it may be fairly concluded that, architecturally, there was nothing worth changing. But the engineering problems everywhere were varied and in some cases exceedingly difficult, and these were dealt with by the existing engineering staff in the commands, reinforced by capable retired engineer officers of wide experience, and by the specialists above mentioned.

VIII.

One other point must be mentioned before leaving Major Armstrong's type plans. The cooking of regular meals for 1,000 men was a problem of no small importance, and for some years before the war the War Office staff concerned had been very carefully considering the question of the best sort of kitchen ranges and boilers. They had been in touch with caterers in civil life, such as Lyons & Co., and with manufacturers in various parts of England. The result was that the types of cooking ranges and of boilers formed the nucleus of the plans of kitchens, serjeants' mess and officers' mess kitchens, etc., and it is satisfactory to note that, in spite of the enormous demands which subsequently were made on these manufacturing firms in the first year of the war, the supply never failed, and in the many complaints which arose from time to time about various matters, no complaint ever came to notice about the nature or the efficacy, or the fuel economy, of the types selected in the first instance. This fact is very much to the credit both of the designer and of the manufacturer. Concurrently with the design of the kitchens was the design for dining-rooms and "wash-up" sculleries, and it is very much to be regretted that, in the interests of economy, Lord Kitchener ordered these to be curtailed as luxuries. Those hutted camps which were provided with them were far better off than those in which the men's dinners had to be conveyed, in some cases, considerable distances, to the sleeping huts.

The economy was, in any case, not very great, though it is not easy to say, categorically, how much was saved in actual cash.

The estimated cost of a type battalion hutment for 1,000 men was £15,000, and at the time it was submitted to the Army Council, the anticipated increase in cost in, say, six months was at the rate of £5 per man extra. This £20 per man was estimated to cover all external and accessory services. As a matter of fact, the cost eventually worked out to about £22 or £23 on the average, and it included not only water supply, drainage, roads and railways, lighting and power, but rifle ranges and all training accessories and hospitals with their constructional requirements. But £15 per man, which was the first estimate, was considered too high, and the Secretary of State ordered every possible reduction, saying that all that was required was the roughest class of shelter as a substitute for tents. He was reminded that he had not soldiered in England during winter for many years, and that he must not think that the "wattle and daub" huts which he suggested, as a result of his Indian and Egyptian experience, would be either capable of resisting an English climate, or quickly erected. He agreed to this expedient being abandoned, but gave orders that, as far as possible, expense must be reduced by the curtailment of every luxury, and by utilizing the building talent of the troops wherever possible.

This last point was taken up in connection with some of the yeomanry and territorial troops on Home Defence duty, especially in Kent and Sussex. Some of these had professional men (architects, etc.) serving with them, who said they were quite prepared to house their units at a lump sum—£8 to £10—per man. They were given permission to do so, and copies of type plans were sent, though they had a free hand to deviate, if they liked, from the types. Some of the hutments thus built were excellent, others were very poor, and when the accessory problems came to be considered, the saving in cost was not worth mentioning. Much the same result followed the patriotic proposals of some of the great cities (Glasgow, Newcastle, Birmingham, etc.), whose municipal authorities not only raised and clothed, but housed, the splendid battalions of their citizens. These city fathers, shrewd business men, visited the War Office, were given all type plans and all collateral information, were told that £12 to £15 per man was the maximum that could be spent, and they built their huts accordingly. But they hardly ever did the work completely without asking for some additional funds. So that one may fairly say that, for the first six or eight months of the war, £15 per man was a good round number for the work required. At Aldershot work was done cheaper, but Aldershot is already supplied with water, drains and electricity, and its then Chief Engineer (General Gibbon) was a master of his craft.

It may be added that, after the war, many of the hutted camps were sold by the Disposals Board at figures considerably in excess of their original cost. It is believed that, all things considered, the country did not pay heavily for the housing accommodation built during the war.

IX.

Major Armstrong's type designs, therefore, swiftly and surely solved the problems of *what* to build for the New Army, but there remained the equally important question of *where* to build, and *how* to get it done. As regards the first of these questions, additions could be ordered at training centres already existing. Aldershot had sites galore, so had Salisbury Plain, the Curragh, Shorncliffe and Colchester. Rainham rifle ranges, near Purfleet in Essex, could take a brigade, and perhaps something might be done at Tipperary or Buttevant. But still there was a division of the First Army "out in the cold." A small sub-committee, consisting of Lieut.-Colonel Pell (of that fine regiment, the Queen's West Surrey), fresh from the Staff College and imbued with latest ideas on military training, and Colonel Cowan, R.E., one of the finest rifle-shots in the Army and the greatest expert on rifle ranges in the country, were dispatched at the same time that Major Armstrong got the word to start on his plans. Cowan and Pell went to the headquarters of Commands to seek for information for available sites. Afterwards we learned (what, indeed, we might have guessed) that this was not the right quarter to seek information. The men who really knew about the country were the Masters of Hounds, and they would have been only too glad to help if they had been asked. However, they were not called in just then, and for a day or two the returns were blank. Then, providentially, a generous offer came from Earl Brownlow, putting his beautiful park at Belton, near Grantham, at War Office disposal. Cowan and Pell went there, were warmly and kindly received, and decided that it was excellent. So Grantham became the headquarters of the 11th Division of the Army, that ill-fated and gallant division which, later on, left so many of its gallant lads in the ravines and jungle of the Gallipoli Peninsula. Orders were given, in August, 1914, that accommodation was to be built for the 13 infantry battalions of the division. Later on, orders were given for the artillery and engineers also to be quartered there. Before the huts for these were finished, orders were given that more infantry, and no R.A. and R.E., were to be quartered there. So stables were converted into barracks and water-troughs into lavatories. Before this was finished, the whole was turned into a machine-gun school, with a huge number of officers under instruction, and a substantial following of Q.M.A.A.C. This involved more and very extensive transformation, and may serve as a useful commentary on the question of "re-appropriation," and the folly of building in too solid a manner.

Later on, the whole question of selection of sites was taken in hand by the Quartermaster-General alone. Pell went off to command a battalion of his regiment in France and was there killed in most heroic circumstances. Cowan continued to evolve rifle ranges in England and Scotland, also a few in France. Altogether, he constructed over 200 of them, and beyond the accidental demise of a cow in Essex, there was not a single accident or complaint on any of them.

Whether the sites subsequently selected were suitable from a training point of view, it is not the province of this article to say. From an engineering point of view, some of them left much to be desired.

The *how* to get the work done was the next problem. It was obvious that even with a moderate programme of hut building, the supply of the three principal materials, corrugated steel sheets (galvanized), timber and asbestos sheets, would be a very big proposition, and so a recommendation was made to the Contracts Branch of the War Office that all these three materials should be placed under Government control. The Director of Contracts agreed as regards the asbestos, he arranged for the forbidding of export of galvanized steel sheets, but he could not agree to commandeer in any way the national supplies of timber, and he did not apprehend shortage, for the Surrey Commercial Docks in London and the timber yards at Hull and other ports were full and import was going on cheerfully. The corrugated steel manufacturers were, however, much perturbed at the embargo on export of their stock, for their colonial trade is the chief basis of their business. They represented that, if only they were allowed to export to British colonies, they would supply the War Office demands at prices lower than those of the market. This was agreed to, and for a while everything went smoothly. Then, suddenly, galvanized sheets became unobtainable. The disagreeable fact came to light that practically the whole spelter, or zinc, trade of the world was under German control, and with the cessation of German overseas trade the supply ceased. This was a serious disadvantage to the hutting programme, for it meant that either the corrugated steel sheets now supplied would have to be painted or otherwise protected from weather (and whatever the process would be, it would involve extra time and labour, both being very precious), or else some other material would be needed for walls and roofs of huts. And no other material was or is so expeditious in every respect as galvanized iron.

The timber question was even more important. It is easy, after the event, to suggest remedies, but it seems clear that if the Director of Contracts had put the matter, on the grounds of patriotism, in the hands of a few leading experts of the timber trade, they would have made arrangements of the very best and most economical character. Private conversations with some of these indicated such a possibility.

And in connection with this, a good deal of what is called in Shanghai "coffee-house pigeon" was effected; that is to say, information by men of influential position and knowledge given unofficially in clubs and railway carriages, etc., resulted in some valuable and advantageous purchases. But nothing officially was done until, some months later, the matter was put by the Treasury in the hands of a purchaser, paid at a percentage on his dealings. It may be remembered that this gave rise to much adverse criticism.

X.

Apart from the material supply, there came the question of contracts or other means of executive work. There are four such methods. First, the work may be done by direct labour, the engineer being his own contractor, purchasing materials and employing labour directly without any contractor intervening. This system, if in the hands of a man born with a special genius for such work, may be most valuable. Such a man was to be found in the then Chief Engineer at Aldershot, whose work was at once economical, swift and excellent. He had the reputation of getting the last ounce of work out of every man under him, for which reason he was not beloved by the usual War Office contractors, nor, indeed, by the financial authorities, who were slow to understand how it was he managed to set at nought their cherished routine. The huts at Aldershot were far the best, and far the cheapest, of any built in the United Kingdom. But the personal and local circumstances which obtained there were unique, and could not be reproduced elsewhere.

The second method was to give out a contract where the work is measured after completion, and payment made according to an agreed schedule of prices. This, however, postulates agreement as to the said schedule and, as a basis of agreement, some fixed rates of labour and materials. Under war conditions anything like fixity of cost was out of the question, and the preparation of a schedule of prices impossible.

The third method was the one normally in vogue, and a sort of fetish among some people as the one and only way to get work done. Plans of all the proposed work having been prepared in full detail, a statement or schedule of the quantities of each class of work is prepared by quantity surveyors—a process normally entailing considerable labour and much time. When the schedule, thus elaborately prepared, is complete, lump-sum tenders for the whole work, based on the schedule of quantities, are invited from selected firms of contractors, and usually the lowest tender is accepted. This method, the normal one in peace, is probably the best and fairest, in times of settled industry when prices have become more or less stabilized. But the time spent on the preparatory work is very considerable, and, moreover, the accuracy of the whole depends largely on the completeness with which the engineer or architect has foreshadowed every requirement. It will be seen that in many respects this was seriously inapplicable to the work proposed in the hutted camps, where not only time was of vital consequence, but where the local conditions varied so much in respect of accessory requirements.

The fourth method was the system of actual cost plus percentage. Here the contractor undertakes to do the work for the actual cost in labour and materials, plus a percentage to reimburse himself. This is, of course, open to the obvious objection that the contractor has every inducement to spend money, and no personal reason for trying to be economical. But if, at the elbow of the contractor, there is a responsible engineer who has full power to say what shall be done, and what labour shall be employed, and if there is a departmental accountant who not only scrutinizes every bill as it becomes due, but also sanctions every order that is issued, this system is not only capable of being made most efficient and speedy, but it is the only one which gives satisfactory and economical results in a time of change and fluctuation. The element of competition can be introduced into it (and was so introduced at a later period of the war) with most satisfactory results. At the beginning of the war, however, very few officers at the War Office knew much about it, or had any experience of it. It was anathema to the Contracts Branch for the obvious reason that it was a negation of contract, ordinarily understood. Nevertheless, the system seemed to present obvious advantages over the third method above mentioned.

Just then, however, a contractor of wide fame, Sir John Jackson, wrote to Lord Kitchener and offered his services to carry out any works at cost price. This offer was most opportune. It was decided to ask Sir John to take up the construction of the camp at Belton Park for 13 battalions, at Purfleet for 4 battalions, and at Ormskirk, near Liverpool (offered generously by the Earl of Lathom), a remount depôt for 1,000 horses. It involved an expenditure of at least £300,000. Sir John Jackson agreed, and a conference was held on the 17th August between him and the officers of the War Office branches mainly concerned, to settle details. During the week that followed he was busy collecting materials and labour, and on the 23rd August—the fateful day when our troops first came into touch with the Germans at the battle of Mons—the work at Belton Park was actually begun.

The hutted camp there was ready for occupation in the first week in November, less than three months after the first sod was cut.

The events of the following week, with its tremendous issues, so far affected the programme of hutting that the attention of the officers of the engineering staff, like that of every other branch of the Army, had to be concentrated on other arrangements of a military character, which were of vital importance to our national safety. With these we are not here concerned, except that there was inevitably less grip of the building developments in some parts of England than ordinarily would have been the case, and certain arrangements as to hutting were made, in the Southern Command especially, which gave rise to a good deal of trouble later. For the raising of the Second Hundred Thousand, followed immediately by the Third and Fourth, meant a vast scheme of new hutted camps. Moreover, the colonial troops from Canada, Australia and New Zealand were announced as coming to the aid of the mother country. It was proposed to quarter these, at first, in Windsor Forest, where the proximity to the Sovereign would appeal to their sense of the bond of Imperial unity under the Crown; the forests of Windsor could be utilized (as they were, very successfully, later) by them in building their own huts, and the comparatively easy access to the site would enable materials to be sent to them without the chance of being held up on railways already congested and strained to the uttermost. But training questions were obviously paramount. Windsor had no troops with whom the Colonials could co-operate and prepare for battle. So the plan, with its obvious advantages, was abandoned, and Salisbury Plain, already a hive of military activity, was chosen instead. Sir John Jackson was again called upon to undertake the work. He was, however, by this time not the only contractor in the field. Early in August his example had been followed by others. A list had been prepared, at the request of the War Office, by the Secretary of the Institution of Civil Engineers, showing the firms most likely to be ready to undertake work on similar terms, and an officer from the Works Department visited them all and learned what they were prepared to do. Other firms applied direct to the War Office. There was thus no lack of willing and capable experts.

Sites for large hutted camps were being selected all over the country by the Quartermaster-General and, as soon as any one site was approved, immediate arrangements were made to start work. In some cases these sites were the gift of patriotic owners, like Earl Brownlow; in other cases they were public commons, with old-established privileges; in a few instances they were grounds taken up under the Defence of the Realm Act. Retired Engineer officers of experience offered their services as supervisors. Fortunately for the nation, some of these were men of great engineering experience and administrative capacity, not too old to be still active and energetic. Thus the great camp for 40,000 men at Catterick (of which more hereafter) was under the supervision of Colonel Exham, C.B., who had been the engineer of the great naval base at Rosyth ; at Ripon (also for 40,000) the superintendent was Colonel Ellis, C.B., a former Chief Engineer of the Bengal Command. Another Indian officer, Colonel Finnis, C.S.I., was at Brocton, Cannock Chase; while Brig.-Genl. Buston, C.B., D.S.O., a former Chief Engineer at Aldershot, supervised the work at Prees Heath in Shropshire. What the country owes to these and other capable men cannot be estimated.

But the materials difficulty was by this time very acute. The rapid construction which was possible at Belton Park, where timber and galvanized iron sheets were easily obtainable, was not possible with timber becoming every day scarcer, and galvanized iron wholly unprocurable. The very rapid construction of the Belton Park Camp gave a false hope to the authorities, anxious, as they naturally were, for the hutting to be accomplished before winter set in. The weather, too, which in September was fine, broke about the middle of October, and resulted in one of the wettest winters on record.

XI.

Meantime hospital requirements had to be faced. Major Armstrong's activities, released to a great extent from the accommodation question, had now to be turned to the design of hutted hospitals, for 600 beds and lesser numbers. By the middle of October the type plans were finished, with the co-operation and sanction of the medical authorities.

The nucleus of hospital design is the ward, and Major Armstrong's ward was for 25 beds, *i.e.*, 24 ordinary cases and one special case. Later on, in France, this design was modified by the omission of the one special case. There was a nurse's duty room and store, and, separated by a clear passage, there were the bathrooms, lavatories and other similar apartments. Wards were connected by covered-in passages, which also communicated with the administrative block in some cases, and with the operating room. The administrative block provided the necessary office accommodation, the waiting-rooms, reception-room, dispensary, etc. There was a separate block for nurses' quarters, and another set of huts for medical officers with their mess rooms, and for the rank and file of the R.A.M.C.

The wards were usually parallel to each other and placed so as to obtain air and sunlight. In some cases in France the wards were placed all round the operating rooms (for these, in the field, had to be on a larger scale than in England), and in the huge hospitals at such places as Le Treport, Etaples, Rouen, etc., the details were somewhat different generally from the type plans. Where private hospitals were designed by such organizations as the Red Cross, St. John of Jerusalem, etc., there were often special features, but, broadly speaking, the arrangements followed the same lines as above indicated. Later in the war, Major Armstrong devised a ward block for 100 beds, with four beds instead of two in each unit of length. This ward had two rows of pillars at intervals longitudinally, the roof in the centre being higher than at the sides. At the place where the roof changed level there were rows of windows above the level of the lower roof. These, opened by cords from below, gave light and ventilation, in addition to that furnished by the side windows. This type of hospital, however, did not come into being until the war had progressed for some time, and the tale of wounded risen far above the early anticipations.

The interior of the wards was lined with asbestos plaster of a special kind, smooth and bright, generally tinted with some restful colour. The effect in the appearance of the wards, especially when these were brightened with flowers and the tasteful care of the nursing sisters, was charming, and would compare favourably with any hospitals in the land. Yet the cost of these hutted hospitals was not great, only some £80 per bed, and it is probable that for practical purposes they were as efficient as the permanent "palaces of pain" which, in civil life (before the war), cost as much, in some cases, as £1,000 per bed. It may be added, also, that such temporary buildings as the ones built in the war lend themselves to alteration, in consequence of the growing demands of sanitary and surgical science, more easily than those of a more substantial character. Yet it must in fairness be added that most civil hospitals, especially in great cities, must necessarily be of an imposing architectural character, and must conform to local building conditions—factors which were, of course, absent in war hospitals.

As a rule, the hutted hospitals in Great Britain were built as an integral part of the large hutted camps and were rarely for more than 600 beds. There were a few isolated exceptions, such as that for Indian troops in the New Forest, and the many additions to the Royal Victoria Hospital at Netley. But in France the hospitals were by themselves, and on a scale of vastness far exceeding anything in England. At Etaples, for example, there were 13,000 beds, divided into groups of 1,000, each completely self-contained. So great, indeed, was the scale of provision that one of these groups was for the accommodation of women patients only, to meet the needs of the great numbers of women working with the armies in the field. The heroism of these ladies, and the brutal conduct of the enemy, in connection with the air attack on Etaples, is a matter too well known to need more than a passing reference.

This hospital work in France, however, belongs to a somewhat later period of the war than that to which our narrative has reached. Allusion is only made to it because all the subsequent work, after October, 1914, was based on Major Armstrong's types modified to suit circumstances. It was of supreme importance to have the type well established at the first, and that certainly was done. The normal hospital construction began in the large camps concurrently with other work, though as a rule it was not finished till other accommodation was complete.

XII.

During the winter of 1914–15 the hutting programme proceeded rapidly. Building work in the country generally was at a standstill. The Ministry of Munitions had not yet arisen, with its rival allurements, and there was little talk as yet of "push and go." The building trades had numbers of men who were either too old for military service or had some other reason for not enlisting. Some, at least, wished to "do their bit" by building work at home, even in places entailing discomfort and hardship. Materials, except galvanized corrugated steel, were plentiful, and the timber shortage was not felt, or, at least, was only in the early stage of scarcity. There was ample employment for most of the building trades, except for plasterers and slaters, and even for these there was some provision made. Thus it is interesting to see that the curve of production rose rapidly in the winter months, despite the unusual inclemency of the weather.

The principal centres of activity were the Southern and Northern Commands. In the former the chief area of intense work was round Salisbury. In addition to new hutted camps near Tidworth and Bulford, there arose a new hutted town at Larkhill, near Stonehenge, camps along the Wylye Valley from Salisbury to Warminster for two divisions, another in the Fovant Valley for one division. Round Winchester there were huts for two more divisions, two huge remount depôts at Romsey and Southampton, and a third near Bristol. At Wareham and Bovington in Dorsetshire there was another division. Altogether the new accommodation in the counties of Wilts, Hants and Dorset amounted to the needs of some 250,000 men. It is a matter of surprise that the splendid training ground of the Cotswold Hills (proved, in the autumn manœuvres of 1909, to be admirably suited to the training of troops) was not utilized. If this had been done (and it was recommended on engineering grounds) the congestion near Salisbury, with its inevitable delay and expense, would to some extent have been lessened. But the nearest place to that open country where troops were hutted, was at Chisledon, near Swindon.

In the Northern Command there were some very large camps, but they were at considerable distances apart. At Ripon and at Richmond (afterwards called Catterick), and at Cannock Chase, there were in each case two divisions, a total of 120,000. At Clipstone (Notts) and at Belton Park, Grantham, a division at each place, another 40,000. The Tyneside battalions (4) were hutted in the Duke of Northumberland's park at Alnwick, under the supervision of the city of Newcastle. Other cities, such as Leeds, followed this example. The total for the Command amounted to about 200,000.

The Western Command had divisional camps at Prees Heath and Oswestry in Shropshire, and Rhyl in Flint, several brigade and battalion camps and a large remount depôt near Liverpool. The total came to about 80,000.

The Eastern Command had, besides extensive additions to Shorncliffe and Colchester, divisional hutments at Halton Park in Hertfordshire (on land given by Lord Rothschild), at Seaford and Shoreham, near Brighton, and many smaller camps round London. The total was about 80,000.

The Aldershot Command is a small one territorially, but it was fully occupied. Large additions were built near Aldershot itself, and at Blackdown, Ewshott and Longmoor, which are permanent military stations. Hutted camps for a division in each case were built at Witley Common and at Bramshott (near Liphook). Total, about 60,000.

In the above summary of work in the English commands it will be observed that no mention is made of those parts of the country nearest to the enemy, the reason being that East Anglia, Kent and E. Sussex were held by Home Defence troops, and their needs were distributed in billets and in small hutted camps all over that area. Nevertheless, there were some fairly big groups of huts, *e.g.*, at Maresfield Park and Crowborough in Sussex, at Forest Hill and Canterbury in Kent, and at many places in Norfolk and Suffolk. The total amounted to about 50,000.

In Scotland there were only a few hutted camps, and those mainly for defence troops near the important naval bases of the Forth and Cromarty. Near Edinburgh (Duddingstone and Dryhorn) there were about 3,000; at Stirling, Dunfermline and Kinross, another 3,000, and near Cromarty, Invergordon and Nigg, about 4,000. In Ayrshire there were a few battalion camps of Glasgow troops, about 3,000. Altogether the accommodation there provided was for about 15,000.

In Ireland, besides large additions to the Curragh, there were battalion or brigade camps near Cork, Tipperary and Buttevant, and in Ulster accommodation for a division (which had the distinction of being the most expensive in the United Kingdom, costing £36 per man). Total, about 40,000.

In addition to this there were groups of coast defence troops, chiefly at the principal naval bases, and additions to all the infantry depôts in the country. The total amounted, in that first winter, to demands for about 800,000 men and 150,000 horses, and involved an anticipated expenditure of at least 16 millions sterling.

It was felt that in view of so colossal an expenditure it was incumbent on the War Office to obtain the very best professional advice, not for purposes of evading responsibility, but to obtain wholesome and sound criticism. It would be far better to scrap type plans, and existing methods of work, at an early stage, if these were faulty, far better to dismiss, wholesale if necessary, incompetent officers if such existed, than to allow any faulty and second-rate work to be tolerated and public money to be wasted. So the War Office asked the Institution of Civil Engineers, with whom there had always been the most cordial relations and co-operation, if they could appoint a committee to visit and criticize the work in progress. The functions of such a committee would be purely technical, but within that general term they would be free to criticize anything, type plan, local arrangements for water supply, roads, etc., contract methods, wages, accounting and so forth.

Lord Kitchener at first demurred to the proposal. He was satisfied with what was being done, and did not think the opinion of other people mattered. But when the point was insisted on that his own responsibility would be strengthened by good expert opinion, he agreed, for he realized that sooner or later criticism would come, and it was obviously better to have it from experts than from "the hare-brained chatter of irresponsible frivolity."

The reply of the Institution was courteous and cordial. The Committee which was nominated was the very best possible, for the Chairman was the President of the Institution, Mr. B. Hall Blyth (since deceased), and the members—Sir Robert Elliott-Cooper, Sir Maurice Fitz-Maurice, Mr. Basil Mott and Capt. H. R. Sankey, all of them members of the Council of the Institution and two of them Past Presidents. Capt. Sankey had been an exceptionally brilliant R.E. officer who, after some 16 years in the Army, had retired to take up civil engineering and had attained the highest reputation in that profession. At the outbreak of war he offered his services, gratuitously, as technical adviser and consultant to the Director of Fortifications and Works, an offer which was very gratefully accepted. Shortly after the war he was elected President of the Institution of Mechanical Engineers.

This Committee was obviously the most competent tribunal of appeal in technical matters that could be found in England. They offered their valuable services to the War Office gratuitously, and spent their very valuable professional time freely in visiting the works in progress and in reporting. In all human enterprises, especially on so vast a scale as this one, there must inevitably be many faults, big or little, and the hutting scheme was not exempt. But, taken all round, the Committee's report was very favourable. They recognized the seriousness of the situation and the magnitude of the undertaking. They considered that, on the whole, it was being adequately handled.

Later on, this Committee was asked to criticize and advise on other engineering works and ultimately to go to France and criticize work there. But in 1915 their functions were confined to the large hutments in England, over 200 of which they visited.

XIII.

It is not our intention, and it would be tedious and entirely out of place, to attempt to describe all, or even a few, of the large hutted camps. But it is thought that some account of one of these may be of interest, and from the description of one, an idea may be formed of the work involved in any other.

The one thus chosen for some description is that known as Catterick in Yorkshire, from the little village of that name whence the branch railway to the camps leaves the existing line. Really, the great camp or cantonment is much nearer the town of Richmond than it is to Catterick, but the confusion with Richmond, Surrey, was found to be so great that the name of Catterick was preferred.

The site was one of the last chosen in 1914, and in selecting it, the assistance of the M.F.H. of the Bedale Hunt was asked, and freely given. The situation is on the plateau to the south of the gorge of the river Swale, immortalized in Turner's pictures, and the historic town of Richmond. In 1914 this upland, partly moorland, partly pastoral and arable land, was as quiet a spot as any in England; cold and wind-swept in winter, fresh and bracing in summer.

Lord Kitchener gave instructions that in one of the Yorkshire hutted camps the possibility of having what he called "an Aldershot in the North," might be borne in mind. In other words, just as Aldershot was, at the conclusion of the Crimean War, a hutted camp for about 20,000 men and was afterwards, at great expense, made into a permanent cantonment, so there might be, after the Great War, a similar demand for a training centre in the North of England. If this were kept in view, it might be possible to give the new cantonment a somewhat more permanent character from the first, without greatly adding to the expense. It so happened that these instructions coincided with the investigation of how to reduce the amount of timber in hut construction, since the shortage of that material was now becoming a serious matter. The Catterick site furnished an opportunity of trying the use of concrete on a large scale, for the river Swale, close to Catterick, sweeps round a bend where large deposits of gravel are found. A railway from this area could be made, with easy gradients, to the site of the camps, four miles away, and easily connected with the existing line on the other side of the river. About the bridging of the Swale we shall have something to say later. Meantime, it is sufficient to say that plant for excavating and sifting the gravel was readily installed in the area in question.

The walls and floors of the new huts were thus projected as of concrete, the former either in slabs, or in fine mortar laid on a network of expanded metal. The floors were of concrete covered with asphalt.

The framework of the huts and of the roofs was light steelwork, and the roof covering of roofing felt on planking.

The contractors who carried out the work, and devised most of the engineering expedients connected with it, were a firm of great colonial experience, which enabled them to take a wide and far-seeing view of the case. The Superintending Engineer, Colonel Exham, who, as previously stated, had built the great dockyard at Rosyth, was a man of great practical experience and power of command.

This hutted camp was one of the very few which was entirely self-contained. Others obtained, perhaps, their water supply or their electric power from existing municipal organizations, or were otherwise to some extent dependent on existing agencies. But in the case of Catterick everything was new—roads, railway, water-works, electric supply, sewage works, and even swimming-bath and laundry. The accommodation provided was for two divisions complete (40,000 men), and the camp was divided into two main parts, named Hipswell and Scotton, after the two principal houses in each area.

The railway into the camp is connected with the main line to Richmond, near the village of Catterick, and in its course has to cross the river Swale, over which a girder bridge was built. While this bridge was under construction the line was temporarily laid over an old stone bridge of three arches, which carries the main road from York northwards. This old bridge was built in the year 1426, in the reign of Henry V., and the original contract for it is in the possession of the present lord of the manor, whose ancestors have held the land ever since. Excellent, indeed, was the work of the stout fifteenth-century masons, for their arches have not only stood for 500 years, but they actually, at that advanced age, carried a broad-gauge railway, with (probably) a 100-ton locomotive, without showing any signs of failure. And it may fairly be said that the men of England and Scotland who went to the camp for training in the reign of King George V. were not unworthy of their forbears who fought at Agincourt and Flodden.

It is satisfactory to know that Lord Kitchener's wish is now being fulfilled and that an "Aldershot in the North" is coming into being at Catterick Camp, though most of the other hutments in Great Britain have disappeared.

THE ERECTION OF AN INGLIS BRIDGE IN WAZIRISTAN

By CAPTAIN C. DE L. GAUSSEN, M.C., R.E., Commanding 19th (Field) Coy., Royal Bombay Sappers and Miners.

IT would be interesting to know if the Inglis Bridge, of which the building is described in this article, was the first to be erected for permanent use, as opposed to temporary or semi-permanent use in war. It is true that peace, as yet, does not fully spread her wings over the land in which it was erected, but it is certainly intended to be permanent.

Three Inglis Bridges, Mk. I, were erected on the Sora Rogha-Razmak road. These had been sent to India at the close of the Great War and had since then been lying in the R.E. Park at Lahore, a constant source of labour to maintain and occupying very valuable space. Their employment on this road, therefore, was in every way desirable, particularly from the point of view of rapidity of erection, and the comparatively light weight of the portions to be transported over roads impossible for any traffic heavier than bullock carts.

These three bridges were erected, two over the Dwa Toi above its confluence with the Baddar Toi to form the Takki Zam, and one further forward over a gap near the village Marobi, where the road leaves the line of the river bed and traverses higher ground over a series of *raghzas*. This last was the first to be erected and is the one described. The gap is normally dry, about 80 ft. deep, and 60 ft. between the abutments, which were built on firm rock of very suitable formation for the purpose.

The difficulties to be overcome were human and geographical rather than engineering. The inhabitants of this part of the Waziristan are particularly troublesome, and it was essential to complete the collection of stores, erection and launching of the bridge in the minimum time, partly in order to withdraw the protection troops covering the operation as early as possible and partly to get the counterbalance bays back so that the launching of the other two bridges would not be delayed. It should be realized that, even though no definitely hostile action was taken by the Mahsuds, anything of an easily movable nature would be stolen if left unguarded, either for its material value or for " pure cussedness." A *badragga* guard (armed inhabitants paid for escort or guard duty by the government) was therefore arranged for and the dwellers of Marobi warned that any tampering with the bridge would entail the destruction of their happy homes. Even so, five large pins disappeared, perhaps because of their potential value as weapons.

The transport available was bullock carts for the transoms and stiffeners and mule carts for the lighter parts—tubes and roadbearers. These had to be taken over a very rocky river bed as far as the last mile and a half, which was along the unfinished formation of the new road, and for the most part up a steady and very rough incline. The component parts of the nine bays (five for the bridge, one for the trolley and three for the counterbalance) were thus brought up to the site in two days. The site was cramped and unsuitable for the reception of the stores, as they all had to be unloaded in the cutting approach to the bridge, and there was great congestion throughout the day (the working hours being limited by the necessity of protection) so that stores had to be off-loaded as they arrived, and were consequently dumped in complete chaos.

On the following day, while the trolley and its pyramid were being erected by one party, the other was laying out stores ready for erection. It may be noted here that it was found necessary when working with Indians to increase the numbers of men, for carrying, over those allowed for in the drill, by about 50 per cent. This laying out took longer than would normally be the case owing to the cramped space between the sides of the cutting. The erection was then commenced, but care had to be taken, as the erecting ladders were not so strong as they had been before their sojourn in Lahore, even after repairs. However, good progress was made, with parties working at both ends, and early the following day the erection was complete.

Meanwhile the very rough road had been levelled in front of the trolley wheels and large stones placed where the channels would be laid, to minimize sinking. An anchorage and preventer tackle was made in rear of the bridge, and hauling tackle from an anchorage on the high road side above the abutment on the far side of the gap (where the road made a sharp turn) took the place of a derrick. The approach to the bridge was down a gradient of about 1 in 18, and as the preventer tackle was not too trustworthy the launching had to be taken very slowly with the frequent insertions of chocks under the wheels, to give time for the channels to be moved forward. The need for an articulating joint was felt, as, in spite of preliminary excavation, the end two transoms firmly fouled the slope of the road when the bridge was about 18 inches short of its final position. The hauling tackle was most useful in giving just the necessary lift to the front transom to seat it on the abutment, owing to the sag in the bridge. The road was then excavated below the two rear transoms to the exact distance the bridge had to go forward, and when the counterweight was replaced the slope was sufficient for the bridge to move gently forward under its own gravity and it quietly came to rest in its correct position.

The Erection of an Inglis Bridge in Waziristan

The bridge was thus erected and launched in two days, and the dismantling and laying of the roadway commenced at once. It was considered that the timber flooring supplied with the bridge would be far too tempting to the Mahsuds, to whom such baulks would be worth their weight in gold, and a decking of corrugated iron, wired down to the roadbearers and covered over by three inches of concrete, was adopted. Fortunately large quantities of clinker were available near by from some smelting process carried on in Marobi, and thus the dead weight of the deck was appreciably less than would be the case had ordinary shingle been used as aggregate. The curb was reinforced, consolidated into the decking by a stirrup round a wire laid in the floor just inside the edge of the curb.

It cannot be claimed that any valuable engineering lessons were demonstrated, but such a use of the Inglis Bridge is interesting and it established a landmark in the history of Waziristan, when a girder bridge was in two days thrown across a chasm-like gap in the heart of the Mahsuds' country.

SOME SUGGESTIONS FOR LIGHTENING THE PONTOON BRIDGING EQUIPMENT.

By CAPT. AND BT. MAJOR A. C. FINNIMORE, M.C., R.E.

(1) *Stainless Iron and Steel.*—The progress of invention has at all times suffered from the objection to "newfangled" devices which is deeply implanted in the average man. This is perhaps the explanation of the continued use of gunmetal in ordnance equipment such as, for instance, the coupling hooks of pontoons, of galvanized steel in wire rope, and of carbon steel for cutlery of all types.

The possibilities of the rustless alloy known as stainless steel were appreciated during the war by the designers of aeroplanes; and this metal was used considerably for the wire stays and tensioning screws which stiffened the wings of aircraft, and also for the plates and brackets to which the stays were attached. The great strength of the alloy, and its absolute freedom from corrosion, enabled a large saving in weight to be effected; its reliability and resistance to frictional wear made it preferable in many cases to aluminium alloys, whose lightness caused them to be used extensively where the stress was not so great.

The main objection which lies in the way of utilizing rustless steel and iron for all equipment is the large cost of these alloys. On further examination it appears, however, that the cost of an article made of stainless steel is not necessarily more than if it were of bronze. Bronze castings are known to be comparatively unreliable, and their tensile strength is low, of the order of 10 to 12 tons per square inch, while good rolled bronze seldom exceeds 26 tons in ultimate tensile strength.

The ordinary qualities of stainless steel have a strength of about 80 tons; special qualities, after forging or drawing, may attain a tensile strength of 120 tons per square inch, while the newly evolved stainless iron averages 60 tons.

This last alloy has been evolved as the result of a search for a metal which, while retaining the same immunity from corrosion as stainless steel, has a ductility sufficient to enable it to be used for rivets, and a reliability under repeated shocks and reversals of stress to warrant its use in chains, engine rods, and steel structures.

The cost of the alloy is at present about twice that of Admiralty bronze, while its strength is from twice to six times as much.

As regards facility of working, suitable mixtures can be produced for casting, and with suitable heat treatment the ductility and reliability of a forging can be obtained in such castings.

All the stainless steels can be forged, and the milder steels and irons can be welded with as much reliability as low carbon steels or wrought iron.

The high temperature required to render the alloy plastic necesstates the use of oxy-acetylene flame or electric arc welding ; but such methods of welding are now familiar to all engineers and manufacturers.

A particular use for which these properties commend the employment of stainless iron alloys is in the fastenings of pontoons and bridging superstructure, where weight is a serious disadvantage, and where freedom from corrosion is so essential that bronze has been considered necessary in the past.

(2) *Anchors.*—A considerable saving of weight in the equipment could be effected by substituting for the 112 lbs. and 56 lbs. anchors as provided at present a more effective anchor of much less weight.

The present type of anchor frequently acts only as a deadweight on account of its ineffective form ; and it is therefore necessary to supply sufficient metal to hold fairly well even if only lying on the bottom without hooking in. Fishermen in some places use anchors weighing not more than 20 lbs. to hold boats in conditions much more severe than those encountered in bridging streams, knowing that the weight need be no more than enough to commence to drive in the point, if the anchor is correctly formed.

Fig. I shows the present equipment anchor. It is equally likely to fall point downward or with the flukes horizontal, and in the latter position is stable, so that it may drag without turning over

Present form of Anchor

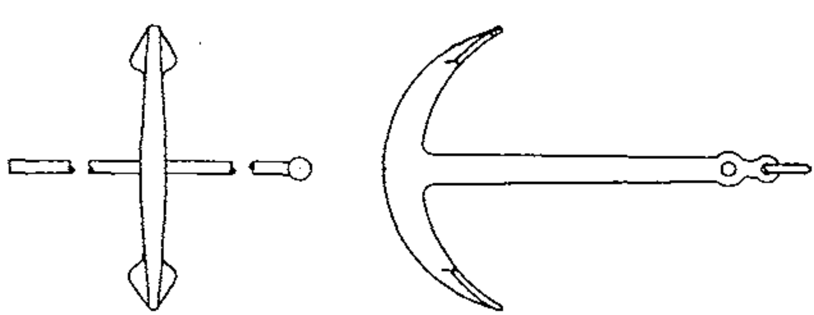

Fig 1

and biting, as in *Fig.* II. Its points are blunt, and the palms are barbed, so that if the rope happens to take a turn round the palm, it is likely to stay there and drag the anchor crown foremost.

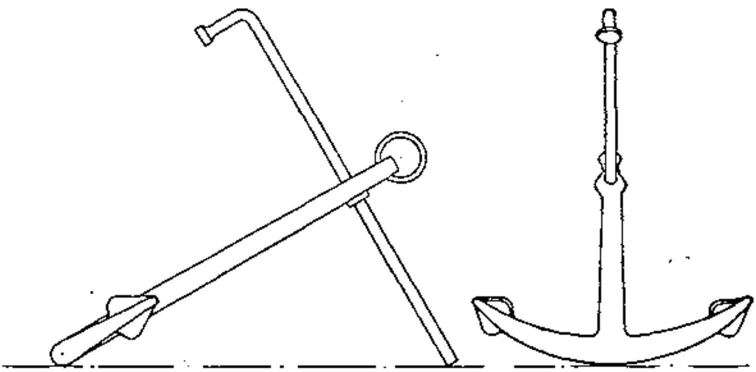

Fig II

Fig. III shows the fisherman's anchor. Its long shank and flukes at 45° ensure that, if once the point enters, the pull on the ring will drive the fluke further in. The long stock, of considerable weight, makes the anchor very unstable if it happens to fall with the flukes horizontal, as in *Fig.* 4 (*a*), and a very small tilt ensures that it will fall over with a point downward—(*b*) and (*c*). Moreover, the point is sharp; and the palm has no barb, so that an accidental turn round it slips off easily.

Such an anchor is certain to bite, and so needs no weight except such as is necessary to provide sufficient strength. In mud or soft clay, such as is found in the beds of many comparatively sluggish or tidal streams, the form of an anchor is of small importance, because anything sufficiently heavy sinks in and then resists any attempt to move it. It is on a sandy or gravelly bottom that anchors tend to drag without biting, and in consequence of experience in such difficult places that the demand for weight arises. This demand is equally well met, however, by an anchor that will bite with certainty.

Anchors seldom fail by dragging when once bit, but rather by failing to bite at a critical moment, or by being fouled by a rope. A bad foul, such as a half hitch thrown round one fluke, will put any anchor out of action; but it is extremely unlikely to occur, unless by dropping a coil of rope over the fluke before, or in the act of, lowering away.

It is the plain turn or half turn on a fluke or the stock which generally causes trouble by turning the anchor over and leaving it with flukes horizontal. It is important, therefore, that the anchor

Fishermans Anchor

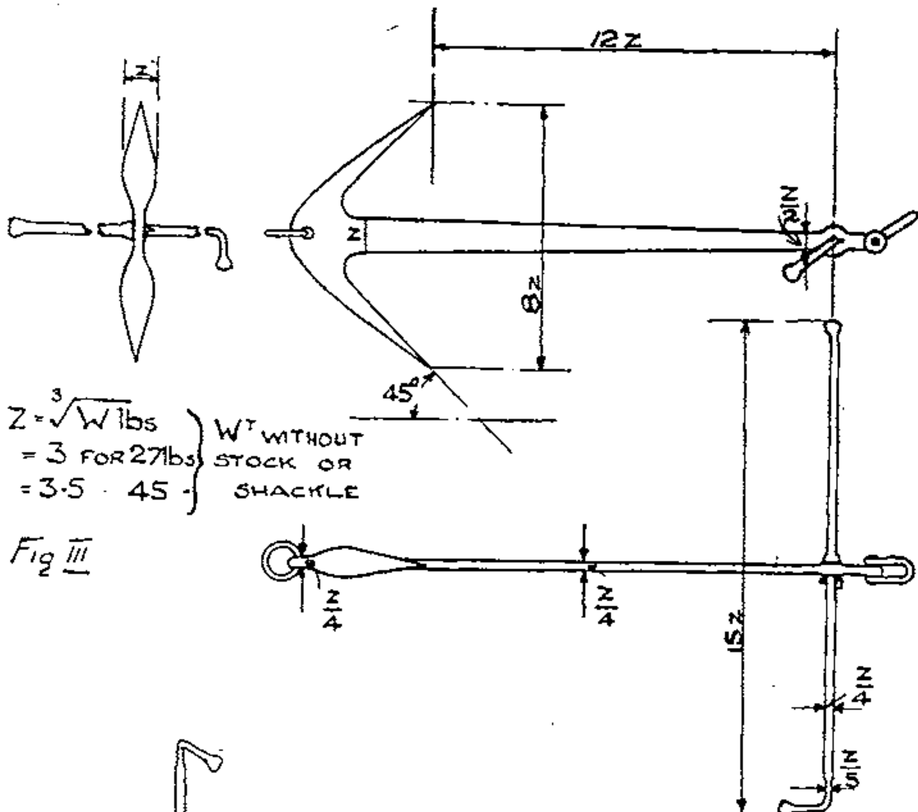

Fig III

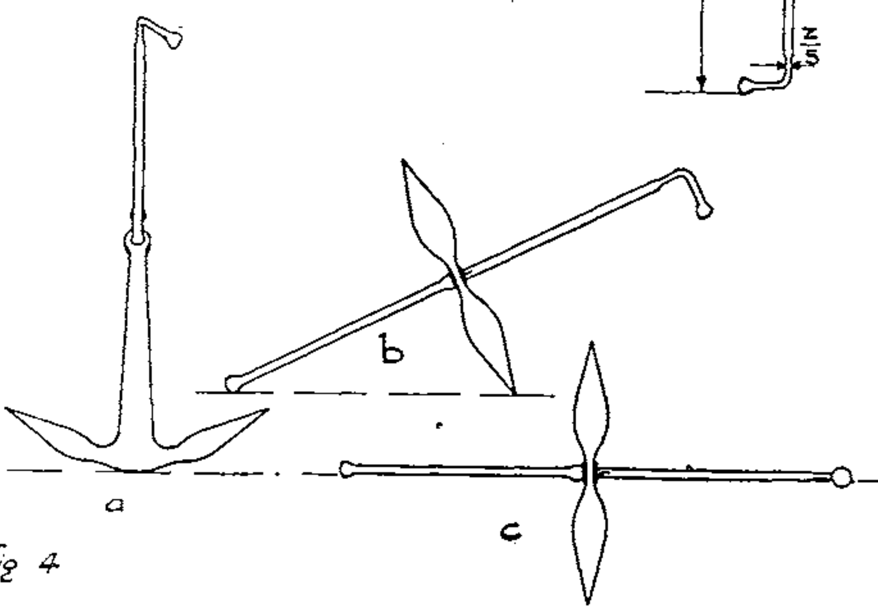

Fig 4

shall be unstable in this position, so that it will fall over point downwards when any pull comes on the cable. It is also equally important that the form of the fluke shall permit the cable to slip off the fluke it has fouled; and anything of the nature of a barb is likely to increase the chance of remaining foul.

It will only be possible to determine the minimum weight of anchor that can safely be applied to the purpose of bridging as a result of practical tests. It may safely be predicted, however, that much lighter gear could be so applied than is in use at present; and at a hazard, the nominal weights of 43 lbs. and 27 lbs. are suggested as sufficient to replace the present types.

The nominal weight does not include the stock or shackle; the gross weights corresponding are 57 and 36 lbs. respectively.

THE EARLY YEARS OF THE ORDNANCE SURVEY.

(Continued).

III. The Survey is Formally Founded.

The Duke of Richmond.—If it is to General Roy that we owe the first conception of a National Survey, it is no less certain that it was the Duke of Richmond who made the scheme possible and created the department officially. Throughout the early records of the Survey numerous references will be found to the practical support given by the Duke to the geodetic operations which were, in those days, under the general control of the Royal Society; and, when the proper time came, it was the Duke who took the initiative and converted what was, till then, mainly a scientific undertaking, into a National Survey. In the preface to the *Account of the Trigonometrical Operations*, by Captain Mudge and Mr. Dalby, it is stated that "the design . . . had not, in its origin, that extensive application which has since attended the endeavours of his Grace the Duke of Richmond, with respect to subsequent trigonometrical operations." In 1791 we find the Duke issuing instructions "to be minute in our Survey of Sussex" with a view to the construction of a map of that county. In 1794 he directed that the operations for that year should commence in Kent and be continued till that county was finished and then be carried over into Essex. Earlier General Roy stated that "the Duke of Richmond, Master General of His Majesty's Ordnance, had, in the most liberal manner possible, given every assistance to the operation (from that great department over which he presides with so much honour to himself and advantage to the publick)." Lieut.-Colonel Edward Williams, the first official Director of the Survey, speaks of "the liberal assistance which his Grace the Duke of Richmond had on all occasions given to this undertaking," that is, to the early operations under the Royal Society. And Portlock, writing in 1853, stated that General Roy particularly acknowledged the attention that the Duke always paid to his representations, and that it was from the Duke that the idea of a National Survey received its earliest and most decided support. Portlock adds, "Taking, then, into consideration the encouragement he conferred on this peculiar branch of the Ordnance service—asserting, by so doing, the claims of Ordnance officers to be looked upon as scientific men—the patience with which he investigated the now popular subject of national defence, and the personal attention he bestowed on all the military departments of the Ordnance, including the Royal Military Academy, it may be justly said that the Duke of Richmond stands in the first rank of Masters-General of the Ordnance."

Charles Lennox, 3rd Duke of Richmond, was born in 1735, and succeeded to the title in 1750. He entered the Army, and distinguished himself at the Battle of Minden. After the peace he was appointed Ambassador to Paris (in 1765). On his return he took a large part in public life, embraced the cause of the American Colonies, and denounced the Ministerial policy. In December, 1775, he declared that the resistance of the colonists was "neither treason nor rebellion, but is perfectly justifiable in every possible political and moral sense." At this period King George III. entertained a strong personal dislike for the Duke, but after the close of the war they became friends; and a few years later the King said that "there was no man in his dominions by whom he had been so much offended, and no man to whom he was so much indebted, as the Duke of Richmond."*

He was appointed Captain in the 20th Regiment of Foot in 1753, and received the rapid promotion to be expected in those days in the case of a man of his position and ability. He was promoted to Major-General in 1761 and was made a Field-Marshal in 1796. He appears to have been particularly interested in two subjects which are dealt with by the Engineers of our Army, namely, fortification and surveys. In 1783, as Master-General of the Ordnance, he appointed General Roy a member of the Board on Fortifications, over which he himself presided. In the same year he nominated a special committee to consider the defences of Chatham. He was supported by Pitt in his proposals to remodel the fortifications of Portsmouth and Plymouth; but the House of Commons, alarmed at the probable expense, threw out these proposals, after a division which required the casting vote of the Speaker.

The existence of the Ordnance Survey is evidence as to his interest in surveying. Not only did he, during Roy's lifetime, give the most effective assistance, in this matter, to the Royal Society, of which Society he was a Fellow, but after Roy's death he took the decisive step of putting the Survey under the Board of Ordnance, and thereby established it as an official department. But for the Duke of Richmond the National Survey, if it had come into existence at all, would almost certainly have assumed a different and less efficient form; and it was a fortunate thing for the Survey, not only that it came under the Board of Ordnance, but that the Master-General was well acquainted with Roy and his work, and was able to preside over its destinies for the first few years.

* *Dictionary of National Biography.*

EARLY YEARS OF ORDNANCE SURVEY.

F.M. the Duke of Richmond, K.G., F.R.S., 1735–1806,
Master-General of the Ordnance, 1782–1795.

Duke of Richmond

The Duke was a man of the widest interests; fond of country life and sports, a patron of literature, science and the fine arts, a soldier of distinction, and a statesman of far-seeing views. He was a great friend of Romney; Goodwood contains many examples of this artist's work, painted to order of the Duke. He was much interested in the work of "that able artist Mr. Ramsden"—an artist in brass and glass. Indeed there were few aspects of life in which he was not interested. Burke is said to have reproached him with spreading his talents over too wide a field. It does not appear, however, that the objects of his interest suffered in consequence. Amongst them may be mentioned racing; he made the famous racecourse at Goodwood. In the *Sporting Magazine* for April, 1801, may be found the following notice: "The new racecourse on the Harroway, near Goodwood, the seat of his Grace the Duke of Richmond, is now completely formed for sport, and much admired by acknowledged amateurs of the Turf."

Many stories are told of his fondness for hunting and of his autocratic, if kindly, ways as Master. "Such was his Grace's desire to give fair play to a good fox, that once, after a capital run, the fox having sought refuge upon the porch of Waltham Church, which was covered with ivy, but not sufficiently to conceal his brush from the view of his pursuers, who with their whips were trying to dislodge him, the noble Master rode up in great haste and anger, asking them to desist, and exclaiming, "Why do you want to murder such a fox? leave him alone. He has shown you a good day's sport, and if left will show you another."*

The Duke was appointed Master-General of the Ordnance in March, 1782, and retired from that position in February, 1795, being succeeded by Lord Cornwallis. The appointment is not to be confused with the less important post which nowadays carries the same name. In those days the Honourable Board of Ordnance was a great department, possessing extended powers. Its history dated back to the middle of the fifteenth century, and for four hundred years it maintained a tradition of independence and authority. The Master-General was responsible for the Artillery and Engineers of the Army, for fortifications and armaments, and all things therewith connected; he was one of the King's principal advisers, and was at all times a military power to be reckoned with. In later years the position was held by the Duke of Wellington. The Duke of Richmond's tenure of the appointment covered those ten years, a brief breathing space, between the war with the American Colonies and their allies, and the war with revolutionary France, extending on into the latter. After his retirement he lived almost entirely at

* *Records and Reminiscences of Goodwood and the Dukes of Richmond.* John Kent. Sampson Low, Marston & Co., Ltd. 1896.

Goodwood, where he died on the 29th December, 1806. He was buried in the Cathedral Church of Chichester.

The Ordnance Survey, which preserves in its name the history of its creation by the Honourable Board, and is the last surviving branch of that ancient institution, is always bound to keep in pious remembrance the name of the distinguished Master-General who founded it.

The word "Ordnance."—The word "ordnance" is a syncopated variant of "ordinance," which is itself derived from the old French word "ordenance" (a regulation and an arranging in order). In the seventeenth century the word "ordnance" came to be exclusively applied to artillery and engineer personnel and material, and the services relating to these.* In the early days of the Survey the expression "Ordnance Survey" was not used, at least officially. Thus, in 1811 was published the third volume of the account of the *Trigonometrical Survey carried on by order of the Master-General of His Majesty's Ordnance*, and the work is sometimes alluded to as the British Survey, or the British Trigonometrical Survey, or the General Survey of Great Britain. In a letter dated 1817, from the Master-General of the Ordnance to the Lord Advocate of Scotland, the expression "Ordnance Map" is used. The first use of the term "Ordnance Survey" that can be found is in a minute dated 1820, when the "eighth part" of the *Ordnance Survey* was presented to the Duke of Wellington, then Master-General; in this sense it meant the map itself. In 1827 the official *Instructions for the Interior Survey of Ireland* are stated to have been lithographed at the *Ordnance Survey Office*, Phœnix Park. In 1842 the official account of the Zenith sector observations is headed *Ordnance Survey*. The term, which naturally arose from the fact that the Survey was administered by the Board of Ordnance, is a very convenient one and saves the use of a longer expression. It became, in after years, the synonym for a Survey of the highest accuracy.

Effect of Roy's Death.—If we wish to measure the influence of a particular factor in any of the affairs of life we can sometimes arrive at a just conclusion by imagining the effect produced by the removal of that factor, or by watching the result of its removal. And the best proof of the large share that General Roy had in shaping these early Surveys, is that on his death they, for a short time, stopped altogether. In the *Account of the Trigonometrical Survey* for the years 1791–94, by Lieut.-Colonel Edward Williams, Captain William Mudge and Mr. Isaac Dalby, it is stated that some time elapsed after the General's decease "without any apparent intention of renewing the business." Portlock says that "after General Roy's death the subject of a Survey seemed, for a time, to be overlooked"

* See *The Oxford Dictionary.*

The Official Foundation of the Survey.—The account above mentioned goes on to say that "a casual opportunity presented itself to the Duke of Richmond of purchasing a very fine instrument, the workmanship of Mr. Ramsden, of similar construction to that which was used by General Roy (*i.e.*, a second 3-ft. theodolite), but with some improvements; as also two new steel chains of one hundred feet each, made by the same incomparable artist. Circumstances thus concurring to promote the further execution of a design of such great utility, as well as honour, to the nation, his Grace, with His Majesty's approbation, immediately gave directions to prepare all the necessary apparatus for the purpose, which was accordingly provided in the most ample manner." According to another account, the Duke of Richmond purchased a 3-ft. theodolite, intended for the East India Company. Portlock says that the Duke, being informed that Ramsden had made this second instrument and the two chains, "recommended to the Government that they should be purchased and the work renewed." The 3-ft. theodolite in question is known as the 3-ft. O.S.; it is now (1924) in the Science Museum, South Kensington, and has the date 1791 engraved on the circle. The reason given for the official prosecution of the Survey is not convincing. The undoubted facts are, that Roy died in July, 1790, and that, as we shall see shortly, officers were appointed to the duty of carrying on the Survey in July, 1791. With regard to the preoccupations of the Master-General, the French Revolution had been in progress some little time—the Bastille fell in July, 1789—but France and England were not at war again until February, 1793. No doubt this was a busy time at the Board of Ordnance, but not so busy as to prevent the discussion of the question of the continuance of the Survey. It must, of course, be remembered that up to Roy's death the operations had been carried out under the general direction of the Royal Society, with assistance from the Board, and that the instruments used had been paid for personally by the King. But the instruments were still available and it is difficult to believe the official story, published after the Duke had ceased to be Master-General, that it was the knowledge of the existence of a second theodolite which caused him to adopt the Survey officially. Such a reason appears to be quite inadequate. Official statements, however old, do not always carry conviction. The course of events was probably something like this: The Duke of Richmond was genuinely interested in Roy's work and we know that he had always materially assisted him. On Roy's death the Duke cast about for some means of continuing the Survey, and no doubt consulted the Royal Society, of which he was a Fellow. The military authorities, in view of the probability of war with France, realized the value of a trustworthy map of Southern England, and the Duke, who was himself a high military authority was of the same opinion. The

Royal Society, having seen the completion of the trigonometrical connection with France, was not unwilling to be relieved of further responsibility for the Survey.

It is known that the Duke applied to Dr. Hutton, of the Royal Military Academy, Woolwich, for his opinion as to the best officers of the Artillery and Engineers to take charge of the Survey, and that Dr. Hutton recommended Major E. Williams and Lieut. W. Mudge, both of the Royal Artillery. "Dr. Hutton said that in so doing he sincerely believed he had named the best mathematicians in the two Corps, and the fittest officers for this duty. Indeed, he added, it would have been very difficult to have found persons better qualified anywhere."*

During the course of a year the various negotiations with the financial authorities, with the Royal Society, and perhaps with the East India Company, and with Ramsden with regard to the second instrument, were concluded satisfactorily and in July we find the two officers above-named definitely appointed, as shown by the following *Extract from the Minutes of the Master-General and Board of Ordnance*† :—

12th July, 1791.

"G. W. Phipps, Esq., Under Secretary to the Master-General, having, by letter of the 10th inst., signified that his Grace had appointed Major Williams and Lieut. Mudge, of the Royal Regiment of Artillery, to carry on the Trigonometrical Survey with the assistance of Mr. Dalby, and desired that they might receive an Extra Allowance equal to their pay and half-pay whilst actually in the field which would be 22s. 6d. per day to Major Williams and 7s. 6d. per day to Lieut. Mudge besides the usual allowance per mile for travelling from place to place and that a party of Artillery who were to assist were to receive one shilling per day each while employed."

"Ordered that the above Allowances be paid."

It may, therefore, be taken that the date of the official constitution of the Ordnance Survey was the 10th July, 1791. The personnel of the Survey consisted of the three above-named, Major Williams, Lieut. Mudge and Mr. Isaac Dalby; they were assisted in the field by a working party of artillerymen. Poles, scaffolds, ladders and such apparatus were provided by the Board of Ordnance. Williams, Mudge and Dalby all worked in the field and Dalby was especially responsible for the computations. The principal instruments used were the new 3-ft. theodolite of Ramsden (the Royal Society theodolite was not used again until January, 1799, being meanwhile laid up in the apartments of that Society), two new 100-ft. chains, and a transit instrument combined with a telescopic level, for use in measuring bases, all by Ramsden.

* *Memoirs of the Mudge Family*. S. R. Flint. Truro. Netherton & Worth. 1883.

† Communicated by Mr. Cary, the War Office Librarian.

It may be interesting to note that the fame of Ramsden's instruments had by this time spread over the world. In the same year (1791) the German geodesist Johann Georg Tralles and the Swiss geodesist Ferdinand Rudolf Hassler, of Aarau, measured a base-line $7\frac{3}{4}$ miles long together, for the Survey of Switzerland, using a steel chain made by Ramsden. Later on, the government of the Canton of Berne voted six hundred dollars for the purchase of a suitable theodolite and " Mr. Ramsden in London, then the most celebrated instrument maker living, for a sum somewhat exceeding this amount, promised to supply in 1794 a complete azimuth circle, at least three feet in diameter. Due to various delays the great instrument did not reach Berne until 1797 . . . Ramsden's three-foot theodolite was a wonderful instrument . . . What a privilege for young Hassler to become practically acquainted with the use of an instrument of the high type that very few surveyors then living had ever seen! The three years' delay is characteristic; we have seen that Roy suffered from a similar delay in the provision of the first theodolite."* The young Hassler was afterwards the founder of that admirable department, the United States Coast and Geodetic Survey, which was suggested by him in 1807, approved by Congress in the same year, but not actually organized until 1816, Hassler being the first Superintendent.

The First Director.—The following are the services of Edward Williams as recorded in the *List of Officers of the Royal Artillery*:—Siege of Belle Ile, 1761; Adjutant, North America, 1777; on the Staff of Lord Hood; on the Staff of General Pattison, Governor of New York, 1775–1780.† (Belle Ile is an island some eight miles south of the peninsula of Quiberon, in Brittany, about midway between L'Orient and St. Nazaire; it was captured in 1761, and was held by British troops until 1763, when it was exchanged with the French for Nova Scotia. The next thing we know about Williams is that, as already mentioned, he was recommended by Dr. Hutton as an officer whose mathematical attainments fitted him to take charge of the Survey; he was a Major when he was appointed, in July, 1791, and if we may assume that he was at least 18 at the siege of Belle Ile, he would have not been less than 48 years old when he first took charge of the Survey. In collaboration with Mudge and Dalby he wrote the account of the Survey for the years 1791–94; he was then a Lieut.-Colonel. With them also he wrote the account for 1795–96, being then described as Colonel He died in 1798, and it is curious to note that Mudge, in his account of the operations for 1797–99, makes no mention of Colonel Williams or of his death.

* *The Scientific Monthly*, Aug., 1921. Article by Professor Florian Cajori on *Swiss Geodesy and the U.S. Coast Survey*.

† Kindly communicated by the Secretary, R.A. Institution.

We may, perhaps, suppose that he was in failing health for some years, and it is not unlikely that Mudge was in effective charge of the work. At the best, Colonel Edward Williams, R.A., the first official Director of the Ordnance Survey, is to us but a shadowy and unsubstantial figure; we know nothing of his form or features, and, beyond the fact that he was a good mathematician, nothing of his abilities or character.

The Headquarters of the Survey.—From 1791, for fifty years, the offices of the Survey were in the Tower of London, which was the headquarters of the Board of Ordnance. On a plan made about 1685, by order of Lord Dartmouth, Master-General of the Ordnance, the office of the Ordnance is shown on the south side of the enclosure, touching the Lanthorn Tower and the Constable's Lodging. This was a small building and probably only supplied for the general administration of the department. The Survey offices were almost certainly in an armoury to the north of the White Tower, abutting on the Bowyer Tower; the site of this armoury is now occupied by barracks. About 1791 the Master-General appears also to have had an office in Pall Mall. However, it was to the Tower that Williams, Mudge and Dalby returned after their season's work in the field, and many of the early letters are written from the Drawing Office in the Tower.

The Royal Military Surveyors.—The chief draughtsman in the Tower was Mr. Gardner, who is thus mentioned in the account of the operation for 1791–94: "We have to acknowledge the services of Mr. Gardner, Chief Draughtsman at the Tower, by whose assistance, from his intimate knowledge of the county of Sussex, we have been able to determine, with certainty, the names of many places, which we might otherwise have considered as doubtful." In the accounts for 1795 "Mr. Gardner, Chief Draughtsman in the Tower," is stated to have accompanied Mr. Dalby into Kent, to assist in observing with a small theodolite. Portlock says that a Corps of Surveyors and Draughtsmen had been established by the Duke of Richmond; and if so, this Corps must have been formed before 1795. The "Corps" was to be employed for filling in the topographical details required for the one-inch maps; Mr. Gardner may have been an official under the Board before the formation of this Corps. In the preface to the account of the Survey for the years 1800–09 it is stated that the secondary triangulation in the south of England was "made subservient to a regular Survey, performed by the Royal Military Surveyors," who are presumably the Corps of Surveyors and Draughtsmen mentioned by Portlock.

The Operations of 1791-98.—We have seen that Williams, Mudge and Dalby formed the Staff of the Survey on its foundation in July, 1791; and that they had available Ramsden's new 3-ft. theodolite, originally intended for India, two new steel chains specially made by Ramsden, and minor instruments. Their headquarters was the Tower of London, and they were immediately under the Board of Ordnance, which provided for them a working party of artillerymen and all necessary material.

The first thing that they set out to do was to re-measure, with Ramsden's new chains, the base on Hounslow Heath that had been measured in 1784 by Roy. It is not necessary to go into the details of this measurement, beyond saying that the chains were supported in wooden coffers, which rested on trestles; the trestles were those used by Roy and were lent for the purpose by the Royal Society. The measurement began on the 15th August, in the presence of Sir Joseph Banks, Dr. Maskelyne, Astronomer Royal, and several other members of the Royal Society. It was finished on the 28th September, Dr. Maskelyne, Dr. Hutton, Professor of Mathematics in the Royal Military Academy, and Mr. Ramsden being in attendance, by desire of the Duke of Richmond. Every precaution was taken and the mean of the two measurements was found to be $2\frac{3}{4}$ inches longer than Roy's glass tube value. The mean of the two results of 1784 and 1791 was accepted as the true length of the base, namely, 27404·2 feet.

On the approach of the Spring of 1792 a reconnaissance was made of the country about to be triangulated, which included some of the points already observed as by Roy. Lamps, to observe to, "were constructed by Mr. Howard of Old-street, which were afterwards found equal to everything which could be expected of them." Later on in the year observations were made with the new 3-ft. instrument, at the Base, and on hills as far to the west as Butser and Chanctonbury Ring. Certain points on the coast were intersected "for the construction of some maps that were making for the Board of Ordnance"—no doubt, maps for defensive purposes. Early in 1793 a site for a base of verification was selected on Salisbury Plain, between Beacon Hill, near Amesbury, and the Castle of Old Sarum. This base was measured in 1794 with Ramsden's new steel chains: the measurement occupied seven weeks. The length, when all corrections had been applied, was found to be 36574·4 feet. The length as determined through the triangulation, from the Hounslow Heath base, was 36574·3 feet. But, when the same base was re-measured in 1849 with Colby's bars, its length was found to be 36577·85 feet. The latter value is, of course, of far higher weight; the error of the 1794 measurement was, thus, about 1 in 10,000. In 1849 it was stated that the guns marking the terminals of 1794 did not appear to have moved sensibly.

Meanwhile, during these seven years, the triangulation proceeded steadily along the south of England, until, by the end of 1795, a double chain extended from London to Land's End, and sufficient numbers of points were fixed in Kent and Sussex for the detail one-inch Survey. "The chief draughtsmen and surveyors belonging to the Drawing-room in the Tower, attended our operations in this county (Kent), and also those afterwards carried on in Essex. It was indeed for their immediate service that we renewed the Survey in this quarter, as the Master-General had given directions to prepare ample materials for completing the map which meets the public eye with this article." (July, 1800.) The organization was evidently imperfectly developed, the chief draughtsmen and surveyors (Royal Military Surveyors?) being apparently under the direct orders of the Board. In 1795 Ramsden's 18-inch theodolite was first used for the Survey of Kent.

The Geodesy of the Operations.—It was considered that "directions of meridians," that is azimuths, should be observed "in order to afford the necessary data for computing the latitudes and longitudes . . . it is expedient that new directions of meridians should be observed when the operations are extended in eastern or western directions over spaces of sixty miles from fixed meridians."

It must be remembered that at the end of the 18th century all the processes of the higher surveying were in a tentative stage, though the fundamental notions were very well known. The actual procedure for calculating the latitudes and longitudes of the trigonometrical points was, briefly, the following: The observed spheroidal angles were reduced to those made by the chords, the spherical excess calculated, and the triangular error equally distributed; the sides of the triangles, *i.e.*, the lengths of the chords, were computed; the curvature of the meridian for the south of England was derived from the observations of 1787–88, between Greenwich and Paris; from this curvature the latitude of one of the connected stations was calculated as deduced from Greenwich, then the latitude of a second connected station; then, knowing the latitudes of these two stations (say, Beachy Head and Dunnose), "and the angle which those stations make with each other and the pole," the difference of longitude was computed by spherical trigonometry. It was for the last stage on the calculation that the *observed* azimuths were required.

In those days it was easy to get a very fair value for the local curvature of the meridian, but there were obvious difficulties in obtaining any accurate determinations of difference of longitude. It will probably be agreed that the system adopted was a good one. There was no accepted, or even approximately accurate, "figure of the earth," and in practice the officers of the Ordnance Survey, at the end of the eighteenth century, measured the curvature in two directions as they went along.

The One-Inch Map.—From 1791 onwards for the next thirty-three years the object of the Survey is definitely the production of a one-inch map of the United Kingdom. The one-inch scale was quite familiar to soldiers in those days, and, though the public was generally accustomed to smaller scales, there was, as a fact, a certain number of privately produced maps on the one-inch or larger scales available for general use. "In the last half of the eighteenth century a great number of county maps were published. Their issue may without much doubt be traced to the offer by the Society (the Royal Society of Arts) of a prize of £100 for the map of any county on the scale of one inch to the mile. In justification of this statement it may be said that, of the county maps mentioned by Gough in his great work on British topography, published in 1780, as being issued or in hand at that date, nearly all appear to be of a later date than 1762; and the same may be said of a list of inch maps . . . by Sir George Fordham, the great authority on this subject."* The earliest maps produced under this stimulus appear to be one of Dorsetshire, by Isaac Taylor, about which Gough states that it "is very faulty in the place names"; and one of Devonshire (1765) by Benjamin Donn, engraved by Jefferys. Donn received the £100 prize.

Other county maps, produced in response to the invitation of the Society of Arts, were those of Derbyshire (1767), Northumberland, Leicestershire, Somersetshire, Suffolk, Lancashire, Hampshire (1793), Sussex (1796), Oxfordshire, North Wales, Cardiganshire, Shropshire (1809). The maps of Hampshire and Sussex were produced by William Faden, who received £50 for the former and a gold medal for the latter. Faden also, in 1799, published a map of Kent, based on the triangulation, by permission of the Board of Ordnance. The Ordnance Survey owes a good deal to William Faden, for it was he who undertook the publication of the *Account of the Trigonometrical Survey of England and Wales*. The first volume is dated 1799, the second 1801, and the third 1811; the three volumes carry the history of the operations from 1784 to 1809. In the preface to the first volume it is stated that "Since the commencement of the operation . . . it has been always lamented that narratives of its progress should be confined to the volumes published by the Royal Society," and the Royal Society "readily acquiesced in Mr. Faden's proposal to" republish what was necessary from their translations. Faden is described as Geographer to His Majesty and to the Prince of Wales. He had a shop in Charing Cross. After Faden's death James Wyld, senior, became Geographer to the King; he was succeeded by his son, James Wyld, junior, and on the death of the latter the title was conferred on Edward Stanford, who started his business on 1st October, 1852, at 6, Charing Cross. Faden seems to have died about 1832.

* *Journal of the Royal Society of Arts*, Jan., 26th 1912. The writer is indebted to Mr. E. Heawood, of the Royal Geographical Society, for this reference.

John Cary received a gold medal in 1804 for his map of Cardiganshire. "The name of John Cary is associated for nearly three-quarters of a century with geographical publications . . . In the manufacture of globes he worked with his better-known brother, William Cary (1759–1825), who had a considerable reputation as an astronomical instrument maker, and in the cartographical work he was associated with others of his name."* In the opinion of Sir George Fordham "Cary probably found his inspiration in respect of the art of cartographical representation of surface details" in the sheets of the map of France by Cassini de Thury, of which the earliest is dated 1756. Most of Cary's county maps were on scales smaller than one-inch, but not all, for we have a map of Oxfordshire in 16 sheets, on the scale of two inches to one mile. Cary is best known as the publisher of the road-book called the *New Itinerary ; or an Accurate Delineation of the Great Roads* of England and Wales, which ran through 11 editions between 1778 and 1828.

Other county maps to be mentioned are those of Derbyshire by P. P. Burdett ; Leicestershire, Cheshire and Lancashire by J. Whyman ; Northumberland (1773) by Lieut. Armstrong, "said to have been a capital map," and others due to the same movement ; also Rocque's map of Shropshire, produced independently. Then there is the admirable 2-inch map of Wiltshire by Andrews and Dury, published in 1773. We are here concerned particularly with maps on scales of about one-inch to one mile. Of maps on smaller scales (atlas scales) there is a long history beginning with Christopher Saxton's Survey of the English counties, published in 1579, and following on with John Speed's Atlas in 1611.

One thing is common to all these county maps ; they were printed from engraved copper plates. In the earlier maps the hill features are shown in profile, as they are in the maps of ancient Egypt ; in the later maps they are shown by hachuring of various degrees of picturesqueness. The public was thus accustomed to engraved county maps, which had been gradually improved since the sixteenth century. The Ordnance Survey, at the end of the eighteenth century, had these various county maps, Cassini's series, and other foreign maps, to serve as models. The well-known atlas of Bacler D'Albe, Napoleon's Directeur du Dépôt de la Guerre, published at Milan in 1795, to illustrate the French campaign in Italy, is a good continental example of an engraved hachured map of the period ; the main features stand up very clearly and it is an easy map to read. The methods of copper-plate cartography reached a high standard.

Inaccuracy of the Old County Maps.—Picturesque and interesting as the old county maps are, they leave a good deal to be desired on

* *The Work of John Cary and his Successors.* Pamphlet by Sir George Fordham. 1924.

the score of accuracy. Errors of 10 per cent. or more may be found on Elizabethan maps; but similar errors exist even on the eighteenth-century maps. Thus, in the preface to the first volume of the *Account of the Survey*, dated 1799, we find the following remarks: "In the prosecution of the General Survey, frequent opportunities have manifested themselves of enabling us to discover the very erroneous state of our maps . . . by laying down on the maps of counties, particularly on Taylor's map of Dorsetshire, the distances of the intersected objects, as Dorchester Church from Nine Barrow Down, where an error of nearly three miles is detected in a distance of eighteen, an immediate proof is obtained of their great inaccuracy. Taylor's map of Dorchester (? Dorsetshire) is here specified, because we think it is the most erroneous of any we have examined; yet those of Devonshire and Kent may be considered as similar specimens of imperfect topography." It may be noted, by the way, that Taylor's map, described by Gough as "a capital Survey," failed to get the Society of Arts prize. The preface goes on to say that "It has been very justly expected by the public, that from the present undertaking they should derive the advantage of an improvement in the geography of their country, and possess some general map, published on the same principle with the *Carte de France*, a performance highly celebrated."

In 1791 the Copley Medal of the Royal Society was awarded to Major James Rennell for his geographical work in India. The President, Sir Joseph Banks, in his address on that occasion, compared Rennell's map of India with the county maps of England, which were then available: "I should rejoice could I say that Britons, fond as they are of being considered by surrounding nations as taking the lead in scientific improvements, could boast a general map of their island as well executed as Major Rennell's delineation of Bengal and Bahar: a tract of country considerably larger in extent than the whole of Great Britain and Ireland; but it would be injustice to the Major's industry were I not here to state that the districts he has perambulated and planned exceed, probably, in extent the whole tract of surveyed country to be found in the maps of the European kingdoms put together, while the accuracy of his particular surveys stands yet unrivalled by the most laborious performance of the best county maps this nation has hitherto been able to produce."*

We may sum up the matter thus: At the end of the eighteenth century there were many county maps, of comparatively recent date, on the scale of one inch to one mile, or on even larger scales. These maps were printed from engraved copper plates, the hill-features being shown by hachures. The engraving was good, and the maps were generally artistic productions. But the English

* *Major James Rennell.* Clements Markham. Cassell & Co. 1895

county maps had no pretensions to accuracy; they were inferior, in this respect, to Rennell's recent maps of Bengal, and their errors cried aloud for correction.

The Field-work of the One-inch Map.—In 1795 the Corps of Draughtsmen and Surveyors belonging to the "Drawing-room in the Tower," under Mr. Gardner, attended the trigonometrical operations in Kent. Mr. Dalby and Mr. Gardner used the new 18-inch theodolite for the fixing of secondary and intersected points on which to base the detail. No information is given us as to how the detail of the "interior survey" was mapped; but it appears to be almost certain that this interior, or detail survey, was carried out by compass and pacing, or cyclometer, and was executed on the 2-inch scale in the field. Although the plane-table had been known practically, in its modern form, for more than two hundred years, and although in certain parts of Great Britain, notably in the Down country, and in the mountains of Cumberland, Wales and Scotland, the plane-table is without rival as a surveying instrument for work on the one-inch and similar scales, it was never adopted by the Ordnance Survey.

The plane-table might have been most profitably used between 1795 and 1825, a period during which there was only the one-inch map to think of. The ignorance which prevailed as to the value of the plane-table lasted to a much later date. For instance, the Palestine Survey, which was begun in 1871, was carried out, as regards the detail, by means of the prismatic compass, and this in a country which is exceptionally suited to the plane-table. The explanation given is that "the N.C.O.s in Palestine were familiar with the compass and it is very handy in riding."* The writer remembers that, as late as 1897, the field training of the topographical section of the Ordnance Survey, which was intended for service abroad, was confined to the prismatic compass. However, for good or ill, the detail of the old one-inch map appears to have been surveyed inside the fixed trigonometrical points, by the compass. There was not room for much accumulation of error; and although such a procedure results in a "loose" Survey, the early sheets of the old one-inch map were, as regards accuracy, greatly superior to any previously existing maps of this country.

* *The Trigonometrical Survey of Palestine.* Major C. R. Conder, D.C.L., LL.D., R.E. R.E. Professional Papers. 1894.

(To be continued.)

REPORT ON THE INTERNATIONAL CEMENT CONGRESS.

April 22nd, 23rd, 24th, 1924.

By BREVET LIEUT.-COLONEL D. K. EDGAR, D.S.O., R.E.

THE International Cement Congress convened by the Institution of Structural Engineers assembled at the Congress Hall, Olympia, on April 22nd, 1924.

The morning was spent in inspecting the exhibits of the Building Exhibition then being held at Olympia, which contained too many interesting features to deal with in detail. After lunch the Congress reassembled and discussed papers placed before the assembly. The following is a brief *résumé* of the papers and discussions.

In the first paper, entitled "The modulus of density of concrete as a means of maintaining uniformity throughout," the author, Mr. Alfred S. Grunspan, B.SC., A.C.G.I., A.M.INST.C.E., points out that the density of concrete, particularly when it has to withstand hydrostatic pressure, is all-important to the engineer. To arrive at a standard of density the author has evolved a table, whereby, after measuring the voids in the sand and in the coarse material, and assuming that sufficient sand is used to fill in all the voids of the coarse material, then the granular volume of the cementitious material, represented by the cement mortar, divided by the volume of voids to be filled, represents the modulus of density.

To arrive at a uniform density throughout any large work it would be necessary to measure the voids in each consignment of sand and coarse material and so proportion the volumes used that the modulus of density remained constant. The author points out that engineers in the past used lime as an admixture to the cement in order to obtain a denser concrete; the addition of lime, however, means a reduction of strength of the concrete, although giving a denser mixture.

In concrete exposed to the action of sea-water the presence of calcium hydroxide is a source of weakness; any filler which combines with the lime set free when the cement sets and which produces a cementitious material instead of calcium hydroxide will therefore give not only a denser concrete but a stronger one. Trass or pozzuolana and also the proprietary material Novoid appear to possess the property of fixing the free lime, and give good results.*

* *Note.*—This property is also possessed by silicate of soda, which is discussed in a later paper.

In the discussion that followed, the difficulty in accurately measuring the voids in any aggregate was pointed out and the fact that the volume of the voids was not a true indication of the superficial area of the surface which had to be covered with cementitious material. The point which the author wished to make was that the proportions of the materials should be adjusted analytically rather than empirically, but it appears to the writer that the method of obtaining the densest possible mixture from given aggregates as described in "Notes on Cement and Concrete," Part I, S.M.E., 1923, page 24, is of more practical value than the analytical method of the author.

The second paper, on measurement of Air Supply to Rotary Kilns, was of more interest to the manufacturer than to the user of cements. It was pointed out, however, that the efficiency of the kiln depended on the air supply, and that the cost of manufacture and consequently the cost of the product, depended on the efficiency of the plant and that therefore all engineers should be interested in the methods of manufacture.

The discussion of the third paper was opened by Colonel H. Vaughan Kent, C.B., M.I.C.E., M.I.STRUCT.E., M.AM.SOC.C.E., on his paper, "Concrete Block Construction," and was replied to by Major W. H. Smith, M.I.STRUCT.E., who had also contributed a paper on Concrete Block Buildings. A lively debate ensued on the merits of slab construction *versus* block construction. In the past many concrete houses have been erected, and experience has shown that the following difficulties have to be overcome in small concrete houses. In the first place, to be economically erected the walls have to be comparatively thin; massive walls cannot be used. In thin walls, if a non-absorbent material is used, condensation takes place on the interior walls and the house is damp; if a porous material is used, moisture penetrates from the outside of the walls and the house is still damp. Rendering the exterior face of the wall is expensive and the rendered surface is liable to deteriorate and scale off. Concrete is usually a good conductor of heat, and a house with solid concrete walls is liable to be hot in summer and cold in winter. With concrete laid *in situ* it is difficult to mould hollows in thin walls and, unless different concrete mixtures are used for the exterior and interior faces, damp walls will result for the reasons given above.

Both Colonel Vaughan Kent and Major Smith claim to have overcome all the above defects, and also claim that concrete houses can be constructed which are cheaper, warmer and more comfortable than brick houses.

The Kent system of construction is one of slabs fixed to upright concrete pillars. The method of fixation is ingenious and provides an ample air space between the exterior and interior slabs. *Figs.* 1, 2 and 3 show the method of erection. P is the pillar cast with shoulders, against which the exterior slabs XS abut, at intervals

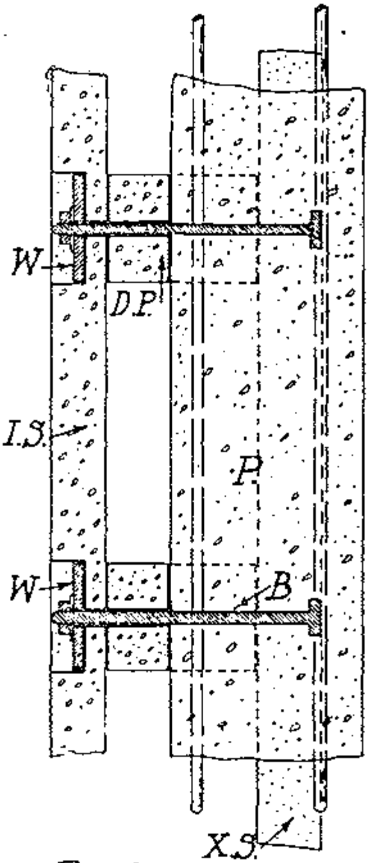

Fig. 2
(Section a·a.)

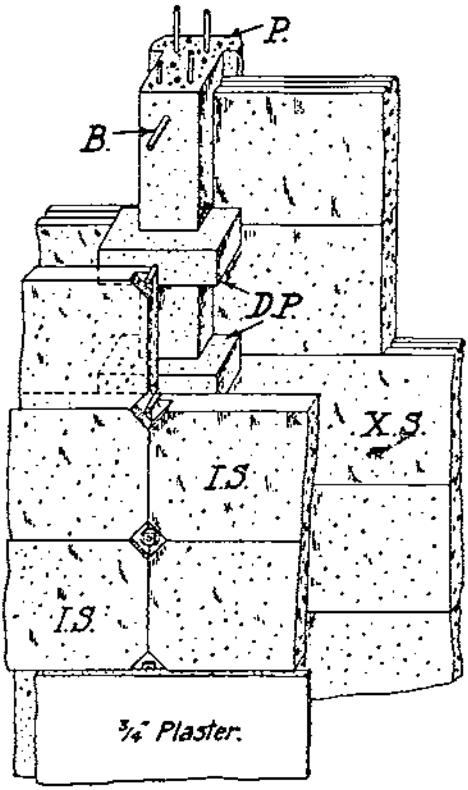

Fig. 3.

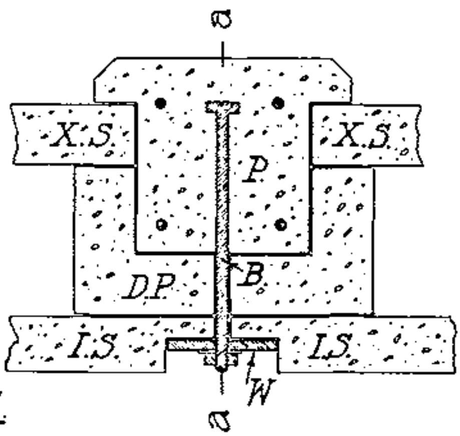

Fig. 1.

equal to the height of a slab, ½-in. iron bolts B are introduced into the pillar and project inwards in a horizontal direction. DP is a distance piece of damp-proof material which slips over the ½-in. bolts and secures the exterior slab. The interior slabs IS are secured against the distance-piece by means of a washer and nut screwed on to the ½-in. bolt, one washer engaging into corner rebates of four slabs which meet at the bolt. By tightening the nut both the interior and exterior slabs are securely fixed to the pillar. The interior face is plastered, thus concealing the nuts and washers. The exterior slabs are moulded with dense concrete to make them waterproof, whilst the interior slabs are of porous material to prevent condensation. As the distance-pieces are only a few inches wide, the wall cavity is continuous all round the house and may be used for containing service water and gas pipes. Door and window frames are fitted between pillars and are of such a size that they replace a certain number of slabs. Details for fixing roofs, floors, partition walls, etc., have all been worked out by Colonel Kent, and the system has proved perfectly feasible in practice. The advantages are that all units are precast and the erection is very rapid after moulding has been completed. The difficulties appear to be the accurate spacing of the ½-in. bolts in the pillars and the erection of the pillars truly vertical and at the correct intervals, as the margin of permissible error is small.

Major Smith's system consists of the use of triangular hollow concrete blocks, the base of the triangular blocks forming, alternately, the exterior or interior face of the wall. By varying the composition of the blocks, the exterior face of the wall may be made of damp-proof concrete, while the interior face may be made of porous material. The ample cavities in the blocks insulate the walls and save material. These blocks are manufactured in the "Trianco Portable Dual Pressure Double Toggle Machine," marketed by the Triangular Construction Company, Ltd., and claimed to be one of the most efficient block-making machines on the market. It is capable of turning out blocks of any shape and is not limited to the triangular blocks, which, however, can be moulded in this machine more efficiently than in any other. The triangular blocks give a good bond when laid and appear to overcome most of the disadvantages of concrete construction.

A paper contributed by Mr. L. A. Munro, B.A., F.I.C., on Silicate of Soda and Concrete with special reference to the treatment of roads, floors, etc., for the prevention of abrasion and dusting, was of great interest. Messrs. Brunner, Mond and Co., Ltd., have investigated this question very thoroughly, and have placed on the market a particular grade of silicate of soda known as P.84 grade, which they make for the purpose of treating concrete.

The method of application of silicate of soda to concrete surfaces is as follows.

Although concrete can be made in such a way as to be almost impervious to water, most concrete surfaces in practice are distinctly porous, and it is only by very careful tamping that a layer of wet cement can be brought to the surface to form an impervious skin.

To get the best results from the silicate treatment it is essential that the concrete should be reasonably clean, free from grease, laitance, etc., and should be as dry as possible. The whole process depends on the penetration of the concrete by the silicate of soda. The solution of silicate of soda should be quite dilute, and there is no doubt that many failures have been due to this precaution being neglected. A solution of silicate of soda differs from a solution of, say, common salt, in that the particles of silicate of soda are not really dissolved at all in the ordinary sense of the word, but exist in a state of extremely fine division, generally known as a colloidal solution. Unless the silicate of soda is diluted with several times its volume of water, it will not penetrate into the concrete to the necessary extent.

To get the best results, the concrete should be sprayed with the diluted silicate of soda solution and the latter worked backwards and forwards over the concrete with a soft broom. A hard brush should on no account be used, as particles of sand and cement may be brushed up from the concrete to form a mud, as it were. Most types of concrete will absorb a dilute silicate solution quite rapidly. When the surface has been allowed to dry the process should be repeated, and, although in most cases three such treatments will suffice, low-grade concrete will absorb more than three coats of silicate of soda, and the treatment in such cases should be continued until the concrete ceases to absorb the solution readily. The treatment does not alter the appearance of the surface to any great extent, nor does it render the concrete slippery; in fact, the original rough finish is preserved.

It should be understood that the binding action obtained does not depend upon the adhesive properties of the silicate of soda itself, but upon the products of the reaction which takes place between the silicate and the lime and calcium silicates in the cement.

Various uses of silicate of soda were enumerated as follows:

On factory floors to prevent abrasion and dust. On concrete roads for the same purpose. In this connection Mr. A. L. Thompson, M.R.S.I., M.INST.M. & CY.E., Joint Burgh Surveyor of Motherwell and Wishaw, writing in the "Contractors' Record and Municipal Engineering" of January 16th, 1924, states—"To sum up, on whatever count it may be taken, the treatment of a concrete road with silicates is decidedly advantageous, giving an increased life, raising the resistance to abrasion and disintegration and reducing the formation of dust. The surface is not rendered slippery, nor is it rendered unsuitable for being skinned over with tar. Finally, the cost is reasonable, and is justified by the results secured, particularly in the case of the all-concrete road."

On concrete subjected to the action of sea water, the silicate forms a dense skin on the surface and prevents abrasion and the penetration of sea water. On concrete subjected to the action of oil the treatment of the surface with silicate of soda gives good results.

Flat concrete roofs can be rendered waterproof by means of silicate of soda.

The opinion of the Congress was that all these claims should be admitted and that silicate of soda will be extremely helpful under certain circumstances to the engineer.

Messrs. Brunner, Mond and Co. have an abrasion machine demonstrating at the British Empire Exhibition at their stand Section A 55B.

Mr. H. K. G. Bamber, M.I.STRUCT.E., A.INST.C.E., etc., read a paper on "Some Disturbing Factors in Cement Setting." Unless subjected to some treatment during manufacture, all rotary kiln cements would be "flash" setting; various methods are adopted to retard the setting, the usual method being to add gypsum during the grinding process. Although the manufacturer can accurately determine the setting time when the cement leaves the factory, he cannot control action due to long storage or exposure to damp or great heat. After prolonged storage the setting time is usually quickened and therefore it is of importance that the structural engineer should test each batch of stored cement for setting time in order to ensure that he will have sufficient time for mixing and placing before setting commences.

On the other hand cement exposed to the atmosphere for long periods may become so slow setting as to be almost inert.

Aggregates may have an influence on the setting of cements. The author cites a case where an aggregate which appeared under ordinary examination to be suitable in all respects, turned out to be useless with one high-grade Portland cement, and satisfactory with another; both being well-known brands of the highest quality, testing far in excess of the British Standard Specification requirements. Chemical and physical examination failed to detect the disturbing element which, while permitting one cement to set satisfactorily, absolutely destroyed the setting properties of the other, a change of aggregate resulting in both cements being satisfactory. Such an experience is an indication to the structural engineer of the importance of thorough investigation into the character of concrete aggregates proposed to be used before actual work is commenced. It is always advisable to test the aggregates to be employed, especially if not obtained from recognized and approved sources, with the brand of cement intended to be used.

At all times the best results are likely to be obtained by the use of slow-setting cement. It is a fallacy to suppose that greater strength is obtained at early dates by the use of moderately quick-setting cements, which are always more liable to be injured if the work is not carried out with the greatest expedition.

In conclusion, the greatest safeguard which the structural engineer possesses is to obtain slow-setting cement from absolutely reliable sources, and, when it comes into his possession or under his supervision, to protect it with all reasonable care against atmospheric influences, regulating his constructional operations so that the time taken for their complete performance is not extended beyond the time when the cement commences to set, which may vary from day to day, depending upon the temperature and hygroscopic condition of the atmosphere.

The paper on "Portland Cement in Sea Water," by F. E. Wentworth-Shields, O.B.E., M.INST.C.E., is of such interest that it is produced below in full.

"The Committee of the Institution of Civil Engineers appointed to investigate the deterioration of structures exposed to the action of sea water reported *inter alia* in 1920, that 'it is taken by most engineers as definitely determined that properly constituted Portland cement concrete, employed as it should be, may be relied upon to produce sound and permanent work.'

This statement will probably meet with general agreement. But it must not be forgotten that a great many cases have occurred of Portland cement structures suffering considerable damage and deterioration in sea water, and that such structures have been for the most part built with what would be called good materials and careful workmanship. So that, even if we accept the Civil Engineers' conclusion, we are faced with the important question, when is concrete 'properly constituted' for maritime structures, and how should it be employed?

Instances of Failures.

Though fortunately the successes of concrete in sea water have been more numerous than the failures, there have probably been a fair number of cases of deterioration that most of us have heard nothing about. Some, however, have been carefully investigated and the results published

Mr. J. Mitchell Moncrieff, C.B.E., M.INST.C.E., the well-known harbour engineer, quotes a remarkable case in his paper read at the recent International Navigation Congress. The scene was a graving dock built on the Tyne in 1892. It was apparent from the first that the concrete walls were not watertight, as a number of small leaks appeared at high tide. After a few years it was found that the entrance walls were steadily growing in height, and that gradually the anchor rings, which secured the top of the gates, rose until they were almost above the gates: more than once these anchor rings had to be lowered down. In fact, the west wall, which originally was about 27 ft. from floor to cope, actually grew in height to the extent of $6\frac{3}{8}$ ins. in 22 years. The concrete, though originally good and proportioned 1, $1\frac{1}{2}$, $4\frac{1}{2}$, with a richer mixture round the stone quoins, was found to be in poor condition, with the pores filled with a slimy material of no cementitious value. Obviously this was a case where the sea water percolating through the concrete walls into the dry dock attacked the cement, with consequent swelling and softening of the originally hard concrete. Sometimes cases occur where softening of the concrete takes place, but without swelling. In almost all cases of deterioration it is found that the sea water is being forced through the concrete owing to a difference of water-level between the two faces of the structure. It often happens with a well-made concrete that this action is gradually lessened as time goes on by the fact that the white substance formed by the chemical actions chokes the pores of the concrete and thus prevents more sea water passing through it, and arrests the decay. This is what probably takes place in all rich and well proportioned concretes in sea water.

Chemical Effect of Sea Water upon Cement.

A very large amount of research work has been carried out, particularly in France and Germany, to determine the exact nature of the chemical effect of sea water upon Portland cement, and also to ascertain how that effect can be rendered harmless. For several years the injurious action of sea water was ascribed to the presence of magnesia, because that element was found in the soft white material formed as a result of that action. But it is now agreed that the trouble is due to sulphuric acid present in sea water in the form of soluble sulphates.

These sulphates combine with the lime which happens to be combined in the cement, or which is freed during the process of setting, to form sulphate of lime. The latter compound combines with the aluminate of lime in the cement and with water to form a double compound which is bulky and non-cementitious. This is the principal chemical action involved (though not the only one) when sea water or other waters containing sulphates disintegrate concretes and mortars made with Portland cement.

Deterioration from Physical Causes.

This unfriendly action of sea water upon cement concrete is, of course, greatly aggravated in cases where the structure is exposed to frost and ice, or to the force of heavy waves, or to the attrition of travelling shingle or sand. Frost is probably the worst enemy, and concrete which is exposed to tidal waters in arctic regions has to be made exceptionally well to prevent its being disintegrated by the alternate exposure to water and air at low temperatures.

Prevention of Sea Action by Chemical Devices.

The experts who have studied the question of how to prevent the decomposition of cement concrete and mortars by sea water might be roughly divided into two opposite camps, namely, those who have sought to protect the cement by altering its chemical composition or adding material which should affect the chemical actions involved, and, on the other hand, those who have sought to protect the concrete by preventing the admission of the sea water into the bulk of the material; in other words, by making it highly impermeable.

As regards the chemical school, the earliest and perhaps the most famous was the great French chemist Vicat, although a very large amount of valuable research has been carried out since his time, particularly in France and Germany. Vicat first explained the chemical action of sea water on cement and laid down rules for its composition in order to secure its stability. He pointed out that lime was the most vulnerable ingredient in cement, and that there should be only a sufficient quantity present to combine with the other salts. Since his time many attempts have been made to vary the ingredients so as to produce a cement which would be more permanent. It seems to be generally assumed to-day that cement which complies with the standard specifications of Great Britain and other countries is suitable for use in sea water, but this view is sometimes contested.

Several materials have been suggested as additions to Portland cement for the purpose of increasing its chemical stability in sea water. Of these by far the best known and most used is pozzuolana or trass, which is much favoured by harbour engineers in Europe. It has not been very popular in Great Britain, although Smeaton used it in conjunction with lime to make his mortar for the Eddystone Lighthouse in 1756. Apparently its virtue consists in the fact that it combines with the lime which is freed during the process of setting of Portland cement, and thus prevents the formation of the dangerous sulphate of lime. Although trass occurs in many different places, it is by no means equally suitable for this purpose. A large number of experiments have been carried out at various times and in various countries to show the value of this material. To the general reader they are not always very convincing; but the fact remains that most of the engineers and chemists who have made these experiments are strong advocates of its use. It would seem that other materials, such as blast furnace slag, have a similar power of combining with free lime; and it may be that our latest standard specification will encourage the manufacture of a material which will prove to have great durability in marine structures.

A cement which promises to have high powers of resistance to sea action is 'Ciment Fondu,' during the setting of which it is said that no free lime is formed. At all events tests by M. Feret and others seem to show that sulphate of lime has no deleterious effect whatever upon it. Its quick-hardening properties and great strength are beginning to be fairly well known, and if it can be shown that its good qualities can always be relied upon, and that the makers can supply it in sufficient quantity and 'up to sample,' it is likely to become popular among harbour engineers in spite of its high cost.

PREVENTION OF SEA ACTION BY INCREASING IMPERMEABILITY.

There are a large number of experts who consider that modern Portland cement will make a concrete which is very durable in sea water, provided the concrete be made in such a way as to offer a high resistance to the passage of the water into its mass. If the concrete is highly impermeable it is claimed that what little sea water does penetrate can do no harm, as the solid products of the chemical action involved tend to choke up the pores of the concrete and make it the more impermeable. Whereas in the case of a porous concrete the products get washed out, leaving fresh surfaces to be attacked by a fresh supply of sea water.

It is well to bear in mind that there is no such thing as an absolutely impermeable concrete. All one can hope to do is to reduce the size and proportion of voids and thus to make the resistance to the passage of sea water as great as possible. But this is by no means as easy as it sounds, and although some fine research work has been carried out on the subject, particularly in France and America, the matter calls for still further investigation. We have, however, at least certain conclusions on the matter. First, the mixture must be rich in cement. Any concrete containing mortar poorer than 1·2 is likely to be useless in cases where sea action is feared. The stones and sand should be well graded, *i.e.*, they should vary in size from coarse to fine, and at all costs a large proportion of fine sand is to be avoided. The concrete should be well mixed by a good machine. The proportion of water should be carefully determined, as either an excess or defect of water when gauging is liable to produce porous concrete. Pouring concrete under water should be avoided, as concrete moulded in this way is of doubtful quality and very permeable.

It has been suggested that denser concretes can be produced by special cements, but the writer has met with no experiments which are conclusive on this point. Again, many materials are on the market for which it is claimed that, if mixed with concrete or mortar, they greatly decrease its permeability. An elaborate investigation was made into a number of such materials by the American Bureau of

Standards in 1911. It tended to show that the addition of such materials was of little use in the case of rich mixtures and that some of them decreased the strength of the mortar.

We are still in want of a really good test for impermeability. Several methods have been used, such as determining the actual volumes of materials used in a cubic unit of concrete, and hence the proportion of voids, or again, measuring the quantity of water which can be forced into or through a slab of known dimensions in a unit of time. But these methods are slow, and do not tell exactly what is wanted. If we could test for permeability as easily as we can test for strength, and compare that test with a standard, it would not be long before we should all be able to use our various materials to make a concrete which would offer the greatest possible resistance to the destructive action of sea water."

Three papers concerning the Manufacture of Portland Cement and Research were contributed, but as these were not of great interest to the structural engineer they may be passed over.

One remark by Mr. Thaddeus Merriman, Chief Engineer Board of Water Supply, City of New York, is of interest. He states that, notwithstanding the great improvements and developments which have taken place recently in the methods of manufacture, there has been no substantial change in the inherent characteristics of the cement itself since it was first produced. No new cements have been announced until quite recently, as in the case of those based on a high alumina content. It is a surprising commentary that in such an important field of endeavour so relatively little positive advance in definite and specific knowledge should have been made. It is inevitable that a better cement will appear and displace that which now dominates the markets of the world. The natural cement of 1890 gave way to the Portland cement of to-day. In like manner will Portland cement yield its high position to some yet unknown successor? The natural laws of progress and development are not to be denied.

In his paper on Structural Steelwork Reinforced with Concrete, Mr. Ewart S. Andrews, B.SC., M.I.STRUCT.E., A.M.INST.C.E., drew attention to the results of experimental tests carried out in the United States and in Canada on the strength of structural steel columns and beams encased in concrete. In each case the strength was increased from 50 to 80 per cent. over that of the plain steel members. Although admittedly this is not an economical method of using steel in reinforced concrete, it offers many advantages in rapid construction, and in the case of a shortage of steel sections allows weaker members to be used to carry the required load. If in a steel structure the steel members are made sufficiently strong to support the dead weight of the structure and the necessary centering, the skeleton can be in the process of erection while the lower portions are being concreted. The centering can be supported on the existing steel work and there is no waste of time in setting the reinforcement bars. Economies can also be effected in the centering, as it can be removed at an earlier date, the steel member taking the weight of the concrete which is not subjected to undue stresses before properly set.

Three papers on aluminous cements were presented; the one by M. T. J. Gueritte, B.SC., M.S.I.C.F., M.I.STRUCT.E., gave some interesting results.

The following results of tests give a good idea of the strengths obtained by use of good aluminous cement. These tests were carried out in many different testing laboratories, and the personal equation of individual tests thereby eliminated from the results.

TABLE 1.

Neat Cement.—In lbs. per square in.

Time.	1 day.	2 days.	3 days.	7 days.	28 days.	12 wks.
Tension:						
Average ...	627	833	877	895	1027	1360
Maximum ...	730	981	915	1033	1060	1382
Compression:						
Average ...	6733	7739	9340	9596	12125	
Maximum ...	7037	9766	10560	11586	13700	
Ratio between compression and tension	10·74	9·29	10·65	10·72	11·8	

TABLE 2.

Cement and Sand.—1 : 3. In lbs. per square in.

Time.	1 day.	2 days.	3 days.	7 days.	28 days.	12 wks.
Tension:						
Average	331	427	455	518	551	632
Maximum ...	412	526	560	593	692	691
Compression:						
Average	3528	5166	5456	5893	6671	8900
Maximum ...	5000	5230	6870	6150	7300	9008
Ratio between compression and tension	10·65	12·09	11·99	11·37	12·10	14·08

Tests over long periods of time are now available, carried out at the Laboratoire National des Ponts et Chaussées, Paris.

The proportions used were 1 cement, 1 sand, 3 gravel (by volume) and the crushing strengths in lbs. per square inch were as follows :—

3 days	6013 lbs. per square inch
7 days	6212 ,, ,, ,, ,,
28 days	7690 ,, ,, ,, ,,
3 months	8345 ,, ,, ,, ,,
6 months	8900 ,, ,, ,, ,,
1 year	9354 ,, ,, ,, ,,
2 years	9482 ,, ,, ,, ,,
5 years	9695 ,, ,, ,, ,,

It was pointed out that the working stresses allowed for Portland cement concrete by the L.C.C. rules for 4 : 2 : 1 concrete is 600 lbs. per sq. inch, but the author considered that working stresses from 1,300 to 1,400 lbs. per sq. inch for aluminous cement concrete of the same proportions would give the same factor of safety.

Stress was laid on the necessity for careful mixing, laying and curing of aluminous cement concrete, and the following rules should be followed when using it :—

(1) A clean concrete mixer, or mixing platform, and conveying skips, landing boards, shovels, rammers, etc., entirely free from Portland cement or dirt.

(2) A thorough intimate mixing in the mixer or on the mixing platform. In practice about twice (some people even say thrice) as much mixing as for Portland cement, this owing probably to the very great fineness to which Bauxite cement is ground. Too great importance cannot be attached to this point.

(3) Sand and aggregate of excellent quality, very clean and well graded. A slight excess of sand seems to be better than a deficiency : sharp sand gives decidedly better results than fine or soft sand.

(4) The concrete should be mixed just slightly wetter than Portland concrete. With aggregate and sand, containing a normal amount of moisture, good results have been obtained by using from 33 to 35 gallons of water for 1 cubic yard of $\frac{3}{4}$-in. gravel, $13\frac{1}{2}$ cubic feet of sand and $6\frac{3}{4}$ cubic feet of cement. An excess of water has a much more lowering effect upon the strength of aluminous concrete than on that of Portland concrete. (For figures on that point, see the author's remarks in the *Institution of Structural Engineers' Journal*, September, 1923, page 266, column 2.) Trouble has arisen occasionally because new users tried to secure the same plas-

ticity as with Portland cement, without taking greater pains in ramming, by using an excess of water. It is not water that is required so much as thorough mixing and thorough ramming.

(5) Water thoroughly the shuttering and steel with fresh water before depositing the concrete. But, as water washes away the cement easily from the aggregate and sand, take care: (*a*) Not to leave water in the mould; (*b*) to use fairly water-tight shuttering; (*c*) to prevent external water from coming in touch with the concrete until the latter has "set off."

(6) Careful and intense ramming during placing of concrete. This again is extremely important.

(7) Immediately after the concrete "sets off," water the concrete freely at frequent intervals for a few hours, and keep on watering from time to time for a few days, or cover the concrete with a layer of sand kept wet, so that the concrete remains moist. This will prevent the water added during mixing, and which is necessary for the purpose of hydration, from evaporating, first through natural evaporation, and later (from the fifth hour onward) owing to the heat generated during the setting. Such heat will also be reduced thereby.

Aluminous cement concrete is immune from attacks by sea water or sulphurous waters. Its behaviour is more satisfactory than Portland cement concrete when exposed to action of oils. Petroleum oils and tar oils have no effect on it, and under the action of vegetable oils it will remain intact under circumstances which will cause Portland cement concrete to disintegrate.

From a military point of view the great advantages of aluminous cements appear to be, firstly, the long quiescent period after gauging with water before the initial set takes place; this period is from 3 to 4 hours, and would enable concrete to be mixed under good supervision in rear of the trenches and carried forward and placed in front line works without deterioration. The second advantage is its rapid gain of strength; works constructed one day can be taken into use the day following, if essential. Still another advantage is the fact that aluminous cements can be used in frosty weather. Provided that the sand and aggregate used are above 32° F., the heat developed in the setting of aluminous cement will raise the temperature of the mass of concrete sufficiently to prevent any freezing even in very severe weather.

The chief difficulty at present with aluminous cements is to find sufficient raw material, "Bauxite," to enable the manufacturers to meet the ever-increasing demand.

The second day of the Congress was occupied with a visit to the Kent Portland Cement Works near Dartford. This plant is one of the most up-to-date plants in England, with an output of 4,500 tons a week of Portland cement.

The delegates were the guests of the Directors of the Associated Portland Cement Manufacturers, Limited, and were conveyed from London Bridge to the works in a launch. An incident on the journey down the river impressed on the delegates the great demand for Portland Cement in this country. In order to replace a broken valve on a wireless installation on board the steam launch, a vessel unloading a cargo in the river was approached; this vessel proved to be an Italian ship offloading a cargo of Italian cement for use in this country, much to the amusement of the guests of the directors of the A.P.C.M.

It is not considered necessary to describe the works visited, as a description of modern cement works has appeared in the March number of the *R.E. Journal*, and although there were a few differences in the detail of the processes, the general principles were the same. One was very much impressed by the small number of men employed on the works, all materials being handled automatically as far as possible. To produce 4,500 tons of cement weekly, about 9,000 tons of raw material has to be handled and the best organization is required to do this efficiently and economically.

On the third day the delegates were the guests of the Institution of Structural Engineers at the British Empire Exhibition. Here one saw the latest examples of reinforced concrete structural engineering in the Stadium and the Palaces of Engineering and Industry. These buildings, however, have frequently been described in many engineering journals, and it is unnecessary to enter into a detailed description of them here.

A PLEA FOR A STRONG ANTI-AIRCRAFT DEFENCE.

By LIEUT.-COLONEL D. M. F. HOYSTED, D.S.O., R.E.

IT is a trite opinion, almost universally accepted, that the opening move in a future war between great powers will begin with a surprise blow dealt from the air with great concentration. In its application to these islands this opening attack will have a twofold object. Firstly, that of putting our naval and aerial forces out of commission before they can leave their stations; and secondly, of terrorizing the inhabitants as well as the defenders of the invaded territory. The last war was a crucial test of nerve, but the next will be far more trying.

The controversy as to the relative merits of aircraft and surface ships on the open sea is being thoroughly tested by the United States as well as ourselves; the ultimate outcome is still obscure. Aircraft enthusiasts declare that they have driven the Navy from the surface, while the Navy denies the aspersion with no little warmth. Be the result as it may, the initial process mentioned above is now generally accepted as a probability. Bombing planes will be able to bomb naval defences and ships in harbour as easily as a battleship could shell them, while the faster type of plane will be used in the place of cruisers and destroyers for minor raids and attacks on shipping or unfortified towns and factories. These bombing planes will be protected by fighters and will be able to operate from a base some 250 miles from their objective. The day of the bombing airship is practically over, as such craft are too uncertain and unwieldy for use in large concentrations: the Allies backed the winning horse before 1914 and the German Zeppelin was beaten before the war began.

So far, the starting-point for such an attack has been a land base, and if a line were drawn parallel to the eastern and southern coastline of these islands and at a distance of 250 miles, it would enclose any land area from which it would be possible to deliver the attack. More definite information as to the actual position of such a base will be gathered from the political situation of the moment.

So much for the land base, but what of the sea base? For aircraft can operate as easily over water as over land. So that in the future the blow may originate from either a land base or a sea base, or both, according to its aim and the situation of the objective. As a naval power it behoves us to consider the possibilities to which we might at any time be open.

Let us think for a moment of the possibilities of a temporary base on the water. Article VII of the Agreement for Limitation of Armaments lays down a total tonnage for aircraft carriers for the British Empire of 135,000 tons ; United States 135,000 tons, Japan 81,000 tons, France 60,000 tons, Italy 60,000 tons. Moreover, no aircraft carrier may exceed 27,000 tons displacement. The gun-power of an aircraft carrier is limited, though the number of anti-aircraft guns is unlimited. Our aircraft carriers have a capacity of 25 planes for 10,000 tons of displacement, or two and a half per 1,000 tons. Probably, in future ships, the ratio will rise to three planes per 1,000 tons of displacement, if not more. Even at that percentage, the tonnage allowed us by the Agreement could produce 405 aeroplanes on properly equipped carriers at any given moment at any desired spot in the Seven Seas.

The aircraft carrier is provided with facilities for both launching and landing. The former requirement is met by catapults and other devices, the latter by shock and momentum absorbers, such as nets, springs or rubber ropes on a specially prepared deck. Such aircraft could probably be launched into the air at the rate of about one every five minutes from each ship. From nine carriers, each of 15,000 tons, making up the total displacement at present authorized for the United States, nine aeroplanes could take wing every five minutes, or, say, one hundred an hour for four hours. In addition to the authorized aircraft carriers, an attacking sea base would no doubt include an establishment of spare planes on special store tender ships, so as to be in a position to make up for wastage. There is no limit to the number of these tenders which can carry planes of all sorts.

So far we have only visualized a law-abiding foe who feels himself bound by the international instrument above-mentioned. But he will not necessarily allow himself to be fettered at the outset by a written covenant merely because he has solemnly signed on his honour to abide by it. He can quote a precedent. He will realize that he must meet a brave and efficient association of nations and will naturally wait till he has perfected in secret all the requirements that a scientifically trained staff can foresee. For instance, large ocean-going submarine seaplane carriers are no more fantastic, than the prophetic *Nautilus* and *Clipper of the Clouds* described by Jules Verne so many years before their time.

In the past, successful surprise raids were more easily carried out from the sea than from the land, because preparation could be concealed and traces destroyed : how much more so will they be possible by air ?

Previous to 1914 a great attack on the United Kingdom must have been preceded by superiority at sea, temporary and local though it might be; even Napoleon conceded this point. Under present conditions, as the radius of efficiency of aircraft increases, great superiority in the air will be advantage enough, and it will be much cheaper to obtain. In the day of hostile superiority in the air and in the face of constant attack from ever-changing bases, the concentration of the Grand Fleet at Scapa Flow for such a length of time would be impossible, and even land mobilization would be greatly disorganized.

This threat of a smothering offensive from the clouds is so imperative and conclusive as to warrant the greatest efforts for the provision of men, money and material to ensure an adequate defence against it by the time it reaches its danger-point. Our counter-effort must be built upon efficient information and a rightly-conceived defensive power. By the nature of things the invention of the offensive weapon must needs precede the design of the countervailing system of defence. The sword preceded the shield. An adequate defence to counter any process of attack will always be produced eventually. The sole question for the defence is, to speed up the new invention so that the period during which that special engine of attack can reign supreme may be reduced to a minimum.

The defence against aerial attack at present consists of aircraft, searchlights, guns on special mountings and sound locators, not forgetting electrical communications and camouflage. There are several other possibilities in the future which will be developed in due course as surely as was the shield and the A.A. gun. At present electrical communications and sound locators must supply the requisite information and the guns, searchlights and aircraft the efficient defence. Sound locators will doubtless become more sensitive and accurate and their intimate connection with the searching beam will become automatic and assured, while gunfire will be more accurate and intense.

But one of the great lessons which the warfare of the past should have taught us regarding warfare of the future, embraces the fact that if the defence at the outset of hostilities does not hold up the attack, the attack will overwhelm the defence: there is no possibility of stalemate in the air. As a nation we seem to have been consistently unprepared for our wars. The sea has been our first defence, and, with our "standing luck" or our national character, it has always enabled us to make up for unpreparedness, so far; but——?

If there should be such an attack on the Empire, where will the blow fall? An overwhelming attempt on either Canada, Australia or any other outlying member of the family, would certainly have but the effect of sending such a thrill through the others as would solely result in cementing them more firmly together and bracing up their spirits to fight it out to the last man and the last shilling. To obtain the best strategic result, the blow should fall not only on these islands, but on the southern portions of Great Britain, the centre of the web. Naturally, therefore, the major part of the defences of the Empire must be based upon Great Britain. The principal nerve centres to be defended from aerial attack are the large harbours and anchorages, barracks, ammunition depôts, the factories of warlike stores and the great cities and towns of England where Bolshevik upheaval might be hoped for by the enemy.

Aerial attacks on inland objectives will generally be carried out in formation by night. Formation flying is imperative in order that the units may not foul each other, especially in a large concentration, and that they may be able to keep up the necessary rain of bombs on the required target. The approach of a formation by night is always made along some route which may be easily picked up in the dark, and which will present some definite and recognizable landmarks, such as the edge of sea-shores or lakes, a river, railway-line or main road.

Though the best defence against aircraft is furnished by aircraft, the other defensive elements on the ground have much the same effect as field fortifications in a land war of movement. In addition to the actual losses they cause, they render it possible to concentrate the main force at the point where it can produce the most telling result. As barbed wire provides the quickest and most effective means of denying ground to a land enemy, so aerial impediments have afforded the most effective way, so far, of denying certain avenues of approach by night to hostile air-raiders. They have one great advantage over barbed wire. They are not immovably fixed to their site, but can be moved about as required so that they combine the element of surprise which is so harassing to the airman's nerves. Other means are also in course of production. In this manner the most probable lines of approach to a target such as has been enumerated can be made extremely difficult by raising across it some such obstruction. For if a flying formation is once broken up at night, it loses at once its greatest asset for successful service, if not its actual existence.

In the past an attacking navy had the power of suddenly concentrating a superiority of gun-fire against its objective and for this reason coast fortifications had to be scattered so as to be ready to take up the challenge instantly wherever it might be flung, and to hold the line till reserves could be brought up to neutralize the superiority due to surprise. In the future the attacking air force will have similar power, and therefore, for a like reason, anti-aircraft defences must be dispersed and in position round the key-points, as the period of warning will be shorter than ever. Successful raids would otherwise be the rule and not the exception.

But a strong enough anti-aircraft defence would confound the tactics of the enemy by leaving the active air squadrons free to defeat him strategically. Even if the defender's air force is strong, compared to that of the opponent, an adequate anti-aircraft defence will ensure economy of force and enable the defender's active air units to be used to the best advantage irrespective of the attack. But when the defender's air force is weak, a supreme anti-aircraft defence is an imperative necessity as an insurance against annihilation.

In the period before the last war, our degree of necessary preparedness was assumed to be less than that of a great continental power because of our insular position and the value of sea power. Now the difference, as far as aerial warfare is concerned, is entirely eliminated and we stand exactly the same danger from an overwhelming lightning stroke as did our allies of 1914. We should, therefore, see that the training and equipment of our anti-aircraft measures shall be the most efficient in the world, so that, if called upon in the future, our defence may prove itself as potent as before. To set the foundation stone to this, it is necessary to plan in detail our anti-aircraft policy and the positions of all its component parts. But it is only by completion of at least one entire section of the defences in every detail that the test for the ultimate limit of efficiency can be applied to it, so as to find the weakness and enable experts to work out the remedy.

Whenever a new means of warfare has been produced, a certain period of time must necessarily elapse before the best means of co-operation with the other arms can be worked out to a satisfactory conclusion. How will it affect strategy or tactics? What modifications will it necessitate for other branches or services? What changes of establishment will it induce?

These vital questions can only be answered by selecting a certain important area for experimental purposes and then by working out the application and technique of the means now coming to fruition. First, the application of the ever-true principles of strategy in making the estimate, *i.e.*, the objective, the difficulties to be overcome, the resources at our disposal and the plan, and when that has been completed on the ground, the application of the breaking test.

THE DECISION TO DEFEND KUT-EL-AMARAH.

By MAJOR E. W. C. SANDES, D.S.O., M.C., R.E.

A SMALL boat, with a picked crew and an expert steersman, once put to sea in fine but threatening weather. She was safely launched, and rode undamaged through several lines of breakers, being handled with daring and skill, so that at last only one line foamed and spouted ahead of her. But the tide was already on the turn, and a storm was brewing, so the steersman hesitated to make the attempt which would bring him to the open sea. In the end he made a dash for the last line of breakers, hoping to get through at the first attempt and relying on the proved courage and grit of his men, but the waves checked the boat, and the incoming tide gradually brought her to a standstill. The exhausted crew battled furiously to make headway. Two men were swept overboard, and the boat was almost swamped and began to leak, so the steersman decided to make for harbour. He managed to turn between two waves and ran for home. The storm roared behind him and his boat was sinking, but he saw a sandbank and grounded her under its lee, intending to rest his crew and repair the boat while the storm lasted, and then to try again. He forgot the tide. It rose slowly, and finally engulfed him and his men within sight of their friends on shore, many of whom perished in attempts to reach the castaways.

This allegory represents, in some ways, the case of the late General Sir Charles Townshend and his force in the attempt to capture Baghdad in 1916, and his retreat to, and surrender at, Kut-el-Amarah. The 6th Indian Division was a highly trained force, and its commander a skilful strategist and tactician who had the complete confidence of his men. The boat was launched at Basra, she forced a passage through the breakers at Kurna and again at Kut, and her commander hesitated before the waves below Baghdad but decided to make the attempt. The tide of Turkish reinforcements from the north checked his small craft, and, with a reduced and exhausted crew, he managed to turn his leaking boat and reach the island of Kut. There the tide of the enemy gradually overwhelmed him within a few miles of the relief force which battled so desperately to reach him through the stormy seas which separated them. The allegory fails in one respect, in that General Townshend's idea in remaining in Kut was not only to rest and save his men but to check the advancing foe; but, just as King Canute found that a tide cannot be checked, so Townshend found that the enemy encircled him and soon passed far beyond the limits which he had anticipated when he halted.

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It was in November, 1915, that the 6th Indian Division, with the 30th Brigade and a few other attached troops, gained a partial success over the Turks at Ctesiphon. The Turks, however, were strongly reinforced during and after the fight, and the British force, under Townshend, suffered such casualties that it was compelled to retire a distance of 100 miles to Kut-el-Amarah, pursued by large bodies of the enemy which had arrived from Erzerum and elsewhere. General Townshend's force of about 10,000 men, including roughly 6,000 infantry, was harassed in the retreat by the advanced guard of the Turkish army under Nur-ed-din Pasha, and that advanced guard was superior to it in numbers, and even in armament. The Turkish force was composed of the best Anatolian troops, elated by the retreat of the hitherto victorious British, and guided by the advice and experience of a large staff of German officers. The British, nevertheless, defeated the Turkish advanced guard at Ummal Tabul during the retreat, and thus enabled most of their shipping to reach Kut. This action checked the enemy sufficiently to give Townshend a few days at Kut, prior to the arrival of the enemy, in which to begin to entrench.

The troops, however, were terribly exhausted—so exhausted that, on reaching Kut on the 3rd December, 1915, they were quite incapable of constructing in a few days a complete system of trenches and redoubts for defence against the advancing hordes of the Turks. Rest was imperative, and the question was whether rest could be obtained. It was partly the necessity for rest and reorganization for his retreating force which caused General Townshend to halt at Kut on the 3rd December, 1915. He had not decided till that date, whether he would remain in Kut or not. To quote his own words: "It was practically impossible for me to retire from Kut. So exhausted were my troops that they lay down and could do nothing but eat and sleep for two days." The human factor, then, became an important one in the situation, as it does so often in actual warfare, and the halt of the British force enabled the Turks to regain touch with it after it had outdistanced their pursuing troops in a series of forced marches.

I have given a brief *résumé* of the operations leading up to General Townshend's arrival in Kut from Ctesiphon as it is necessary to visualize clearly the circumstances under which he was forced to decide whether he would halt at Kut and subsequently continue his retreat, or whether he would remain in Kut and defend it against the advancing enemy. I think that any officer who took part in

KUT in 1918

the retreat will agree that, whether Kut was held or not, a *halt* at Kut was imperative. The marvel is that the British force ever reached Kut. I do not think that it would have done so if the pursuit had been pushed with vigour and in a scientific and efficient manner. Fortunately, the Turks still had a wholesome respect for our offensive powers, and the Turkish leaders made several gross tactical blunders which prevented our retreat from being cut off.

Field Service Regulations, Volume II, Chapter XI, which deals with the subject of " Defence," gives the following axiom :—" When a commander decides to adopt a defensive rôle, the manner in which he will be able to carry out his plan will depend largely upon the time available for preparing his defensive organization, and upon the general situation in the theatre of war. Thus circumstances may only allow of a hastily organized defence, or they may permit of the deliberate occupation of a well-organized defensive position *commanding a line of advance which is essential to the enemy.*" The line of the River Tigris was essential to the advance of the Turks, though the Kut peninsula was not a well-organized defensive position. The fact that the line of the Tigris was essential to the enemy, if he desired to advance any considerable distance into Lower Mesopotamia, was the main point which decided General Townshend to establish himself at Kut. By remaining there until relieved he also denied to the Turks the use of the Shatt-al-Hai Channel leading to Nasariyeh, which might have enabled them to advance on Basra or Amarah, by a flank attack from the west, when that channel filled with water early in January.

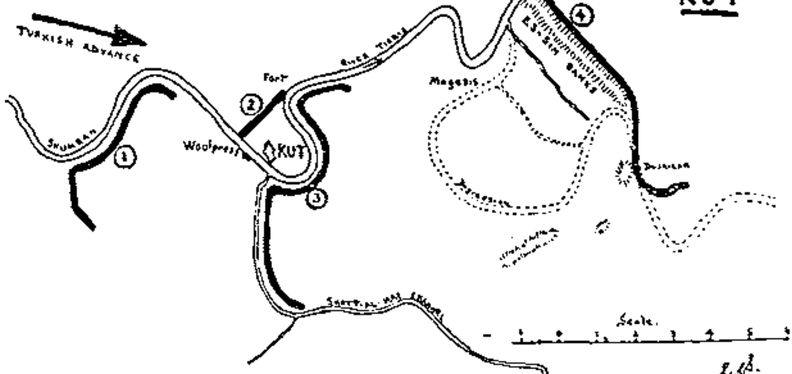
On the 3rd December, 1915, General Townshend decided not only to halt at Kut but also to *remain* in Kut, and he informed the Army Commander, General Sir John Nixon, to that effect. So momentous a decision, in a minor theatre of war, has rarely been taken by a subordinate officer. The responsibility of making that decision was left to General Townshend by the Army Commander, who, however, on the 4th December, gave him seven arguments in favour of defending Kut and notified his approval of the decision. In his own opinion General Townshend was forced, in the first instance, to decide between the possible loss of his Division and the probable loss of Mesopotamia. Can one wonder that, maintaining the tradition of offensive action so dear to the British Army, he decided to fight and to risk the loss of his force rather than to retire and perhaps lose the country which he had conquered ? That he did actually lose his force, and that more than 20,000 men were sacrificed in vain endeavours to save that force, was decreed by fate ; yet, if it was a mistake to defend Kut, his action should not be judged without a full consideration of the circumstances which induced him to make his decision. Let us consider those circumstances.

Firstly, the British force was exhausted on reaching Kut. It could retreat no further, though in a few days it might be able to do so. It was accordingly tied to Kut for, say, three or four days.

Secondly, if it remained in Kut and fortified that locality, it blocked not only the River Tigris to the enemy's shipping, but would also deny the Shatt-al-Hai channel to that shipping when the channel became flooded. The Turks had only five ships upstream of Kut, and they depended on those ships for their ammunition and equipment, and to some extent for their reinforcements and food, though they could live on the land as no British force could. They could not carry the war far into Lower Mesopotamia if Kut was held. They had not sufficient land transport to maintain a large army advancing further and further into a pestilential region, even though the Arabs of that region might be friendly while success attended the Turkish advance. While Kut was held, the Turks were tied to it by a string of a certain length—not by a piece of elastic. If too much strain came on the string it would break; it would not stretch.

Again, General Townshend was fully aware that reinforcements were only dribbling into Mesopotamia and were a long way off. He was informed on the 5th December, two days after his arrival, that he might count on being relieved in two months, and that a force was being concentrated as soon as possible at Amarah, more than 100 miles away to the south-east, with a covering force of only one brigade at Ali-al-Gharbi, 30 miles to the east. Note the words "as soon as possible." Townshend could not hope to be *adequately* reinforced at Ali-al-Gharbi if he retreated from Kut. He might meet reinforcements before he reached Amarah. But could he reach Amarah, harassed by thousands of Arabs, and possibly pursued in time by large bodies of the best Turkish troops? It seemed problematical at the time. Those who had seen the force enter Kut on the 3rd December might not even have conceded that it was problematical. General Townshend decided that his reinforcements were not sufficiently near him to warrant a further long retreat in an endeavour to meet them. He decided to await their close approach and then to co-operate with them. He was exhausted. They would be comparatively fresh.

The British force was small—about 7,000 infantry. Supposing that a prolonged retreat was impossible, the question arose as to whether this small force could take up a position where it could reasonably expect to withstand the Turkish onslaught for a time, preparatory to further retirement towards its reinforcements. It had very few machine-guns, and little modern artillery except for three batteries of 18-pounders; therefore it could not occupy an extended line. It had not much barbed wire, and no bombs. For defence it had chiefly to rely on rifle fire. Was there a position of, say, not more than two miles in length where its flanks would be secure? Yes. A position across the neck of land forming the loop of the river Tigris containing Kut would fulfil those conditions. It has been said that General Townshend should have retired to the Es-Sin position, a line of embankment some seven miles below Kut town, where trenches existed. That position was six miles long on the right bank of the Tigris and three miles long on the left bank. The trenches also faced the wrong way. Possibly an Army Corps with plentiful machine-guns might have been able to hold Es-Sin and to protect its flanks from envelopment, but certainly not a force of four weak brigades. Supposing that General Townshend had retired to the Es-Sin position, how long could he have maintained his force there? There were no supplies in the position. There was no transport to bring sufficient quantities of provisions and ammunition from Kut to the position if it was to be held for a week or more. There was no water at Es-Sin except near the river. Amarah was the nearest point from which supplies could be obtained from downstream. General Townshend subsequently wrote as follows:—" Had I taken up my position at Es-Sin, I should have been enveloped and overwhelmed in a decisive battle in three or four days' time." Was there, then, any other position which the British force might have occupied for a time preparatory to retirement? If it could have crossed to the right bank of the Tigris it might have taken up a position on that bank near Shumrān, four miles above Kut, placing the Tigris between it and the enemy owing to a bend in the river, and with its left flank only exposed to envelopment if the Turks crossed to the right bank. This they



could not do at once as they had no bridge. On the other hand, we had a Bridging Train and I think that I could have constructed a bridge for the crossing of our force, though not at Kut itself. This Shumrān position was recommended by the Brigadier-General, R.E., and a further retirement could have been executed from it to the Shatt-al-Hai channel which could have been held temporarily as a rear position; but the occupation of the Shumrān position would have meant the abandonment of the left bank of the Tigris and of Kut town with all its supplies, and a subsequent retreat under fire from Kut on the flank. Also, we could not have taken sufficient supplies to the position for more than a few days.

General Townshend decided that the only locality in which he could put up a defence, and also maintain his force for a reasonable time, was in the loop of Kut. Here he was secure. His flanks were safe, his rear was safe, he could hold his front line against determined attacks, and, as *Field Service Regulations* put it, "He commanded a line of advance essential to the enemy." He has been criticized for adopting an attitude of passive defence. That was not his intention. To quote his own words once more: "I intended to use my entrenched camp as a pivot of manœuvre, when, by improvising a bridge and a fortified bridgehead, I should be able to throw the principal mass of my force on to either bank of the Tigris in an offensive against an isolated fraction of the enemy. Had my troops been able to work and get the bridge across the Tigris opposite the town of Kut, I should have been able to make an *active* defence." General Townshend was well aware of the usual fate of a force which shuts itself into an entrenched camp for a passive defence. The outstanding example of Marshal Bazaine at Metz in the Franco-Prussian war was ever in his mind. But his plans for an active defence were stultified by a lack of engineering information, and in this respect I should like to indicate how important is the question of the *liaison* of the General Staff with the engineers. A bridge across the Tigris opposite Kut was impossible. I commanded the Bridging Train and had lost most of my boats and all my pontoons during the retreat from Ctesiphon when we were chased by cavalry and had no escort. The river was 600 yards wide opposite Kut town, and I could have told the G.O.C. at once that the maximum length of bridge which I could construct, given several days to do so, was, roughly, 300 yards. If General Townshend had been aware that his system of active defence was thus rendered impossible, he might have altered his decision to remain in the loop of Kut. But he apparently assumed also that he could prevent the Turks from bombarding any bridge with artillery. A large bridge cannot be maintained for more than a few days under hostile artillery fire without great reserves of material and boats, and we had no such reserves of a suitable nature. If a bridge had been constructed it would infallibly have been destroyed by the Turkish artillery or mines, or captured by a determined assault, and the defence of Kut would then have become passive, at least, as regards the right bank of the Tigris. On the Kut side, *i.e.*, the left bank, the Turks quickly surrounded our entrenched system with three lines of trenches, well wired, strengthened by redoubts, and supported by artillery. Sorties in force on this bank soon became difficult, and later impossible, owing to the flooded ground. Again, it would seem certain that the intended active defence was doomed to develop into a passive one. However, the Kut loop was considered to be the only possible defensive locality, and it was occupied and strengthened as far as our men were able. The land front to be defended was $1\frac{1}{4}$ miles long and the river protected the flanks and rear. The Turks were in front and the river behind; in fact, we were between the devil and the deep sea.

Another point influencing the decision to defend Kut was that it was our advanced base for supplies, stores and ammunition. These had been accumulated for weeks. The shipping downstream was fully employed in bringing up reinforcements and could bring no more stores. The enemy was naturally short of supplies and would benefit greatly by the recapture of Kut. It was therefore of great importance to preserve our supplies and also our store of ammunition. There was not sufficient transport to remove the bulk of the supplies and stores if we evacuated Kut. On the other hand, the supplies would enable us to withstand a siege of some duration—at any rate, as long a siege as then seemed likely.

However undesirable they may be, political considerations are apt to influence military operations. Kut was no exception. The Political Department was emphatic regarding the bad political effect which would be produced throughout Mesopotamia by a further retirement downstream. The Political Officer pointed out that in such an event our half-hearted Arab allies would go over to the Turks, the country would rise against us, and our prestige would be gone. Also, the failure of the Gallipoli campaign, and the situation in Persia and Afghanistan, made it advisable to avoid the bad effect of a lengthy retirement towards Amarah. Again, when General Townshend had decided to remain in Kut and wished to evacuate all the 6,000 Arabs in the town, he was advised politically that the death of the Arab women and children in the desert, which would probably result from this evacuation, would be a cause of renewed hatred against us, and so most of the Arabs were allowed to remain in Kut where they did little work and ate a vast amount of food. The necessity of maintaining British prestige in Mesopotamia thus influenced General Townshend in reaching his decision to retire no further than Kut, and certainly shortened the period of resistance of which the garrison was capable when surrounded by the Turks.

The Russians under General Baratoff were demonstrating towards Baghdad from Persia, and it was advisable to co-operate with them. By holding a large Turkish force at Kut the British assisted their allies from Russia. The Russian force, however, had little driving power. It consisted mainly of irregular cavalry with only a few guns. When the Kut position was occupied the limitations of the Russian offensive were scarcely understood.

A last consideration, which doubtless influenced General Townshend in his decision to hold Kut, was the necessity of allowing the increasing force downstream as much freedom of action as possible, *i.e.*, space in which to manœuvre in country suitable for manœuvre and well above the swamps at Amarah. The force downstream could then concentrate unhindered and manœuvre freely for offensive action. It would have the initiative.

I have tried to show what were the considerations which induced General Townshend to hold Kut, but there are two sides to every question and many people have disagreed with his decision. He had eluded the Turks by a skilful rearguard action and a rapid retreat, and, though he had not been reinforced to any extent, he then allowed himself to be overtaken and surrounded by greatly superior forces. Again, on his own admission, he underestimated the capability of the garrison to hold out. This was caused partly by incomplete reports of the amount of supplies available in the town (a very difficult matter to estimate), and partly, perhaps, by too modest an opinion of the ability of regular troops to exist on reduced rations. But it was due, also, to his estimate of the condition of his troops. He considered that they were too exhausted to withstand the physical and mental strain of a heavy assault or a long siege. The Indian regiments had lost most of their British officers, and the casualties early in the siege were heavy. Most of the General Officers in Kut considered that a really determined assault by the Turks within the first six weeks would have succeeded if pressed home regardless of losses. The Turks actually assaulted on the 10th and 12th December, 1915, and, on Christmas Eve, they almost captured Kut, but by that time we had some trenches, and the assault was not made in sufficient strength. Anyhow, the underestimation of the garrison's ability to resist the Turks was unfortunate for the relief force, which attempted attacks without adequate preparation in order to save Kut. The repeated failures of the small relief force gave time for the Tigris to rise to flood level and thus to render the relief practically an impossibility. General Townshend, when he decided to remain in Kut, never contemplated a siege of such length as to last till the flood season in March, and he was supported in this estimate of the probable duration of the siege by the receipt of a telegram from the Army Commander in which the latter stated that two months might be considered the outside limit before a general move forward would be made by the relief force. General Townshend stated in his book, written after the war, that he did not realize at first that the Turks were being directed by a German staff, and he was consequently surprised at their initiative. The unbroken series of successes of the 6th Indian Division had greatly impressed the population of Iraq and also the Turks themselves, and Townshend considered that the Arabs would exaggerate, in their reports to the Turks, the numbers of reinforcements for the relief force and that the Turks would, in consequence, hesitate to advance much beyond Kut. Events proved that he was mistaken. The Germans clearly realized the situation and sent the Turks to occupy positions as far downstream below Kut as their overland transport would admit. The Turks were soon organized in depth below Kut, and that fact, aided by the floods, gradually brought the relief force to a standstill and finally led to the surrender of the Kut garrison from starvation.

General Sir Charles Townshend was a most capable commander in the field; he had the complete confidence of all ranks during the campaign preceding the siege; he was a keen student of military history and a man of remarkable character; but he was broken by the failure of the attempt to capture Baghdad—one of the most desperate ventures in military history—he was crushed by the change in his luck, by illness, and by the collapse of his hopes. A commander's reputation must depend to some extent on his success. Townshend never failed till he attempted the impossible at Ctesiphon. As the man most conversant with the difficulties of the situation, should he have refused to advance on Baghdad? It is not my business to offer an opinion on this question. But in war there is always the chance that the unexpected may happen, and Townshend, an optimist and born, apparently, under a lucky star, took the chance. He made a magnificent fight, but was overwhelmed. He was forced to retreat, and yet, in retreating he dealt the enemy a shrewd blow at Ummal-Tabul. He longed to find a position in which he could stop his retreat—a movement so repugnant to an ambitious commander who had always been victorious. He reached Kut. He thought he could soon resume the offensive, or at least carry on an active defence and thus retrieve the prestige of his force. He decided to remain. He paid for that decision as a prisoner in Turkey, and a large part of his force paid for it with their lives.

The decision to defend Kut exemplifies the variety and number of the factors which the commander of a force may have to consider, and the extreme difficulty in which he may be placed. Military opinion now appears to incline to the idea that whatever loss of stores, ammunition, prestige, or men, was involved, Townshend should not have defended Kut, and that, though he might have halted in Kut for a few days to rest and reorganize his force, he should then have crossed the river and retreated on Ali-al-Gharbi. It was unfortunate that the old Turkish bridge below Kut was dismantled before he arrived from Ctesiphon. It occupied the best and only proper bridge site from an engineering point of view, and it could have been covered and defended till the British force crossed the river. It could then have been destroyed. No bridge which I could make with my remnants of boats after the retreat, could have enabled a whole division to cross the Tigris. In his retreat towards Amarah to meet his reinforcements, General Townshend would have been greatly harassed by Arabs, but he would have had the Tigris between him and the bulk of the Turkish army until the Turks could construct a bridge, and he would then have had a long start. He might have lost 3,000 men from exhaustion in this retreat, but by staying in Kut he caused, directly or indirectly, the loss of nearly 30,000 men. It is easy to be wise after the event. I think, however, that our force would have been capable of resuming the retreat as far as Ali-al-Gharbi, or even Amarah, after three days' rest in Kut, and in the retreat the 6th Cavalry Brigade and the artillery could have held off the Arabs and the Turkish cavalry. Amarah held considerable quantities of supplies and ammunition. It was only about 280 miles by river from Basra, the main base, so that reinforcements could reach it with moderate speed. It seems probable that we could have reached Amarah in ten days from Kut, before the Turks could have bridged the Tigris and overhauled us. Our shipping, with the most essential supplies and our sick and wounded, could have gone with us in the retreat as it did from Ctesiphon. At Amarah the force would have covered Basra and the valuable oil-fields at Ahwaz, and we should have been nearer to our base, and the enemy further from his.

The garrison of Kut, which was really a covering force for the concentration of the British army gradually assembling in Lower Mesopotamia, failed to fulfil its proper rôle for the following reasons :—

(i) Its use as a covering force was neutralized, as its action was to some extent ineffective and it was immobile.
(ii) It did not, except at first, engage a greater hostile force than itself, though it prevented the advance of a greater force beyond Shaik Saad, 20 miles downstream.
(iii) It could not rejoin the main body, or be reinforced without the risk of the defeat of those reinforcements in detail.
(iv) It risked destruction without compensating advantages to the army as a whole.

The Army Commander left to General Townshend, the commander of a detachment, the decision as to whether that detachment should remain at Kut as a covering body, or rejoin the main army. The Army Commander was the officer with whom rested the strategical conduct of the campaign. On him depended the arrangements for the concentration of his army for the offensive. On him devolved the duty of securing space for that concentration. He was a keen and capable soldier, his scheme for the capture of Baghdad had failed, and he had great faith in the ability and judgment of General Townshend. Was it, or was it not, his duty to decide whether a covering force at Kut was essential?

In conclusion I may say that my object in writing on such a very controversial subject is that it illustrates clearly the complexity of modern warfare in which a commander has so often to make a rapid decision of vital importance when swayed by many conflicting considerations. All honour to him who, under such circumstances, is capable of a rapid decision, even though fate decrees that it should lead to disaster, but happy is he whose decision leads his troops eventually to victory.

THE POST-WAR ACTIVITIES OF THE ROYAL ENGINEERS.

INTRODUCTORY.—In the ensuing pages an attempt has been made to summarize the more important events affecting the Corps, outside India, which have occurred since the termination of the war.

Details which are common knowledge to officers serving at home have been included, as it is thought that they may be of considerable interest to officers serving abroad, as well as to retired officers.

ORGANIZATION.—The organization of the Royal Engineers has undergone considerable changes since 1914. The responsibilities of the Corps have been reduced by the separation of the Signal Service from the R.E. and the reduction of the coast defences.

But they have been largely increased by :—

(*a*) The addition of new activities in connection with anti-aircraft work and chemical warfare.

(*b*) The fact that, owing to the general mechanicalization of the Army, engineer work in the field has become very much heavier and more important than in 1914.

(*c*) The addition of transportation units to war establishments.

Expeditionary Force for Small Wars.—In 1914 the engineer units, other than transportation units, allotted to the expeditionary force, consisted of a field squadron with a cavalry division; two field companies per infantry division; two bridging trains with Army troops; and two fortress companies, one works company and a printing company with the L. of C.

The post-war organization has been increased so as to include the following :—

Field Squadrons.
Field Companies.
Field Park Companies.
Army Troops Companies.
Field Survey Companies.
Light Bridging Parks.
Electrical and Mechanical Companies.
Tank Bridging Companies.
Workshop and Park.
Field Survey Companies.
Anti-gas Laboratory and Demonstration Units.
First Class Workshops.
Second Class Workshops.
First Class Store Depôts.
Second Class Store Depôts.

In addition, a Searchlight Battalion, R.E., forms part of the Air Defence Brigade which is included in G.H.Q. Troops.

In nearly every case, too, it has been found necessary to increase the war establishments of pre-war units.

As a result of the increase in both units and establishments the total number of R.E. personnel (other than those for transportation units) required on mobilization for the expeditionary force for small wars has been largely increased above the corresponding total in 1914.

The duties and responsibilities of the field squadron and field companies remain very much as they were.

Army Troops Companies are required for engineer work of a general character such as hutting, water supply, and Electrical and Mechanical Companies for analogous services (including the supply of power generally).

The Field Park Companies consist largely of skilled tradesmen for employment in the divisional area on hutting, water supply, and other kindred services. They also run the Divisional lighting set, formerly operated by the Divisional Signal Company R.E., and provide the organization for the Divisional R.E. stores and workshops, for which personnel had in the past to be withdrawn from field companies. The bridging equipment of the division is also attached to the field park company. It is undesirable to use the personnel, who are difficult to replace, on front line work.

The Searchlight Battalion is organized into a headquarters and four companies, each company being divided into four sections, and each section working six searchlights. Thus there are 24 lights in a company and 96 in the whole battalion.

This unit works in the closest co-operation with the anti-aircraft brigades, R.A.

The requirements of modern artillery, aircraft, etc., have made the compilation and issue of accurate maps more than ever essential. The need of field survey work in an undeveloped and ill-mapped theatre of war is obvious. In 1914 we relied, in the first instance, on the maps of our allies, but speedily developed a large field survey organization of our own.

With a view to keeping the regular peace establishment of the Corps, for financial reasons, at a minimum, in spite of this large increase in mobilization requirements, a considerable number of units is to be provided on a militia basis. The remaining units are to be regulars, but it is not proposed to maintain all of them in peace.

Field Units.—There is one field company on the Rhine, the peace establishment being the same as at home—*i.e.*, 4 officers and 111 other ranks—and two field companies in Egypt, with an establishment of 4 officers and 141 other ranks. The increased establishment in Egypt includes 24 additional draught horses, 13 drivers and some 20 sappers, so as to make the units more mobile and able to take the field without immediate reinforcements.

Fortress Companies.—The R.E. in fortresses have been very much reduced. The present establishments represent the minimum necessary, and are calculated on a certain scale for each light.

The establishments abroad have been reduced from a total of 57 officers and 1,365 other ranks to 21 and 522 respectively.

A reduction in officers and other ranks has been effected by amalgamating the two fortress companies at Gibraltar.

Before the war, although the fortress units at home held on their establishment a number of recruits who were still completing their recruits' course in the Training Battalion, their peace establishment was sufficiently large to enable them to lend certain personnel for service with other units, and to give substantial assistance in connection with works services, in peace. It was also possible to draw on them largely on mobilization. With the severe reductions which have been made, it is no longer possible for them to perform these additional functions. It is, therefore, necessary to make additional provision in the Supplementary Reserve to meet the position on mobilization.

School of Anti-Aircraft Defence.— The School of Anti-Aircraft Defence, which is situated at Biggin Hill, near Westerham, Kent, gives instruction in the following subjects :—

(*a*) Anti-aircraft defence generally.
(*b*) R.A.F. tactics.
(*c*) Anti-aircraft gunnery and tactical handling of guns.
(*d*) Anti-aircraft searchlight and sound locator work.
(*e*) Camouflage and passive measures from the point of view of defence against aircraft.
(*f*) Aircraft intelligence and communications.

Courses are held for officers and other ranks of the Regular and Territorial Air Defence Troops, and for Senior Officers of all arms.

The Commandant is a Colonel. The first was an officer of the R.E. and his successor, who now holds the appointment, is an officer of the R.A. He is assisted by an Adjutant who, in theory, is a Gunner when the Commandant is a Sapper and *vice versa*. The instructional staff is organized in two wings, an R.A. wing and an R.E. wing and, in addition, there are two small detachments called the R.A. Cadre and the R.E. Cadre. At present there are three R.E. Instructors, while the Cadre consists of one officer and 14 other ranks.

Anti-Gas School.—An Anti-gas School was started in 1923 at the Experimental Station, Porton, Salisbury Plain, in order to train regimental officers as instructors for defence against gas. In addition, short courses are held for senior regimental and staff officers. The present output per annum of the school is some 30 senior officers and 100 regimental instructors.

Boys' Technical School for Training Boys as Tradesmen to Assist in Meeting the Requirements of the Army Generally.—Great difficulty having been experienced in obtaining sufficient tradesmen recruits from the labour market to meet the needs of the Army, it was decided that endeavours should be made to meet the demand by training boys. With this end in view a Boys' Technical School was formed in September, 1923. It had been intended that the location of this school should be at Blandford, but it was subsequently decided that Chepstow would be more suitable.

The School is designed eventually to train approximately 1,000 boys. This number will be reached gradually by sending 110 boys every four months. Before enlistment the boys have to pass a competitive educational examination. They are then enlisted, when about 15 years old, for general service, and for a period of 12 years (8 years' colour service and 4 years' reserve service) from the date at which they attain 18 years of age. They are trained in a trade until they attain the age of 18 years, when they are posted to the various Corps requiring them. At present, trade training is given in the following trades :—Blacksmith, electrician, fitter, carpenter and joiner.

Tradesmen, who have been trained at similar establishments in the past, have attained a very high standard of manual skill and theoretical knowledge, and have proved themselves to be far superior to recruits obtained through the usual channel.

The Commandant of the School is a Lieut.-Colonel, who has under him the necessary administrative and instructional staff. The instructional staff at present consists of a Chief Instructor (Major), an Assistant Instructor (Captain) and 12 N.C.O. Instructors. This instructional staff will be gradually increased *pari passu* with the increase in trainees.

It is anticipated that the School will reach its full strength in May, 1926, when the approximate establishment will be :—

Headquarters : 4 officers, 96 other ranks.
Administrative staff : 8 officers, 20 other ranks.
Instructional Staff : 4 officers, 79 other ranks.
Boys under training : 990.

Interpretation of Air Photographs.—Courses have recently been started at the R.A.F. School of Photography, South Farnborough, for training regimental, battalion, etc., instructors in the study and interpretation of air photographs.

The instructor is an Army officer and the position is at present held by an officer of the R.E. The annual output is 60 officers.

Regimental Headquarters, Aldershot.—This Headquarters is responsible for the administration of the following R.E. units, which are stationed at Aldershot and are commanded by the senior C.R.E.—

The Mounted Depôt. Five Field Companies. One Field Squadron.

It is considered preferable that the W.O.'s, N.C.O.'s, and men required for Headquarters should be shown separately, rather than be included with the R.E. Mounted Depôt, as in 1914.

R.E. Mounted Depôt, Aldershot.—This unit carries out the training duties formerly carried out by the Training Depôt for Field Units. Its functions remain the same as in 1914, *viz.*, the entire training of all driver recruits and of farriers and trumpeters, and the training in driving and special field works of all mounted sappers. The establishment is designed to deal with 52 drivers, 20 mounted sappers, 10 farriers and 22 trumpeters at a time. In addition, instruction in equitation, lasting about a month, is given to R.E. officers on their first appointment to field units, or before proceeding to the Indian Establishment. Short refresher courses are also held for officers and N.C.O.'s in field units of the R.E. Territorial Army.

S.M.E.—The functions of this establishment are the same as in 1914, with the exception that there are large arrears of instruction to be made up owing to the fact that the course for young officers was very considerably curtailed during the war. In addition, about 31 non-regular officers, who, during or since the war, were granted direct commissions into the Corps, have to complete their full training at Chatham. These officers join the S.M.E. as they become available and undergo instruction at the same time as the young officers and "war-trained" officers. The "war-trained" officers are formed into classes known as "Supplementary Classes," and have been undergoing instruction at Chatham in batches since 1919. During 1920 it was decided that all remaining "war-trained" officers were to complete a portion of their post-war course at Cambridge, after which they were to return to Chatham for instruction in military subjects. The first batch of 50 officers went to Cambridge on 1st October, 1920, and batches of similar strength have continued to be sent to Cambridge up to date. The last batch of this class of officers will proceed to Cambridge on 1st October, 1924.

R.E. Depôt.—The R.E. Depôt is organized into two battalions, called the Depôt Battalion and the Training Battalion. It is under consideration to alter the title of the former to "Administrative Battalion," as more adequately describing its functions. Generally speaking, its functions are the same as before the war, although its organization is somewhat different.

The Depôt Battalion:—

(i) Receives men from abroad for discharge and prepares drafts for abroad which cannot be sent direct from units.

(ii) Is responsible for the discipline and administration of the R.E. Band and trade boys who are included in the Depôt Battalion establishment, of the instructional staff of the S.M.E., and of all personnel undergoing courses at the S.M.E., except young officers who are dealt with by the Training Battalion.

(iii) At present holds the documents, arms, equipment, and clothing of the dismounted R.E. Reservists, but the establishment is based on the assumption that the proposal, now under consideration, that all reservists allotted to service units shall join them direct and that only the unattached reservists shall join the Depôt at Chatham, will be approved.

The Training Battalion is divided into a Headquarters wing and four companies. It is responsible for:—

(i) The administration of all dismounted R.E. recruits and their training in military duties. It carries out no trade training.

(ii) The discipline and administration of junior officers under instruction at the S.M.E., and their training in military duties, including tactics.

(iii) Certain courses of instruction for officers and N.C.O.'s of the Regular and Territorial Army in military duties.

The Headquarters wing consists of an administrative staff and an instructional staff.

In 1914 the actual number of recruits under training at the Training Battalion averaged about 600. Of these some 304 were on the establishment of the Training Battalion, the remainder being found from within the establishment of other R.E. units. The establishment of recruits, which is based on the peace requirements of the Corps, is now 690. This increase is partly due to the abolition of the pre-war policy of including a proportion of the recruits in the establishment of other units and partly to the lengthening of the training period from 29 to 36 weeks. The battalion is at present accommodated partly in barracks and partly in hutments on the Great Lines, but the question of concentrating it in a single barracks is under consideration. The establishment of the Headquarters wing is based on the assumption that this concentration will be carried out. The duties of this unit as regards young officers will be materially diminished when the number of officers under instruction returns to normal.

58th Company R.E., Porton.—This unit, formerly a field company, has since the war been resuscitated for attachment to the Chemical Warfare Experimental Station at Porton, to assist in the work there carried out.

Officers' Cambridge Course.—It has been decided that, in future, the time spent at the R.M.A. is to be reduced from 2 years to 18 months, and that all cadets commissioned in the R.E. will complete their training by courses of instruction at Chatham and Cambridge. The total course, including leave and vacations, is 143 weeks, of which 73 weeks are spent at Chatham and 70 weeks at Cambridge. The amount of training done at Chatham prior to proceeding to Cambridge will depend upon the time of year the cadets leave the R.M.A.

The first cadets to do this shortened course at the R.M.A. will be those to enter in September, 1924. This batch will go to Cambridge in October, 1926, together with the batch leaving the R.M.A. in

August, 1926. As mentioned above, the last batch of "Supplementary Class" officers will go to Cambridge in October, 1924, and will complete their instruction there in the autumn of 1925. Thus there will be a period from October, 1925, to October, 1926, when there would normally be no R.E. officers at Cambridge. For various reasons it is considered very undesirable that there should be any hiatus, so 17 selected candidates from the batches passing out of the R.M.A. in January and August, 1925, will be sent to Cambridge to fill it.

Engineer Services.—The withdrawal of the Imperial Garrisons from Iraq, Palestine, South Africa and South Ireland, the paramount necessity for economy, and various changes in organization which are referred to more fully below, have led to considerable reductions since the war in the establishments of officers and subordinates employed on engineer services. In 1921 the subordinate establishment cost £825,000. This year it is estimated to cost £410,000. In 1921 the number of officers employed on engineer services was 429. This year it is 227.

In carrying out the reorganization of works establishments rendered necessary by these large reductions, endeavours have been made to improve matters by:—

(*a*) Reducing the number of C.R.E.'s and D.O.'s appointments and enlarging the areas of their charges.
(*b*) Standardizing these charges as far as possible upon a basis of comparative average expenditure.
(*c*) Further decentralizing technical and financial responsibility.

The chief object aimed at (in addition to economy) has been to increase an officer's responsibilities and powers with a view to making employment on engineer services in peace afford more adequate training for war.

There are, however, and must be under present conditions, certain D.O.'s appointments at home stations which, either owing to their geographical situation or to the fact that the work is chiefly confined to minor maintenance, do not afford useful training and experience to an R.E. officer at all. There are others which are only suitable to be held by junior officers. All D.O.'s appointments at home have, therefore, been graded in accordance with their importance, and postings are made to correspond.

The procedure to be adopted in filling appointments which are not suitable for R.E. Regular officers to hold is still under consideration.

ADMINISTRATIVE CHANGES.

Replacement of the Royal Engineer Committee by the Royal Engineer Board.—The R.E. Board was formed in August, 1920, to take over the work which had been previously carried out by the R.E. Committee, the objects being:—

(*a*) The prosecution and guidance of scientific research.

(*b*) Experiment and design in connection with engineering equipment and material required for the R.E. and the Royal Corps of Signals.

(*c*) That the Board should act as an intermediary between the War Office and the productive engineering resources of the community in carrying out the general lines of policy laid down by the General Staff in regard to such material and equipment.

The R.E. Board is also responsible for studying the progress made by the above-mentioned branches of the Service in foreign armies and developments in engineering in foreign countries.

The duties and responsibilities of the Board in pursuit of the foregoing objects are as follows:—

(*a*) *Research and Investigation.*—To decide upon matters entailing research and maintain touch with Scientific Associations and Technical Institutions which undertake it, and other Government Departments.

(*b*) *Experiments.*—To determine the scope and extent of experimental work, the allocation of this work to the various Experimental Establishments or elsewhere and the control of the technical work of these establishments.

To furnish technical reports upon inventions or proposals referred to them.

(*c*) *Design.*—To design or to arrange for the design and preparation of specifications (with due regard to the utilization of commercial products) of technical machinery, material and stores for Military Engineering, and Signals, and to make recommendations as to their adoption in the Service.

(*d*) *Records and Intelligence.*—To collect and collate such information:—

(i) Regarding scientific and engineering developments in the British Empire as may be published or otherwise made accessible, with a view to its adaption to Military Engineering, and to facilitate making full use of the technical resources of the Empire in Military Operations.

(ii) As published in foreign scientific and technical journals regarding engineering developments in foreign countries.

(iii) As shows progress made in the organization and technical equipment of the Engineering and Signals branches of foreign Armies.

(iv) To disseminate the above information to all concerned.

Constitution and Organization.—The Board consists of a permanent central body composed of a President, three members and a secretariat, who have no other duties, together with certain *ex officio* members. With them are associated representatives of other Experimental and Educational Establishments, of the branches of the War Office concerned, selected Regimental Officers, and representatives of other Government Departments and Engineering Institutions. As a matter of convenience, it is found desirable to subdivide into committees, and to hold separate meetings for those concerned in the various subjects, for example :—

(i)	Bridging	Committee A.
(ii)	Mining, Demolitions and Explosives ...	
(iii)	Camouflage	
(iv)	Survey and Photography	
(v)	General Field	
(vi)	Electric and Mechanical Equipment, Water Supply	Committee B
(vii)	Searchlights	
(viii)	Sound Locators and Acoustics ...	
(ix)	Signals, General	Committee C.
(x)	Signals, Wireless	

Experimental Establishments.—The undermentioned Experimental Establishments are under the direct control of the Board as regards all experimental work carried out by them :—

(i) Signals Experimental Establishment (Woolwich).
(ii) Searchlight Experimental Establishment (Biggin Hill).
(iii) Experimental Bridging Company, R.E. (Christchurch), Experimental Section, R.E. (Christchurch).

Office of the A.A.G., R.E.—The responsibilities of this branch of the War Office remain unchanged, with the exception that the A.A.G. now holds the dual rôle of A.A.G. for R.E. and A.A.G. for Signals, and he has a D.A.A.G. to assist him in the administration of the latter Corps. The A.A.G. is also responsible for the administration of the Boys' Technical School, referred to elsewhere in this article.

The number of R.E. regular officers is still considerably less than that required by the peace establishment, thus rendering it necessary to employ a number of temporary officers.

D.F.W.'s *Branch.*—No great administrative changes have been made in the D.F.W.'s Directorate, although the great advance in electrical and mechanical functions, and the demise of the Director of Barrack Construction's Department, has necessitated a considerable increase in the staffs of the branches dealing with these subjects.

The powers of local officers as regards :—

(*a*) Approval of designs, (*c*) Purchase of Stores,
(*b*) Sanctioning Services, (*d*) Making Contracts,

have been considerably increased.

The selection of all "Capital" Services for execution costing less than £1,000 is now left to the Commands.

The responsibilities of D.O.'s as regards measurements have been reduced by the appointment of an Inspector of Works to each

C.R.E. for employment on surveyors' duties only—a reversion to the practice which obtained prior to 1907.

In most home Commands the employment of direct labour has been superseded by lump sum or term contracts.

The introduction of cost accounting has necessitated a complete change in the system of engineer accounting formerly in force. The new system is necessarily more complicated than the old, and is somewhat more expensive.

Advantage was taken of the change to revise the R.E. system of store accounting by the introduction of a stock or suspense account to which the purchases are debited in the first instance, credit being given by their user in due course.

Every Army Form used in connection with Engineer Services has been reviewed, and as many as possible have been either simplified or abolished. But the introduction of cost accounting has necessitated the introduction of a good many new forms.

Sections VI, XII and XIII of the *Regulations for Engineer Services* have been re-written and promulgated. The revision of the whole book, and of the *Instructions for Fixed Electrical Communications* is now in hand. The former is in proof stage and should be issued shortly.

The issue of the new *Schedule of Prices for Works and Repairs* has facilitated the reversion to contract procedure referred to above.

In connection with the new system of Engineer accounts a *Priced Vocabulary of R.E. Stores* has been prepared and issued so as to ensure uniformity of pricing at all stations. It is now in course of revision.

A new *Barrack Synopsis* and new *Drainage Manual* have also been issued.

Pay and Conditions of Service of Personnel.

By the issue of Army Orders 324 and 325 of 1919, the total emoluments of effective and non-effective officers and other ranks of the whole of the Army were considerably increased on account of the increased cost of living. In the case of officers it was stated that the revised rates were subject to revision after 5 years, either upwards or downwards, to an extent not exceeding 20 per cent. according as the cost of living rises or falls. No such stipulation was made in the case of other ranks.

This revision—a reduction of $5\frac{1}{2}\%$—has just been promulgated. A further revision will be made with effect from 1st July, 1927.

Although the total emoluments of officers were considerably increased by Army Order 324 of 1919, the rates of Engineer pay for R.E. officers were reduced. The issue of Engineer pay to officers joining subsequently was also made dependent upon officers qualifying as Associate Members of the Institution of Civil, Mechanical, or Electrical Engineers, or upon their possessing such other equivalent qualifications as might be accepted by the Army Council. A proposal is under consideration to substitute an examination to be held by Cambridge University for the outside qualifications referred to above.

A considerable number of civil engineers, and subordinates, were recruited on short-term contracts for service in Iraq in connection with works. On termination of the War Office responsibilities there, they were either discharged or transferred to the Air Ministry.

Sanction has been obtained for amelioration of the pay and conditions of service of the permanent Inspectors of Works, thus removing a long-standing grievance. The conditions to govern the recruitment of their successors are still under consideration.

Subject to careful scrutiny of annual staff estimates and subsequent local inspection, Commands are now given a free hand as regards the engagement and discharge of civilian subordinates employed on works services within the limits of the bulk allotments made to them for payment of staff.

The pay of civilian employees has fallen considerably in accordance with civil rates. The pay and conditions of service of the civilian mechanists, Foremen of Works, and R.E. storekeepers have been improved and now conform to their responsibilities. A scheme for making civilian Foremen of Works, Surveyor's Clerks, draughtsmen and clerks employed on Engineer Services pensionable is being considered.

By the issue of Army Order 325 of 1919, the old system of granting rates of Engineer pay was abolished. Trades were divided up into groups, and each group was sub-divided into classes. Tradesmen's pay is now drawn by all arms of the Service which have tradesmen on their establishment. This necessitated the revision of all existing trade tests and the institution of new ones. To secure uniformity in dealing with this question, a Trades Committee was formed under the Presidency of the A.A.G., R.E. The duties of this committee, serving on which are representatives from all the technical arms of the Service, include the drawing up of trade tests for every trade in the Army, and dealing with questions arising therefrom.

In order to insure uniformity in carrying out trade tests, Command Testing Boards have been formed, which have authority, with the approval of the G.O.C.-in-C. or G.O.C., to convene Area Testing Boards to carry out the actual tests. Full details of the various tests and of the necessary procedure are contained in the *Regulations Governing the Issue of Tradesmen's Rates of Pay*,

CORPS ACTIVITIES.

Boundary Commissions, etc.—The termination of the War has necessitated the formation of numerous Boundary Commissions, on a number of which R.E. officers have been employed, *e.g.*, German-Polish, Saar Valley, Germany-Belgium, Austria-Italy, Hungary, Jugo-Slavia, Hungary-Czecho-Slovakia, Albanian-Serb-Croate, etc.

R.E. officers have also been extensively employed on the Military Inter-Allied Mission of Control at Berlin, and on the Railway Sub-

Commission of the Inter-Allied Railway Commission at Wiesbaden. An R.E. officer has also been employed on the Supreme Economic Council, and as British Arbitrator on the Arbitral Tribunal under the Colonial Office to consider the claims of compensation against His Majesty's Government and the Government of Palestine by the Jaffa-Jerusalem Railway Company. This officer was also employed under the Foreign Office to form one of the British Delegation to Paris to discuss the future status of Tangier, particularly in regard to the question of Tangier Harbour, which for years had been a subject of dispute between the British, French and Spanish Governments, and for which an expert of technical knowledge and diplomatic experience was required.

Turkey.—The occupation of Constantinople by a large Allied force at the end of the War threw a great deal of work on the R.E. The British troops were spread over a large area with many small and shifting detachments. In addition to holding the city of Constantinople itself, the British force had detachments throughout the area extending north to the Black Sea, on the west to the Bosphorus, as well as across the Bosphorus from Haidar Pasha (opposite Constantinople) northwards and eastwards from Ismid. Chanak and its vicinity, in the narrows of the Dardanelles, was occupied as well as the town of Gallipoli in the Peninsula of that name. Later on detachments were sent to Thrace and to the Ismid Peninsula; still later the recent Near Eastern crisis developed. This involved much work for the Corps at Kilia, described in a recent article in the *R.E. Journal.* For a short time also the Chatalja front was occupied.

At all these places the R.E. work was of the nature usual to such occupation, *e.g.*, the improvement of water supply, making hutted camps, improving the poor Turkish barracks and billets, installing electric light, etc., etc. At first large numbers of troops were under canvas, but hutting became necessary as winter approached. When the occupation started, work was carried out under war conditions, but as time went on the usual peace methods of accounting were gradually resorted to. Changes in policy led to rapid variations in the strength of the force and in its distribution, with the result that the rôle of the Engineers was made extremely difficult. In September, 1919, the strength of the British force was some 45,000; by February, 1920, it had dropped to 23,000. It then increased again temporarily, only to drop again in the autumn of 1920 to 15,000 and then to 11,000. During 1919–20 the cash expenditure on Engineer Services amounted to £150,000 and in 1920–21 to £230,000.

Iraq.—The conclusion of the Armistice found the troops in Iraq occupying tents, huts and such accommodation as could be found locally. For the next 16 months this accommodation was supplemented at the discretion of the G.O.C., during which time the administration of Engineer Services was carried out from India, the War Office merely providing the money. This dual system of control led to much delay, so from the 1st April, 1920, the War Office took over the administration.

In the absence of a decision as to the boundaries of the territory to be held, it was impossible to lay down any definite general policy, and consequently any definite works policy. Most of the troops, still quartered under active service conditions in tents and temporary shelters, were therefore not merely without comforts, recreational facilities and other conveniences normally provided for soldiers in time of peace, but were exposed to a climate which was dangerous to the abnormally young personnel then garrisoning the country. To a certain extent the situation had been relieved by billeting, but this, in addition to being an undesirable expedient, was very expensive. In October, 1919, the annual cost of billets in Baghdad alone was £28,000, and threatened to reach £98,000 in the event of payment at the rates for which the Civil Commissioners were pressing. Further serious loss was accruing from the deterioration of tentage and the pilfering of stores kept under canvas. The value of tentage alone was estimated at £1,250,000 and the annual cost of maintenance £500,000.

That permanent or semi-permanent barracks would be required was evident. The matter became urgent. In April, 1920, it was decided to provide accommodation for 1 Infantry Brigade, 1 Cavalry Regiment, Headquarters and other troops, making a total of 6,000 men. These buildings were to be of mud brick on permanent foundations, a type of construction largely used in India, as affording excellent protection against the heat. All buildings, other than those required at the base at Basra, were to be concentrated in the first instance at Baghdad. The proposed cantonments were to be at Baurah and Hinaidi—sites to the south of Baghdad occupied by existing camps. Certain roads, drains, water and lighting services, already provided at a cost of £142, 000, were available for the service of the new buildings. The cost in cash was estimated at £1,500,000. Subsequently, further provision was required in connection with water supply, hospitals, ordnance depôts, etc.

As in the case of Turkey, political uncertainty rendered the work very difficult and expansion and progress slow. In April, 1922, whilst it was still incomplete, the War Office handed over charge to the Air Ministry. At that time the following additional items had just been commenced :—

Electric Power Plant, Hinaidi	£61,000.
Engineer Shops and Stores, Hinaidi	£3,000.
Concentrate S. and T. Depôt, Hinaidi	£4,000.

Palestine.—For two and a half years after the Armistice the troops in Palestine were accommodated in standing camps and commandeered buildings. A certain amount of winter hutting had been erected, but most of the men were still under canvas and lived under conditions of much discomfort. About June, 1921, it became clear that it would be necessary to maintain a force in Palestine for a considerable period. The cost of upkeep of the temporary camps was considerable and some 4 millions in all had already been spent on them. It was, therefore, decided that cantonments should be constructed for 75 per cent. of the force at Ludd and for the remainder at Jerusalem, Jenin and Nazareth. Only preliminary work, such as water supply, roads, etc., was to be started in the first instance at the three last-named stations. In this way there would be a minimum loss in the event of a subsequent reduction in the strength of the force. As a result of this decision work was started at once at Ludd and elsewhere and £600,000 was provided in estimates for these cantonments.

However, the political situation was still very uncertain, and a few months later Mr. Churchill suggested that the whole of the British garrison should be withdrawn, leaving only Indian troops and one or two squadrons of the Royal Air Force, the whole to be administered by the Colonial Office. It was also suggested that the Colonial Office would probably delegate the administration of troops in Palestine to the Air Ministry in the same way as arranged for Iraq.

Owing to further changes in policy much work had to be suspended, although a good deal was done. About 100 barrack huts which had been sent out from England had been erected by the end of 1921. The huts were of timber framing with "trussit" (a form of expanded metal) and cement walls and plaster lining; the roofs being of corrugated iron and timber lining. The huts proved very satisfactory.

In 1922 further constructional work was carried out, including the erection of a number of store huts sent out from England. In addition, much progress was made in well boring, and water supply at Ludd was considerably improved. Many miles of metalled roads were constructed in the new cantonments. About June, 1922, the Air Ministry took over control in Palestine on the lines already suggested and relieved the R.E. of all further responsibility.

Engineer Services Generally.—Administrative and executive officers have carried on under conditions of extreme difficulty during the period under review. Policy has been subject to rapid fluctuation, due firstly to the "establishments" of the post-war Army not being fixed, and secondly to the absence of a decision as to the final peace stations of the Army. It was consequently necessary so to arrange work each year that programmes could be rapidly stopped down instead of being completed. Furthermore, it has never been possible to ensure that the funds for continuing any particular service would be forthcoming in succeeding years. The maintenance, and subsequent transfer of works services in Iraq and Palestine, affairs in Ireland, industrial unrest, the non-conclusion of peace with Turkey, and the occupation of the Ruhr, with all its consequent repercussion on the Army of the Rhine, have all contributed to the difficulty of smooth and economical administration of works services.

The formation of new units, (*i.e.*, Tank Battalions, Air Defence

Brigades), the establishment of new schools (*e.g.*, Tank School at Bovington, the School of Military Administration at Chisledon, now defunct), the inception of the new scheme for securing tradesmen for the Army, (*e.g.*, the Boys' Training School at Chepstow, see above), the broadening of the scope of the married roll, the recognition of the married officer, and the necessity of research work in connection with chemical warfare, resulting in the establishment of the Porton Experimental Station, have all thrown an immense amount of work on the Corps, not only in administering the schemes actually carried out, but in preparing and examining the numerous alternatives which never mature at all. At the end of the War, enormous numbers of huts became surplus to requirements, and, as the most pressing need at the time was for the provision of married quarters, many of them were converted to meet the need, more especially in view of the very high prices then ruling for permanent building materials.

With the gradual exhaustion of the supply of huts, the rapid deterioration of those still remaining unused, and the necessity for clearing camps, a return to brick construction is now taking place: the fall in prices since 1919–20 has rendered the difference between cost in permanent material and cost in hutting much less marked.

Since 1920 some five million pounds have been expended on "capital" services, six million pounds on "maintenance" services, and four million pounds on services necessitated by the reinstatement of private property used for war purposes.

Electrical and Mechanical Services.—Considerable progress has been made in installing electric light in barracks, resulting in large economies in actual cost of lighting and at the same time adding to the comfort of the troops. Progress has been made in the modernization of some of the more important W.D. power stations, with the result of reducing the annual running costs.

Further economies in annual costs have been obtained by the introduction of electric power drive into W.D. installations instead of steam or oil prime movers.

Design and Research Work.—A standard floating (medium) bridge has been designed to replace the old pontoon equipment and 7 bridges (126 ft.) of this type are being ordered in 1924–25.

Far-reaching results may be expected from the results of research work carried out in sound location.

Wireless sets to stand the conditions of war have been evolved and produced in consequence of the expansion of the use of wireless in the field.

Considerable progress has been made in the search for efficient Anti-Aircraft projectors (and their accessory equipment).

A new system has been adopted for the rapid erection of field telegraph lines to carry 16 wires.

Progress in wireless telephony continues and a start has been made in research of wireless mechanical transmitters.

THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914–19.

EXPERIMENTAL SECTION.

The Experimental Section grew from small beginnings. It originated in a detachment to manufacture hand-grenades organized in October, 1914, at St. Omer, by Lieut.-General Sir G. H. Fowke (then performing the duties of Engineer-in-Chief, but officially styled Engineer Adviser attached G.H.Q.). It was first under the command of Lieut. (now Captain) E. S. R. Adams, M.C., Special Reserve, R.E., who, on being ordered to the Ministry of Munitions, London, was succeeded by Lieut. (now Major) C. G. H. Bellamy, O.B.E., R. of O., R.E. The Corps was exceedingly fortunate in being able to command the services of two such officers. Backed up by Serjeant (later Q.M.S.) Griffin, R.E., and a party of N.C.O.'s and Sappers, they never failed to invent and manufacture at the shortest notice any device required by the General Staff. They developed and investigated the improvement of the service stores mentioned in the account, and conducted trials of inventions submitted. Although they had to handle many dangerous weapons, bombs, grenades, etc., they did so with so much care that the Section did not have a single casualty: for Lieut. Breeze, who was unfortunately killed by the explosion of an experimental rocket bomb, though working with the Section, did not belong to it, and was under the direction at the time of the inventor, the American, Colonel Lewis. The Section may well be proud of its record.

Chapter I.—General History.

The History of the Experimental Section dates back to the early period of the War, after the British Army had left the Marne, and when the first Battle of Ypres had been fought and the German rush to the coast definitely checked.

General Headquarters was then located at St. Omer, and amongst many units forming G.H.Q. Reserve was the 2nd Bridging Train, R.E.

The opposing armies having dug themselves in, in preparation for the coming winter, a demand naturally arose for weapons suitable for trench warfare, and the Indian Corps were amongst the first troops to use a trench mortar in its simplest form. What was probably the first 90-mm. trench mortar was made at a small paper factory outside St. Omer. The mortar consisted of a steel tube, and was mounted on steel legs with a flat steel base plate.

It was at this period, during the month of October, 1914, that the O.C. of the 2nd Bridging Train, R.E., was called upon by the Brig.-General R.E., G.H.Q. (Brig.-General G. H. Fowke), to furnish an officer to make suitable ammunition for the 90-mm. mortar from whatever local materials that were available.

The officer, Lieut. E. S. R. Adams, Special Reserve, R.E., who was detailed for the duty, had already had practice on the Aisne in manufacturing hand grenades from jam tins to supplement supplies to Field Companies, and had also had civil workshop experience before the War.

Formation of the Section.—In the barn of a farmyard of the château at Tilques, near St. Omer, the unit which eventually became the Experimental Section, R.E., was founded, and for two months, until the end of December, an officer with 8 Sappers of the Bridging Train manufactured ammunition for the 90-mm. mortar, and during this period produced several hundred projectiles. At the same time another improved pattern of hairbrush hand grenade was turned out in considerable quantities and supplied to the troops in the line.

Rocket Gun.—In January, 1915, the B.-G., R.E., directed that experiments should be taken in hand to develop an invention brought out to France at that period by Colonel Lewis, of the American Army, the inventor of the Lewis gun. The invention consisted of firing from a mortar a shell on the principle of the rocket, and considerable experiments were carried out with it. The mortar and shells were manufactured locally, except for certain parts which had to be obtained from London or Paris.

These trials continued for some considerable time and were successful, but, owing to the great visibility of the trail of the rocket and consequent danger of the battery position being easily located, together with the erratic flight of the projectile, the rocket gun was dropped and superseded by the 2-in. trench mortar produced at Woolwich, which fired a projectile commonly known as the "football" bomb.

During this period, the workshop was removed to the château at Tilques, and in March a corporal (Corporal S. Griffen, R.E.) and eight men were detailed from the 29th Advanced Park Co. R.E., G.H.Q., to supplement the small staff of Sappers available from the Bridging Train.

Rifle Grenades.—In the summer of 1915 the demand for grenades was insistent, and in August the Experimental Section was transferred to St. Omer and fitted out with a barge on the canal. The barge was equipped with a 5 h.p. Aster engine and one lathe, which was obtained from Paris, and another lathe from the 29th Advanced Park Co., R.E.

The Section became then definitely (though unofficially) part of the R.E. Establishment at G.H.Q., and the officer in charge became known as the Experimental Officer to the Chief Engineer.

Experiments with rifle grenades continued for a considerable period. The No. 3 Hales rifle grenade had been in use for some time, but in small quantities. The demand for a good rifle grenade was considerable, and, to meet the demand, the No. 5 Mills grenade, in use as a hand grenade, was fitted with a rod; the cup attachment introduced later into the Service was the production of the Experimental Section.

About this period, the Newton, Sangster and Townshend rifle grenades appeared, and considerable experiments were carried out to devise a good percussion rifle grenade both in England and in France during the winter of 1915-1916. Two patterns were made, but difficulties in manufacture in England prevented these being taken up.

Of those produced in local army workshops in France the Newton was the only grenade which eventually went home for manufacture, and for some time the No. 5 Mills hand, No. 23 Mills rifle, No. 20 Hales (modified No. 3) and No. 22 Newton grenades, were all manufactured and sent out from England, and supplemented by local supplies from workshops in France.

General Experimental Work up to 1916.—During the summer and autumn of 1916, considerable experimental work was done in connection with devising simple types for manufacture in bulk, either in England or in the army workshops, of varied trench warfare stores and devices, such as trench barriers, parapet shields, rifle clinometer for grenades, screw pickets, torpedoes, portable charges, etc. Experimental work was also carried out with various grenade throwers, spring guns and catapults.

In October, 1916, the 3-star parachute signal was initiated, and eventually the No. 27 smoke rifle grenade with yellow phosphorus was developed, and this superseded the red phosphorus "P" bomb with its various types of fittings for firing from the rifle.

In the early part of 1916 the first percussion flare to fire from the $1\frac{1}{2}$-in. Very pistol was suggested, and a flare was designed and produced in the Experimental workshop which was made and tested with very good results, and was sent home for manufacture in quantity.

Inventions Committee.—During the whole of this period, the Experimental Officer to the Chief Engineer, apart from his duties in the experimental workshop, had been a member of the Experiments Committee formed in June, 1915, and consisting of officers appointed by the General Staff, Artillery Adviser, and Chief Engineer. Inventions submitted to G.H.Q. in connection with trench warfare stores and devices were considered by the Committee, and action taken accordingly; and experiments were carried out whenever the suggestions put up warranted further investigation. The Experiments

Committee, though not definitely abolished, eventually dissolved, and the Experimental Officer R.E. was called in by the General Staff to advise directly on various inventions submitted, the experimental work being closely followed by the General Staff and directed as occasion demanded.

Efforts were made to have the Section brought officially on to the Chief Engineer's Establishment, but for various reasons this was not approved.

Move of General Headquarters.—In March, 1916, General Headquarters moved to Montreuil-sur-Mer, and the Section took up its abode in the back shed of a private house by the South Gate near the main Montreuil-Abbeville road.

At this time the Section consisted of 1 officer, 1 serjeant and 8 sappers of various trades, and had 2 lathes, 1 drilling machine, 1 blacksmith's forge and 1 acetylene welding plant, together with various bench tools—a press, shears, etc.

Experimental work during the autumn of 1916 had been concentrated on devising improvements in rifle grenade cartridges, and experimenting to ascertain the causes of accidents when firing rodded rifle grenades. The 35-grain cordite rifle grenade cartridge had never been satisfactory, and a considerable number of burst barrels and prematures with the grenades were occurring. It was owing to these experiments that the cause of many accidents was traced to the use of wax wads in the mouth of the cartridge, which had been inadvertently introduced during manufacture in England.

Change in Command.—About the end of 1916, it was decided that it would be an advantage to have an officer in the Ministry of Munitions who had had experience of the requirements of the British Armies in France, and who had sufficient technical knowledge to be able to assist in controlling the design of various stores demanded from England from time to time, and who, in this capacity, would be able to represent the views of the General Staff on the subject of trench warfare production. The Experimental Officer (Lieut. Adams) was therefore transferred to the Design Branch of the Ministry of Munitions, and in March, 1917, handed over his duties at G.H.Q. to an officer from the 29th Advanced Park Co. R.E., Lieut. C. G. H. Bellamy, Special Reserve, R.E.

Further Developments in Grenades.—About Christmas, 1916, a change had come in the history of grenades, when the introduction by the French of a bulleted round grenade, fired from a cup attachment on the rifle, drew attention to what appeared to be a great stride in the development of rifle grenades. The attachment of a cup discharger on the rifle did away with the necessity of fitting rods to the grenades—a continual source of damage to the rifle—and an endeavour was made to devise some means of attaching a discharger cup on to the Short M.L.E. rifle in use by the British Army.

Various fittings were made and experimented with and in March, 1917, an officer of the Munitions Inventions Department brought out to France a fitting which was taken up as being the best design, and a demand arose immediately for supplies of dischargers fitted to the short rifle, and which could fire the Mills grenade.

Experimental work then was turned on to evolving a gas-port for varying the range, and the Experimental Section produced a pattern, which in April, 1917, was taken home to the Ministry of Munitions, and was used as a guide in designing the type which was embodied in the discharger eventually produced.

In June, 1917, a revised establishment was approved for the Engineer-in-Chief's Office, and the appointment of Experimental Officer, graded as a Staff Captain, was included in this establishment.

Smoke Screens.—Considerable experimental work was done during the summer of 1917. A demand arose for smoke barrages for operations in screening infantry concentrations and attacks and also artillery positions, and a smoke case was evolved which was made of materials supplied by Ordnance, mixed and poured into 18-pounder shell cases. A small party of the Section was sent to the Fourth Army on the coast to manufacture these cases in quantity, and during the six weeks they turned out several thousands with the assistance of local labour.

Armour Plating Protection.—Considerable trials were carried out during the summer of 1917 to find a material for facing loop-hole plates as a protection against armour-piercing bullets. In April, 1917, the armoured cars of the Cavalry Corps were found to be penetrated by German armour-piercing ammunition. After experiments were carried out, the cars were fitted with sheets of uralite as a protection, but not with very satisfactory results. Trials with Japanese parapet shields showed that uralite was one of the best protective coverings, but that no material light enough to be of practical use offered any appreciable protection, and these experiments were dropped.

Combined Hand and Rifle Percussion Grenades.—In the summer of 1917 endeavour was made to evolve a suitable design of percussion grenade mechanism for a grenade for combined hand and rifle use. The discharger, in doing away with rodded rifle grenades for a range up to 200 yards, necessitated using the Mills time grenades without a rod, but fitted with a flat steel gas check. With its extra time of burning of the fuze for a maximum range of 200 yards, the Mills rifle grenade was introduced into the Service as the No. 36. Several types of hand percussion grenades had been submitted to G.H.Q., including the Humphries, Nissen, and Daniels and Gardner grenades, but none of these were quite satisfactory. Experiments were carried out to improve the Nissen percussion mechanism and a bulleted round grenade on the same lines. The Experimental Section tested all the types submitted and reported on their various defects, and suggested methods for improving them. It became evident at this period that, if a satisfactory percussion mechanism could be evolved, which was simple to manufacture, another big step in the development of grenades would have been reached.

The Egg grenade had been previously developed with a "hit" mechanism on the same lines as the phosphorus grenade and 3-star signal, and was known as the No. 34 Egg grenade. Experiments were carried out to fire this from the Mills discharger or a discharger with smaller diameter, but owing to the development of percussion mechanisms, and obvious advantages of such, the method of firing the Egg grenade from the rifle was not introduced. Eventually about December, 1917, a promising percussion mechanism was evolved in the Experimental Section shops, and the Ministry of Munitions were asked to turn out a large quantity for trial purposes.

During the winter of 1917 the workshop was increased considerably in size.

In order to cope with the work, the Section was given a second officer, a trained mechanical engineer, Lieut. J. McAllister, R.E., who had served 2½ years in the infantry.

With this extra assistance a larger variety of experimental work was enabled to be taken up.

The demand for repetition work for making percussion mechanisms and other devices necessitated obtaining more lathes and other machinery. The shop was therefore equipped with a capstan lathe, a shaper and power press, and another shop was erected behind the buildings, in order to accommodate the tinsmith, carpenter and extra blacksmith, and also stores to contain explosives and grenades.

Various other devices were experimented with at this period, including the development of the mud punt, designed by Lieut.-Colonel Nissen, and the design of a suitable model aeroplane track for training machine gunners at the Lewis gun schools.

Anti-Tank Defence.—In the early spring of 1918, a demand arose for contact mines for anti-tank defence, and these were satisfactorily developed, the mechanism depending on the shearing of a gramophone needle. Considerable quantities were used prior to the German attack in March.

An anti-tank grenade was also developed, and, after a long series of exhaustive experiments, the No. 44 grenade was evolved, which proved to be a very deadly weapon.

Various experiments with machine-guns and mortars were undertaken during the summer of 1918, and at this period the duties and scope of the Section had considerably increased.

The duties at that time consisted of the following :—

Experimental work.

Investigation of new types.

Improvement of existing types.
Reports as to the suitability of new types.
Investigation of accidents and general advice as regards:

(1) Hand grenades.
(2) Rifle grenades.
(3) Rifle grenade dischargers.
(4) Grenade guns.
(5) Firework signals for all branches of the Service, including the R.A.F.
(6) Light machine-guns in connection with mountings and various mechanisms connected with the same.
(7) S.A.A.—including tests for penetration of all types.
(8) Loophole plates.
(9) Parapet shields.
(10) Body armour.
(11) Periscopes.
(12) Hyposcopes.
(13) Smoke generators.
(14) Illuminating devices.
(15) Message-carrying projectiles.
(16) Mines.
(17) Light mortars and mountings.

This work included comparative trials between British and German types, and trials of types used by other Armies in the field.

The Experimental Section was responsible for compiling technical portions of handbooks dealing with the experimental workshop, and also to the Engineer-in-Chief for giving such advice under the above headings as was necessary to enable the General Staff to decide the various questions of policy which constantly arose.

Dangerous Nature of the Work necessitated Change of Site.—During the whole history of the Section, for a period of over four years, although continuously dealing with explosives and materials, no serious accident occurred, with the one exception of the fatal accident to Lieut. Breeze, an assistant of Colonel Lewis, killed by a premature during the closing experiments with the Rocket Gun.

This general good fortune was greatly due to the care and skill of the senior N.C.O., Serjeant (afterwards Q.M.S.) Griffin, a regular R.E., who invariably did the really dangerous duties himself.

The congestion due to increasing work, as well as the possibility of danger to the local inhabitants, made a change of site essential, and in 1918 the use of a field outside the town was obtained, and the necessary buildings erected.

The office of the Officer in Charge of the Section was moved at the same time from the Headquarters offices to this new site, and the Section became practically an independent unit.

In September, 1918, with the approval of the General Staff, an establishment for a separate unit was drawn up, and was eventually sanctioned in October.

The unit then consisted of the following :—

1 Major.
1 Lieut.
1 Q.M.S.
2 Corporals. } Artisans.
10 Sappers. }
1 Clerk.
3 Draughtsmen.
with one box car.

The last period in the history of the Experimental Section during the winter of 1918–1919 was spent in the development of the Lewis gun, percussion grenades, Stokes mortar, anti-tank Stokes mortar mounting and various miscellaneous fireworks and stores.

Considerable time was spent during the summer of 1918 by both the officers of the Section on the evolution of an aeroplane height finder and a system of automatic sights for aeroplanes. Two height finders were evolved, one of which was introduced into the Service for instructional purposes at Schools.

Aeroplane Height Finders and A.A. Automatic Sights.—The system of automatic sights was demonstrated to a committee at the Lewis Gun School, and created a very favourable impression.

It was proposed by the officers concerned to make it the subject of a special paper, and to offer it to the Government, after the principles had been protected, as it was chiefly applicable to anti-aircraft guns.

Lewis Guns.—Experimental work on the Lewis gun consisted of evolving a satisfactory method of varying the rate of fire, and a suitable mechanism was demonstrated at the Lewis Gun School with satisfactory results.

At the same time, a simple trigger mechanism was designed, by means of which single shots could be fired at will, and which could be clamped to the gun without alteration.

Samples were being made, as it was proposed to introduce this, when the Armistice was signed.

All this experimental work was carried on before the light Lewis gun had been introduced, for by means of a single-shot firing mechanism the radiator and casing of the standard Lewis gun could be dispensed with, thereby reducing the weight of the gun by about 9 lbs.

When the new light gun with its single-shot firing mechanism arrived in France no further experiments were made with the slowing-down gear, and attention was turned to designing a mounting for the Stokes mortar, by means of which the mortar could be fired at low angles for anti-tank use.

Stokes Mortars.—Various experimental work with the 3-in. Stokes mortar had been carried out, and all the sample brackets for the use of the mortar for anti-aircraft fire were evolved in the shops and sent to England. The anti-tank Stokes mortar mounting consisted of single man loads, and the gun could be fired at high and low angles at will. This mounting proved to be the only one of its kind produced, although many had attempted a solution of the problem; the difficulty being to make all the parts light enough to break up into single man loads.

Final Percussion Grenade.—The final effort of the Experimental Section was the evolution of the combined hand and rifle percussion grenade, started at the beginning of 1918. Three types of grenades were evolved, all on the same principle, but requiring different degrees of skilled manufacture. The final pattern, practically all the parts of which were pressed and stamped, was taken to the Second Army Headquarters at Cologne in February, 1919, and, after trial by three different Divisions and one Corps School, was very favourably reported on, and a recommendation was made that this type should be introduced into the Service in place of all other types of grenades, except the smoke grenade, and also that the smoke grenade should be fitted with a similar mechanism. The safety mechanism for this grenade consisted of a lever which only came off in flight if thrown by the hand or fired from the rifle, and with a 2-in. discharger the range obtained was about 350 yards, with considerably greater accuracy than any rodded type of grenade.

This practically terminated the history of the Experimental Section, and it was broken up in April, 1919.

It would be impossible to make a complete list of all the various articles experimented with and dealt with by the Section during the whole of its history, but it is safe to say that practically no device invented at home or in the Army in France connected with grenades, firework signals, and trench warfare weapons generally, did not at some period find its way to the Experimental Section for consideration or experiment, while many of the stores in regular use were actually initiated in the workshops.

In the following pages technical details are given of the evolution of the more important articles, with illustrations of the principal types designed or experimented with.

CHAPTER 2.—GRENADES.

The earliest hand grenades produced were of two types, the jam tin and the "hairbrush," both of which are illustrated (see *Plate* I, *Figs.* 1 and 2). A few of these were made, before the formation of the Experimental Section, by various field units. They were necessarily crude, and usually consisted of gun-cotton slabs and primers made up into the most suitable forms and fired by a detonator, with 5 secs. of safety fuze lit with a match.

At Arques, on the formation of the Experimental Section in October, a second and rather less crude form was produced, illustrated in *Fig.* 3. Splinters were introduced as much as possible amongst the high explosives, and tin cases were filled with fragments of iron, and in the "hairbrush" pattern pieces of scrap metal and nails were let in under the wire holding the gun-cotton slab in its place.

Some time before service grenades began to arrive in quantity from England a great demand arose, and the Battye, Pitcher, Bethune and No. 8 double cylinder hand grenades were manufactured in army and local workshops. The patterns were illustrated in *Notes on British, French and German grenades* (O.B./711 Confidential) issued in France in September, 1915.

Local contracts were also placed for manufacture of the Mills No. 5, which was in great demand after its introduction, but supplies of which were at first very slow in arriving from England.

During the summer of 1915, owing to the incessant demands for a rifle grenade that would outrange the ordinary throw of the hand grenade, troops of several Divisions put up suggestions and carried out experiments in firing the Mills from the rifle, and the Experimental Section developed what eventually became the No. 23 Mills rifle grenade (*Fig.* 4) with its cup attachment.

One of the original suggestions submitted to G.H.Q. consisted of simply fitting a clip to the bayonet, so that the lever of the Mills grenade was held in place until the grenade left the rifle. This necessitated placing the bomb in one particular way and was therefore not sound.

The cup attachment illustrated in *Plate* II, *Fig.* 1, produced by the Experimental Section, was adopted after trial by armies, and sent to England for manufacture in quantity. The attachment was stamped out of sheet iron, and bent round and welded, and was very simple to manufacture, and owing to its being in the form of a ring the grenade could be placed in any position with safety.

Attempts were made to devise a really safe percussion mechanism for a rifle grenade, and the Experimental Section produced two types, one of which was the conversion of the Mills No. 23 with a percussion mechanism (*Plate* II, *Fig.* 2), and another with a delay trail which rendered the grenade exceedingly safe to handle, as it did not arm until the trail had burnt away, after it had travelled some distance in its flight. This percussion rifle grenade, illustrated in *Plate* II, *Fig.* 3, had two steel balls which kept the striker pellet in place. On firing, the striker pellet, which carried the trail of black powder, set back on to another striker in the base of the grenade and started the trail burning. The trail burnt away in a few seconds, and on impact the balls were pushed into the holes left by the burnt-out trail, and the striker pellet was free to move forward and fire the cap.

Difficulties, however, were encountered in England in making a satisfactory delay trail of black powder, and this pattern was not manufactured.

The shortness of range obtained with the Mills percussion (*Plate* II, *Fig.* 2) did not give it any great advantage over the No. 23, but the mechanism was interesting. The lever acted as the safety device, and it prevented the striker, carrying the mushroom head, from firing the cap. When fired from the cup attachment on the rifle, and the safety pin removed, the lever flew off in flight, leaving the mushroom head free to move on impact. A balance spring was introduced below the main spring to prevent the mushroom head from setting back on shock of discharge and jamming the lever, and so preventing it from falling off. Also, as the grenade was fitted with an instantaneous fuze, a special cap holder was used to prevent the cap being fired by the flat striker of the ordinary Mills grenade, should the igniter set have been inadvertently placed in the No. 5 or No. 23 time grenades.

Prematures occurred at all times with all types of grenades, and the difficulty was to design a pattern that could easily be manufactured and which did not arm itself until it had left the rifle. The Newton was dangerous for this reason, but, after considerable experiment, a lighter cover was introduced, and various other safety devices were tried with it, but none of them were introduced for home manufacture. The Experimental Section fitted two clips under the cover, which were held in place by a collar setting back on shock of discharge and releasing the clips. This was an ingenious scheme, but the supplies of grenades from home were fitted with the light cover and a tin protective cover over the cap of the detonator sleeve, so that it could only be fired by a severe blow. Few, if any, prematures occurred with this type.

The Gauchet grenade (*Plate* III, *Fig.* 1) was given several tests and improved upon by the Experimental Section, but was by no means safe, and was given up, as was also the Sangster (*Plate* III, *Fig.* 2). The Hales No. 3 (service) rifle grenade was modified into a much improved pattern and the wind vane done away with. The grenade had simply a set-back collar releasing two pellets holding the striker, and was called the No. 20. The grenade was found satisfactory and supplied in large quantities, and, except for a few prematures which occurred, was safer than any other pattern. Manufacture was concentrated on it, and improvements were made which produced the No. 24 (*Plate* III, *Fig.* 3).

The cartridge used for the rifle grenades was at this time the cartridge supplied for the No. 3 Hales, and consisted of a blank round of 35 grains of $3\frac{3}{4}$ cordite. *Plate* IV shows this cartridge and the various developments from it. Owing chiefly to inferior cordite, the rifle grenade cartridge (35-grains) was not a complete success, and experiments were carried out in France by the Experimental Section to ascertain the cause of burst barrels and prematures that occurred with the Hales grenades.

In the case of burst barrels, the grenade frequently prematured as well, and the rod was found stuck in the barrel. The barrel after a few rounds began to bulge at a place opposite the end of the rod both with the No. 23 and Hales grenades, and in many cases the bulge eventually developed into a burst, unless detected in time. This was attributed to the gases impinging on the end of the rod, and if the rod was at all chamfered the bulge was considerably worse. To prevent this, gas checks on the end of the rod were tried. The ranges obtained, however, were so very erratic with grenades fitted with gas checks that they were abolished. *Plate* IV, *Figs.* 2 and 3, show two patterns used with the Newton (Second Army) grenades, the Adams pattern with the coned washer being the type made by the Experimental Section.

It was not until after considerable experiment that it was discovered that many of the failures of the barrels and prematures were due to the introduction by some manufacturers of a wax wad in the mouth of the cartridge. The first specification drawn up by the Ministry of Munitions showed that the mouth should be filled with varnished tallow. Some manufacturers used beeswax. The effect of firing the blank round with wax in the mouth was that the end of the rod received such a severe blow that it was set up; the grenade, then being propelled and armed, was suddenly checked owing to the setting up of the rod, causing the percussion mechanism, in the case of the Hales grenade, to function while still in the barrel.

Steps were taken immediately to stop the use of cartridges filled with wax and any further manufacture of them, and tallow was reverted to. Tallow, however, was not good, as it melted in the summer and affected the cordite, causing short rounds. It was not until the Munitions Design Department produced a paper cup pressed in to seal the cartridge that a cure was found, and by that time the 43-grain cartridge had been introduced, and all the 43-grain cartridges were sealed in this way (*Plate* IV, *Fig.* 4).

A 43-grain cartridge, filled with tallow, appeared during 1916 with the object of improving the degree of cordite, but was no great improvement on the 35-grain.

The advent of the paper wad for filling the mouth of the cartridge, in the summer of 1917, gave the first cartridge which was suitable for use with all types of grenades. The 43-grain used a thicker and better brand of cordite—$4\frac{3}{4}$—and was slower burning, and suited all grenades except the Hales. The set-back collar of the Hales No. 20

and No. 24 did not always function with the 10 in. rod, and the No. 35 was fitted with an easier fitting collar accordingly.

With the long rodded Newton grenades, the 35-grain was unsatisfactory, as the rate of burning was high, and owing to the small chamber space left by the long rod the temperature set up was too great and caused the casing to be brazed to the barrel. In these grenades, therefore, the ordinary bulleted round cartridge with the bullet removed and filled with tallow was employed. This cartridge used with short rods was a danger and unsatisfactory, as, owing to the long chamber space, the cordite did not always burn through in time and blew up the barrel, causing short rounds with the No. 23 Mills.

The Experimental Section took a big part in the development of these cartridges, and it was to a great extent owing to their experiments that the causes of defects were found and a universal cartridge introduced.

Above all types of grenades the Mills was supplied in the largest quantities, and experiments were continually carried out to improve it, and to investigate various accidents that occurred from time to time. Locally made Mills grenades were not in many cases successful, and were condemned by the G.H.Q. Board. Prematures frequently occurred with the Mills, and for a long time the causes were not clear, owing chiefly to the difficulty of getting particulars.

All accidents were reported to G.H.Q. and investigated technically for the period of the whole War by the O.C. of the Experimental Section and, as a result of experiments, one great cause of failures was found, *viz.*, that the gases from the burning fuze could not escape easily enough when the cap had been fired. A central fire cap was used and, although the cap holder had holes in it for gases to escape from the fuze, the striker and spring blocked most of the passage way. The Experimental Section then devised the rim fire cap, and a slotted striker, so that the gases blew up the centre of the cap, out past the slot in the striker, and then up the central passage past the spring. Frequently accidents occurred from the striker slipping out through the jaws of the lever while it was still in hand. If the thrower then lost his head the grenade would go off in the hand. The striker introduced into the No. 36 Mills grenade prevented any possible failure from this cause, and the Mills of the last period of the War, thanks greatly to the work of the Experimental Section, was as safe a grenade as its design permitted it to be.

Prematures still occasionally occurred when fired from the rifle even in 1918, and this could only be attributed to bad crimping of the fuze, so that, on shock of discharge, the fulminate in the detonator set back on to the end of the fuze and detonated. Only careful manufacture and inspection could avoid this cause of danger, as owing to the design of the grenade, it could not be altered.

During 1916, the Newton No. 22, Mills Nos. 5 and 23, and Hales Nos. 20 and 24 were the patterns mostly used, and during this period the Experimental Section occupied considerable time in investigation and working on improvements of these grenades and experimental patterns, and also in the production of a good cartridge.

About Christmas, 1916, the French invention of a discharger cup fitted to the rifle opened up a new era in the experimental work on grenades. The grenade had a hole in it and was fired by a bulleted round. Attempts were at once made to fit a similar discharger to the short M.L.E. rifle. The best fitting of its type was produced by the M.I.D. in London, illustrated in *Plate* V, *Fig.* 1, and was introduced into the Service in the summer of 1917. Experiments were then concentrated on the design of a gas-port for this discharger. It was decided to use the Mills grenade and not a special pattern similar to the French. Experiments were carried out, and trials showed that a plain disc was more suitable and gave more accurate results and greater ranges than with a ring cast on the body of the grenade, or than a flanged gas check for firing the grenade (*Plate* V, *Fig.* 2). The Mills was then given a 7-secs. fuze, had a range of 200 yards, and was known as the No. 36 grenade. A suitable gas-port was evolved for varying the ranges, and in May, 1917, was sent to England to the Ministry of Munitions, where it was used as a guide in manufacture.

The introduction of the cup discharger necessitated experiments being undertaken to produce another cartridge, as different conditions were set up in the barrel. The cordite cartridge was too slow in burning to develop pressure rapidly enough to eject the grenade with any degree of consistency, and only one pattern of 35-grain cartridge, manufactured by Messrs. Eley Bros., gave anything like fair results, the other 35-grain cartridges and particularly the 43-grain being useless for the purpose.

A cartridge containing 30-grains of ballistite was therefore introduced for the purpose and is illustrated on *Plate* IV, *Fig.* 5. This cartridge had its case bronzed for the top half of its length, while the 43-grain, to distinguish it from all others, was completely bronzed.

The use of the discharger naturally opened up a new field of investigation for grenades, especially as regards the "Always" type of percussion hand grenades. A grenade of this nature, which should be both safe in use and simple in manufacture, provided much food for thought.

It was clearly an advantage if the hand percussion grenade with an "Always" mechanism, which would fire in whatever position it fell, could also be used with the discharger, so that the same grenade might be used for both purposes.

The first percussion hand grenade to be sent out to France and tested was the R.L. percussion grenade, but at that time, 1916, this was not safe enough, although it developed later into the Humphries and

C.S.O.F. patterns. The No. 19, which was a percussion with a mushroom head but not an "Always" fuze, was not satisfactory, and, although more scientific as regards its fragmentation and functioning mechanism, was not a great advance on the No. 1.

Experiments were put in hand to develop a suitable "Always" percussion mechanism, in accordance with the following conditions:

PERCUSSION GRENADES.

Essential.

(1) The grenade must be damp-proof.
(2) The grenade must be capable of withstanding rough usage, and its action must not be impaired by mud.
(3) The grenade must be furnished with a positive safety device, such as a safety pin.
(4) The grenade must only arm itself in flight, and must be safe when dropped on the ground, the safety device having been removed.
(5) The grenade must be safe when held in the hand after the safety device has been removed.
(6) The grenade, having armed, must be sufficiently sensitive to function on impact with soft mud.
(7) The fragmentation must be satisfactory.

Desirable.

(1) It should be capable of being used as a hand or rifle grenade.
(2) The weight should not exceed $1\frac{1}{2}$ lbs. and the design should be such that smaller sizes down to 12 ozs. can be made.
(3) The shape should be convenient for throwing.
(4) It should not have stick or streamers, nor should it be necessary to throw it in any particular way.
(5) "Blinds" should be safe to handle with reasonable precautions.

After much trial and experiment with various types, a pattern was evolved in the experimental workshops which was simple to manufacture and which gave very promising results (*Plate* VI).

The first pattern of the kind was sent to England in January, 1918, for 1,000 to be made for trial, and experiments were continued to improve its simplicity from the manufacturing point of view. The mechanism thus developed is illustrated in *Plate* VII and it was further developed by the Experimental Section into the "B" pattern illustrated in *Plate* VIII.

This latter grenade was made of parts nearly all stamped out and pressed from sheets, and with a 2-in. diameter discharger a range of 350 yards was obtainable. The safety device was the greatest problem of all, as the tape used in the "A" pattern was never considered favourably. The lever evolved and introduced into the "B" type met with great success and, in November, 1918, 200 of the Bellamy "A," which had eventually been manufactured by the Ministry of Munitions, and five other types were tested in comparison. Of these, the two types of Bellamy and one known as the C.S.O.F. were selected in preference to two others—the Vickery and Coles. 2,000 of each of these three were demanded from home for trial by troops, but after the Armistice no further experimental contracts were placed in England. In order, however, to get a practical opinion on the question of percussion grenades, the two types available in France, the Bellamy "A" and "B," were shown to the Second Army at Cologne, who recommended that the "B" pattern with lever should replace *all* other types of grenades in use except the smoke grenade, and this opinion was endorsed by the General Staff and communicated to the War Office accordingly.

This closed the history of development of the percussion grenade with which the Experimental Section had been so long and closely connected.

The Bellamy grenade was so safe that it could be shaken and carelessly handled, or rolled on the ground, without danger, even with the safety lever off, and yet was sufficiently sensitive to go off if lobbed over a parapet on to soft soil. All other patterns were very much more sensitive, and a more sensitive grenade did not appeal to the troops asked to give these grenades a trial.

The Experimental Section was called upon to test various other types, including the Humphries grenade in June, 1917, and the Chamier in June, 1918.

The Chamier was highly dangerous, but the Humphries developed into the C.S.O.F. referred to previously.

Suggestions were made in 1917, to alter the range of grenades by means of allowing different lengths of rod to protrude from the barrel, and *Plate* IX shows a method devised in the XIII Corps with the Newton grenade.

The Experimental Section in July, 1917, carried out experiments on these lines and rubber was used in the form of a ring slipped over the rod. The rubber ring was simply stamped out of sheets of inner tube of a motor car tyre, and was quite satisfactory. This method was adopted, and range cards made out for use with the rings, and supplied to the troops in 1918. This method of altering the range was, of course, only suitable for trench warfare, and after the introduction of the discharger and No. 36 grenade little use was made of the device.

Several suggestions were submitted from time to time for the use of clinometers when firing grenades, but the general opinion was that the long rodded rifle grenades were not nearly accurate enough to warrant the introduction of such refinements. A simple clinometer was evolved in the workshop but was never introduced, as the demand was small. The rubber rings were considered a better method of altering ranges than altering the elevation, as low angles could not easily be got in a trench without exposure, and high angles made the flight still more erratic. With the No. 36 the gas-port met the case, and even then a clinometer to regulate the fixed angle of 45° was not called for, as the rifle could be held after practice at very nearly the correct angle—in any case sufficiently correct in relation to the accuracy of the grenade itself.

A complete history of grenades needs a volume to itself. All that has been attempted here is to describe and illustrate the types actually experimented with and developed by the Section in the course of work which had a considerable share in, and influence on, the evolution of the grenade.

The anti-tank grenade is described later under "Anti-tank Defence Weapons."

Appended will be found a list of all the service grenades and signals to which series numbers were given, and a table of ranges of rifle grenades.

RANGES.

Grenade.	*Length of Rod.*	*Ranges.*
No. 24.	15 in.	360 yards with 43-grain cartridge.
		345 ,, ,, 35 ,, ,,
,, 35.	15 in.	350 ,, ,, 43 ,, ,,
	11 in.	260 ,, ,, 35 ,, ,,
	11 in.	270 ,, ,, 43 ,, ,,
,, 39.	11 in.	260 ,, ,, 43 ,, ,,
	15 in.	330 ,, ,, 43 ,, ,,
,, 22.	15 in.	340 ,, unbulleted.
,, 27.	15 in.	250 yards with 35-grain cartridge.
		260 ,, ,, 43 ,, ,,
		Open. Yds. — *Shut.* Yds.
,, 37.	Cup.	100 — 250
,, 36.	Cup.	80 — 210
,, 23.	Cup attachment.	100 yards with 35-grain cartridge.

GRENADES AND SIGNALS.

No.

1. Service, Hand, R.L. Percussion—Cane Handle.
2. Tonite or Mexican (Hales Percussion with cane handle).
3. Hales Rifle (J.A. pattern) with Vane.
4. ——
5. Mills, Hand.
6. R.L. 1 lb. friction igniter, hand.
7. R.L. 2 lb. ,, ,, ,,

No.

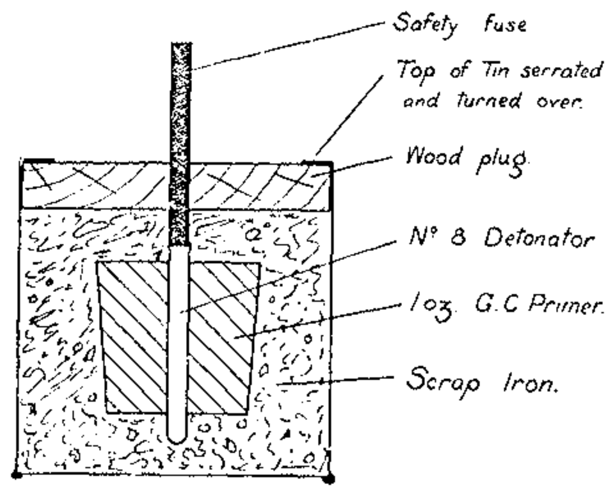
8. Double Cylinder, light patt. (No. 8 Detonator), shrapnel bullets in tin container.
9. Double Cylinder, heavy patt. (No. 8 Detonator), shrapnel bullets in tin container.
10. ——
11. ——
12. "Hairbrush" or Box Pattern, wood handle, No. 8 Detonator, Spring Striker.
13. ——
14. Battye.
15. Pitcher.
16. Oval.
17. Ball.
18. ——
19. Mushroom Percussion Grenade.
20. Hales Vaneless Rifle (long tube).
21. Newton Pippin Rifle Percussion.
22. ,, ,, ,, ,, Mark I and II.
23. Mills No. 5 and Rod—Rifle.
24. Hales Vaneless No. 20 modified—Mk. I modified known as Mk. II, Mk. II known as No. 35 Mk. I.
25. ——
26. "P" Bomb—Red Phosphorus.
27. Phosphorus, white, rifle and hand.
28. Gas Bombs, M.S.K.
29. ——
30. ——
31. Signal Rifle Grenade, Rod (Day).
32. Signal Rifle Grenade, Rod (Night).
33. Hilite.
34. Egg Bomb, Mark III.
35. Hales No. 24 Mk. II—Mk. I.
36. Mills No. 23 with disc for Discharger.
37. No. 27 for Discharger.
38. Signal Rifle Grenade, Rod, Changing Colour.
39. Steuart Fuze Rifle Grenade.
40. ——
41. ——
42. Smoke Parachute Discharger Signal.
43. 3-Star Parachute Discharger Signal.
44. Anti-tank Grenade.
45. Changing Colour Parachute Discharger Signal.
46. ——
47. ——
48. ——

(*To be continued.*)

Plate I.

Fig. 1.

JAM TIN HAND GRENADE MADE ON THE AISNE, 1914.



STICK HAND GRENADE MADE AT ARQUES.—November, 1914.

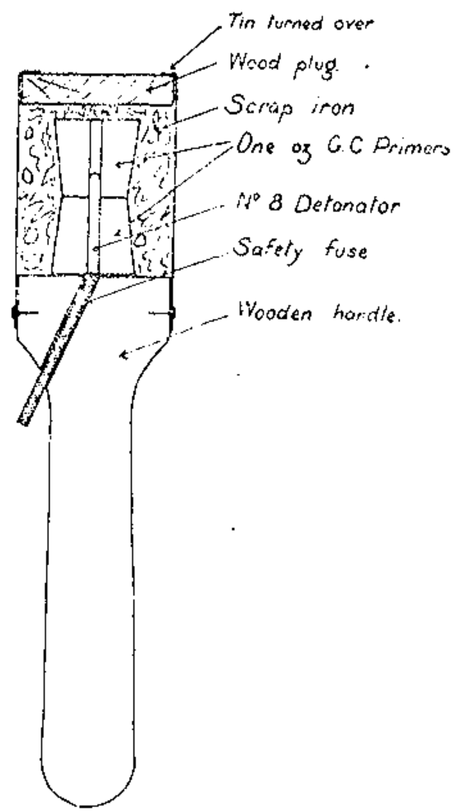


Fig. 3

Fig. 2.

STICK HAND GRENADE MADE ON THE AISNE.—September, 1914.

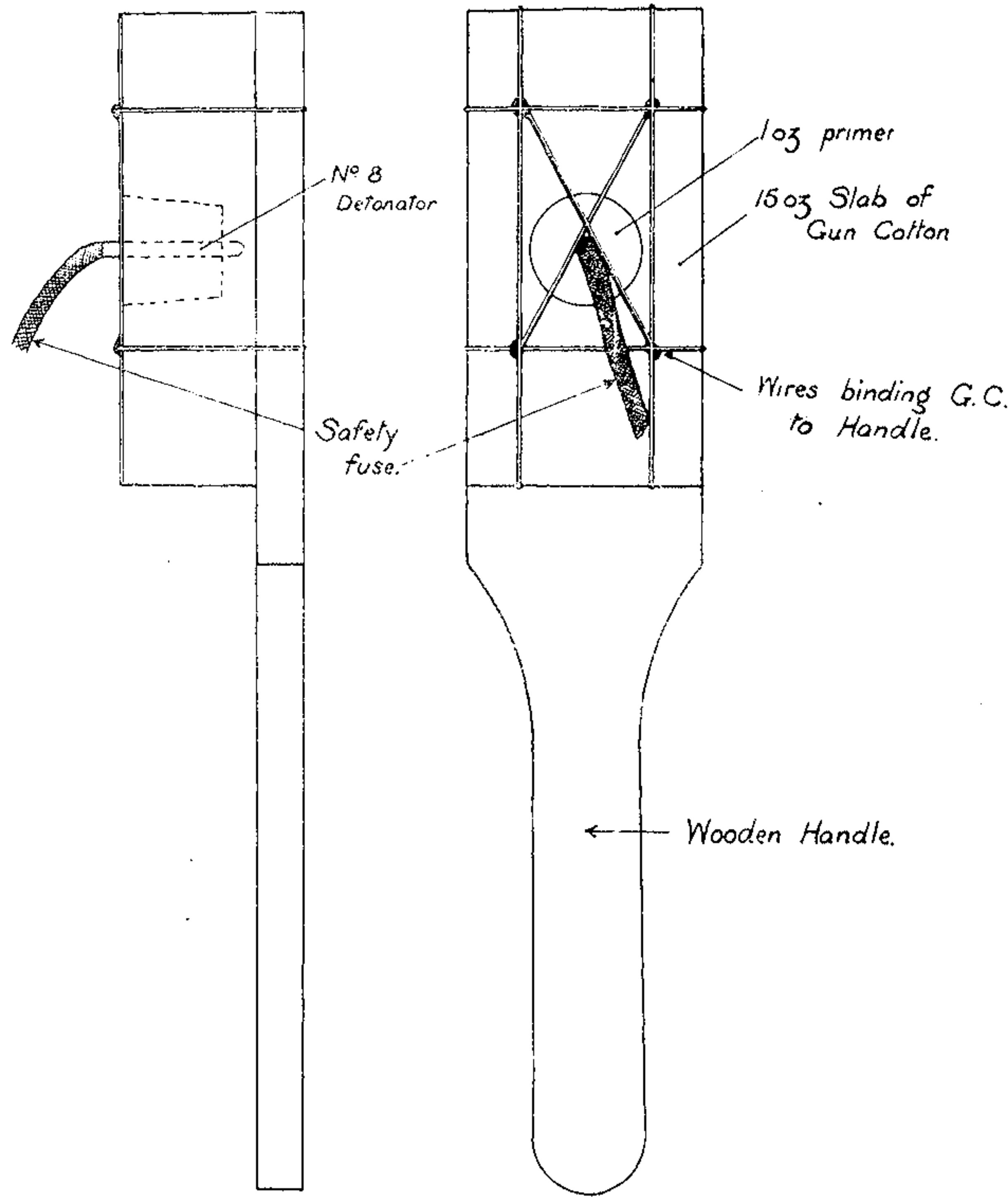


Fig. 4.

MILLS RIFLE GRENADE.

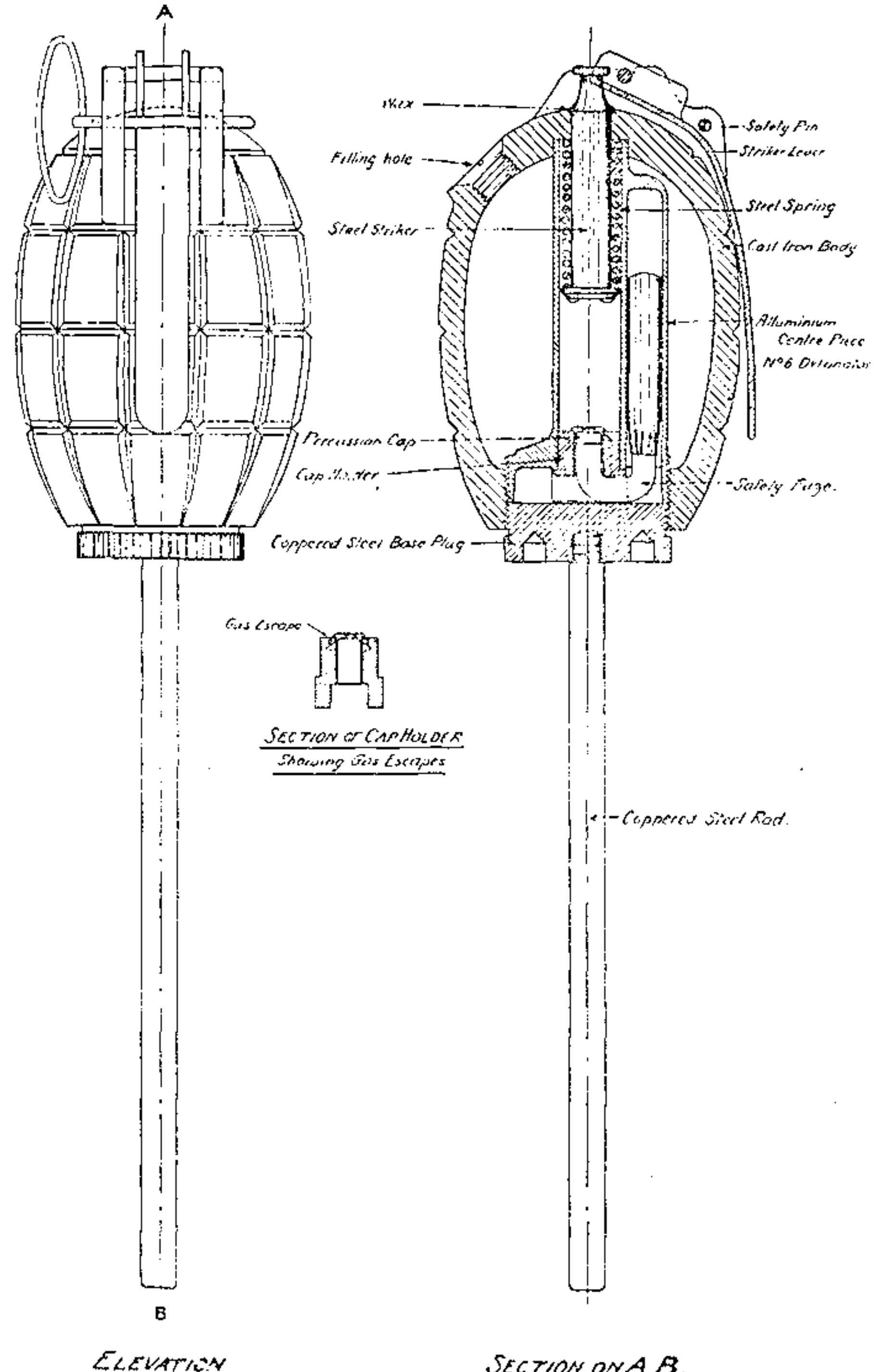


Fig. 1.

ATTACHMENTS FOR GRENADE MILLS, No. 23, Mk. II. (WITH ROD).

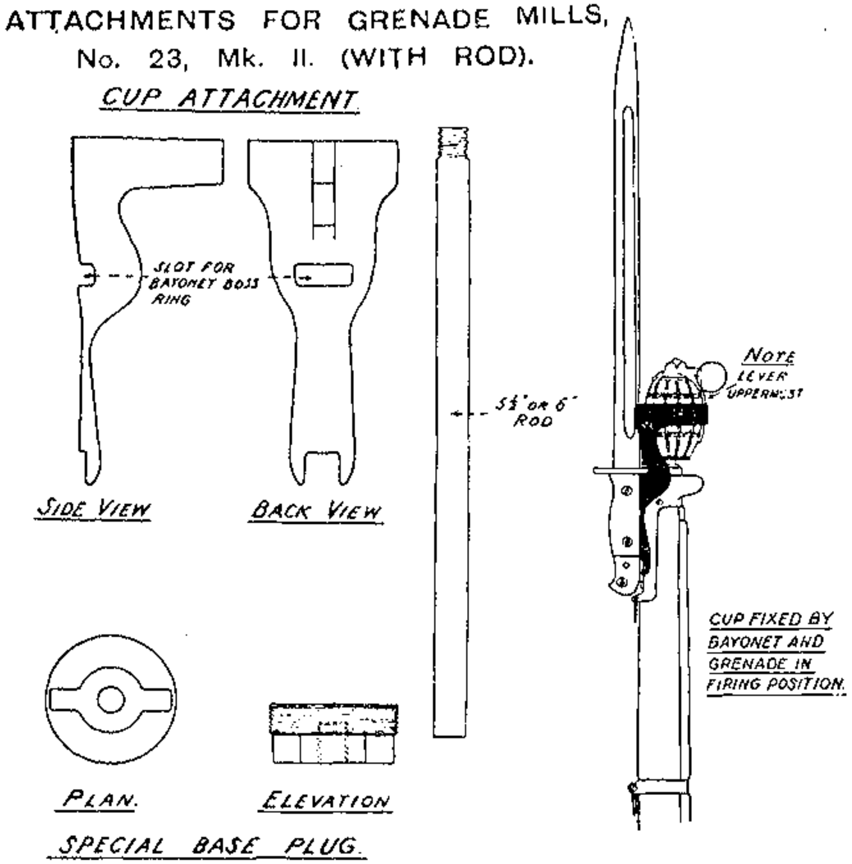


Fig. 2.

ADAMS EXPERIMENTAL PERCUSSION MILLS RIFLE GRENADE ST. OMER, 1915.

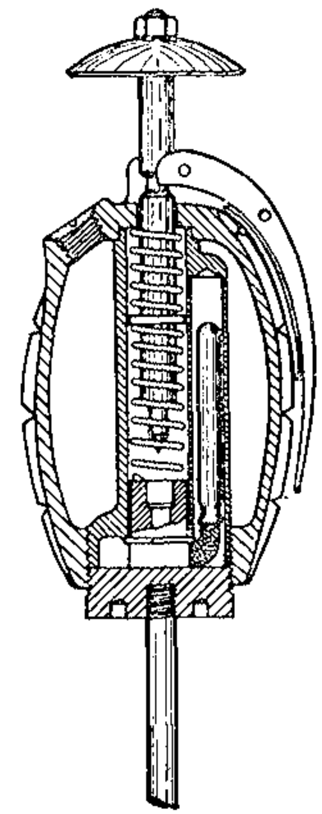


Fig. 3.

ADAMS EXPERIMENTAL PERCUSSION RIFLE GRENADE. ST. OMER, 1915.

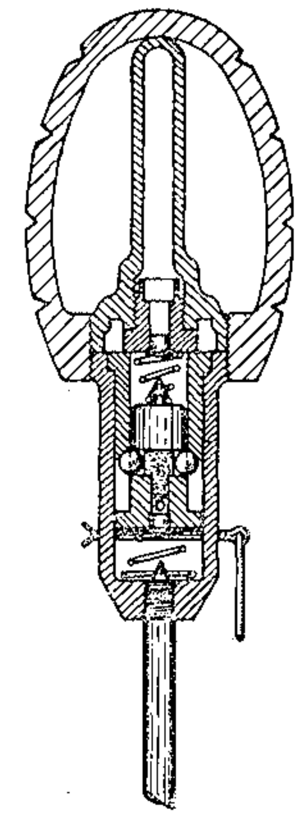
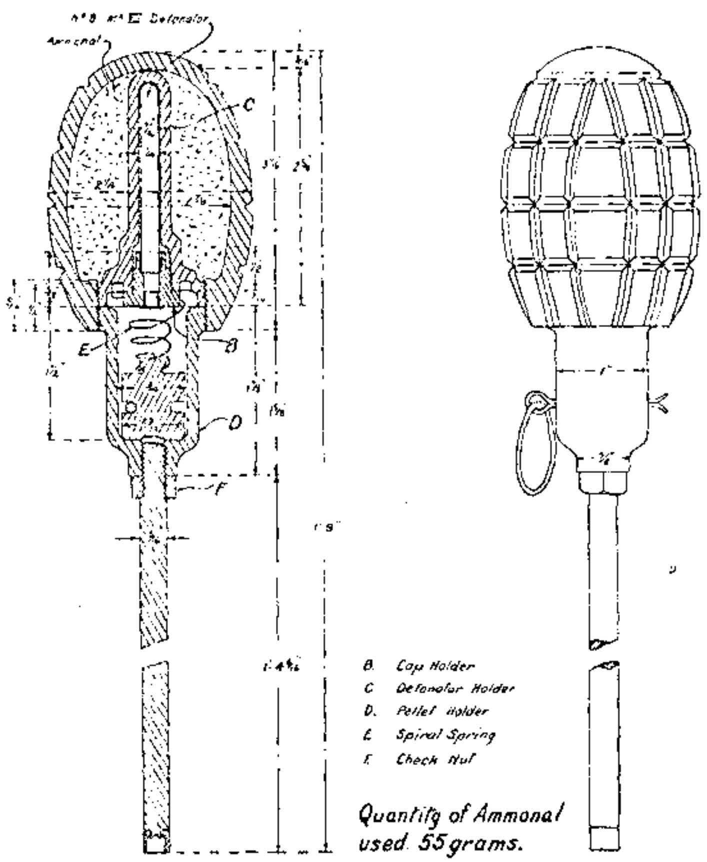


PLATE III.

Fig. 1.
GAUCHET GRENADE.



Quantity of Ammonal used 55 grams.

Fig. 2.
SANGSTER RIFLE GRENADE.

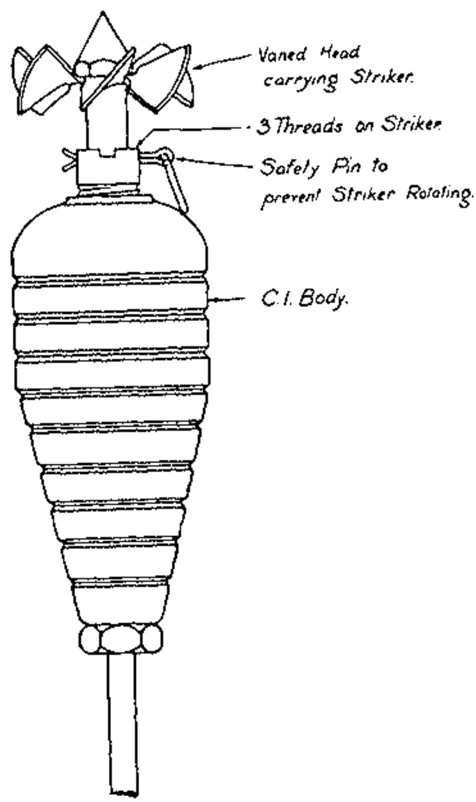


Fig. 3.
RIFLE GRENADE.
No. 24.

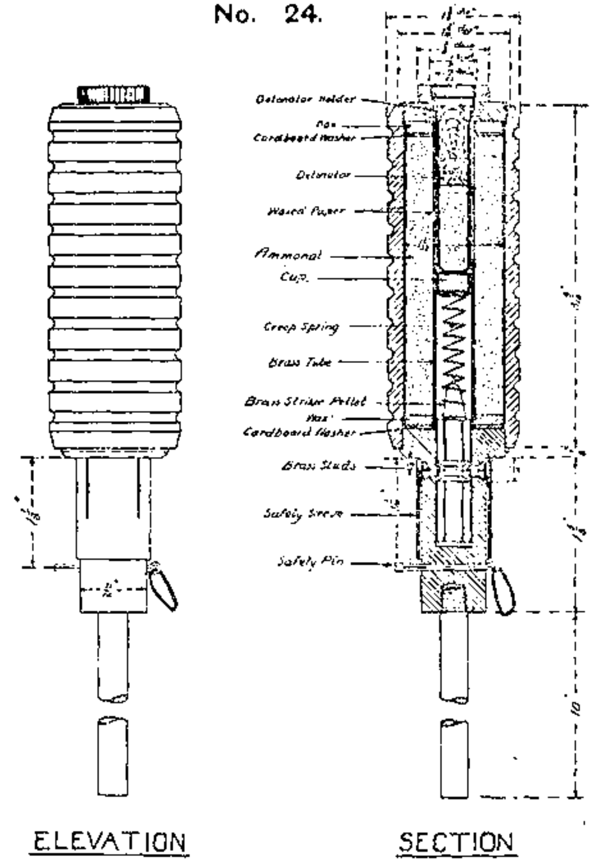
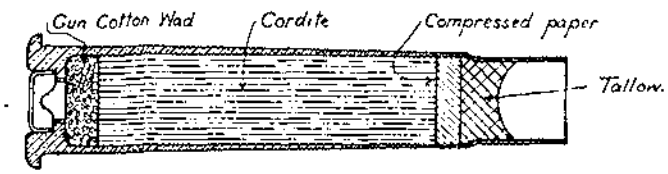


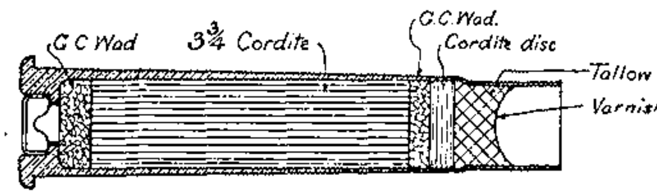
Plate IV.

Fig. 1.



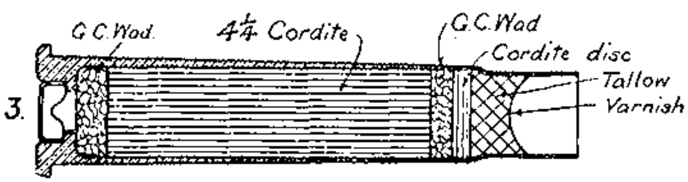
Unbulleted Round.

Fig. 2.



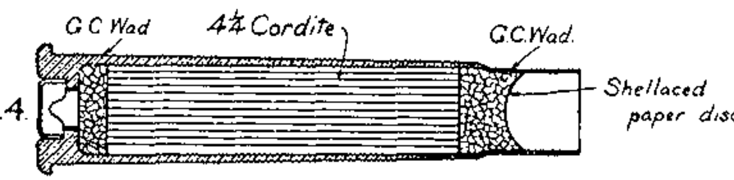
35 Grain.

Fig 3.



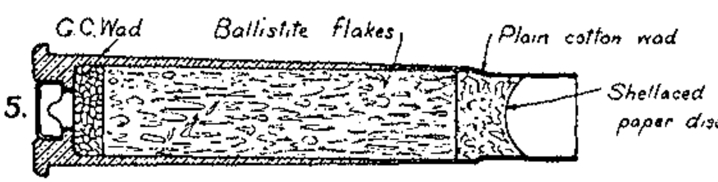
New 43 Gr. (Bronzed, full black case)

Fig. 4.



New 43 Gr. (Bronzed full case)

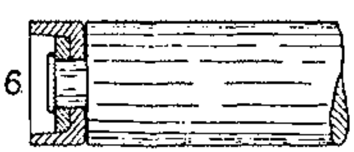
Fig. 5.



30 Gr. Ballistite. (Bronzed half case.)

GAS CHECKS FOR RODS
FOR NEWTON RIFLE GRENADES.

Fig. 6.



ADAMS PATTERN

Fig. 7.

NEWTON PATTERN

Fig. 1.

COMBINED MILLS HAND OR RIFLE GRENADE FOR USE WITH DISCHARGER.

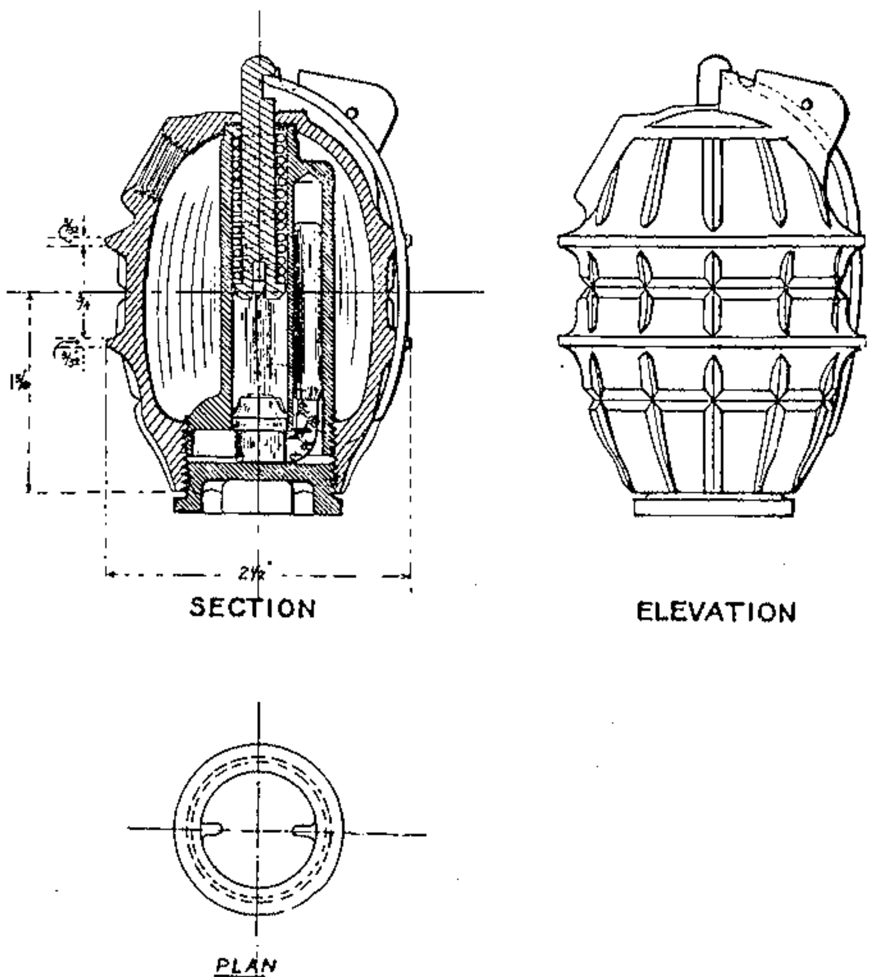


Fig. 2.

DISCHARGER. No. 1. MARK I.

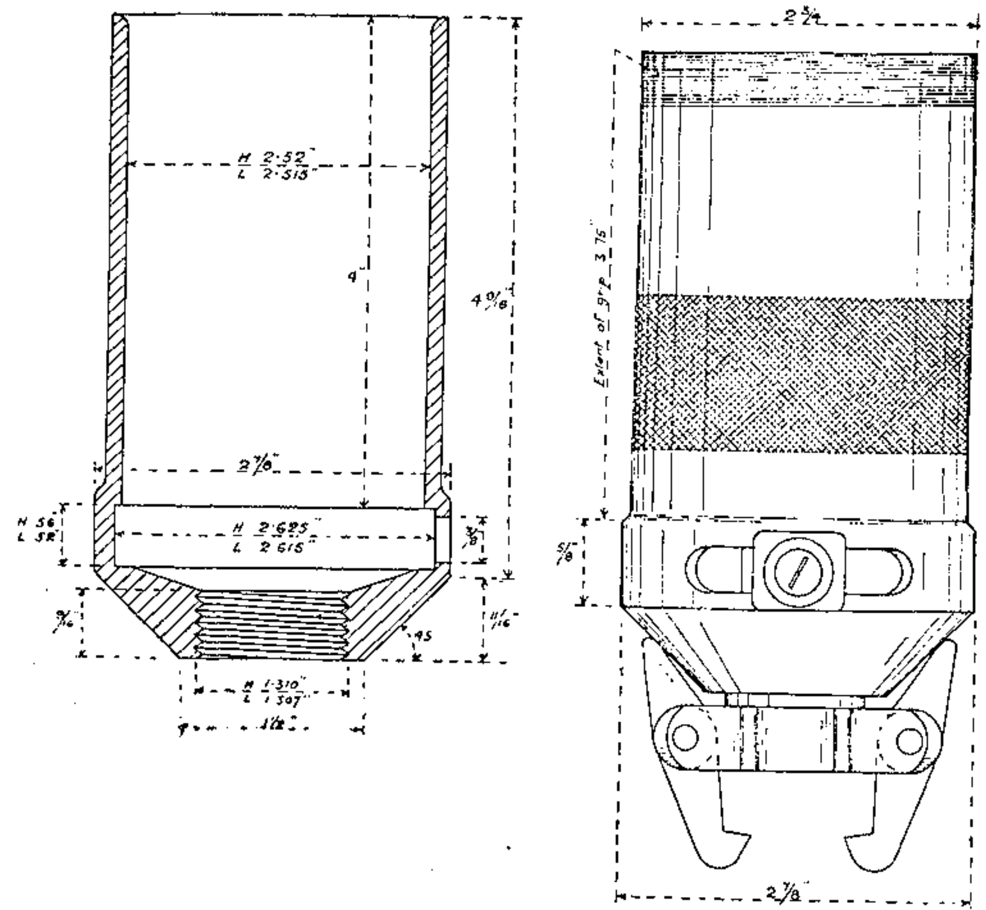
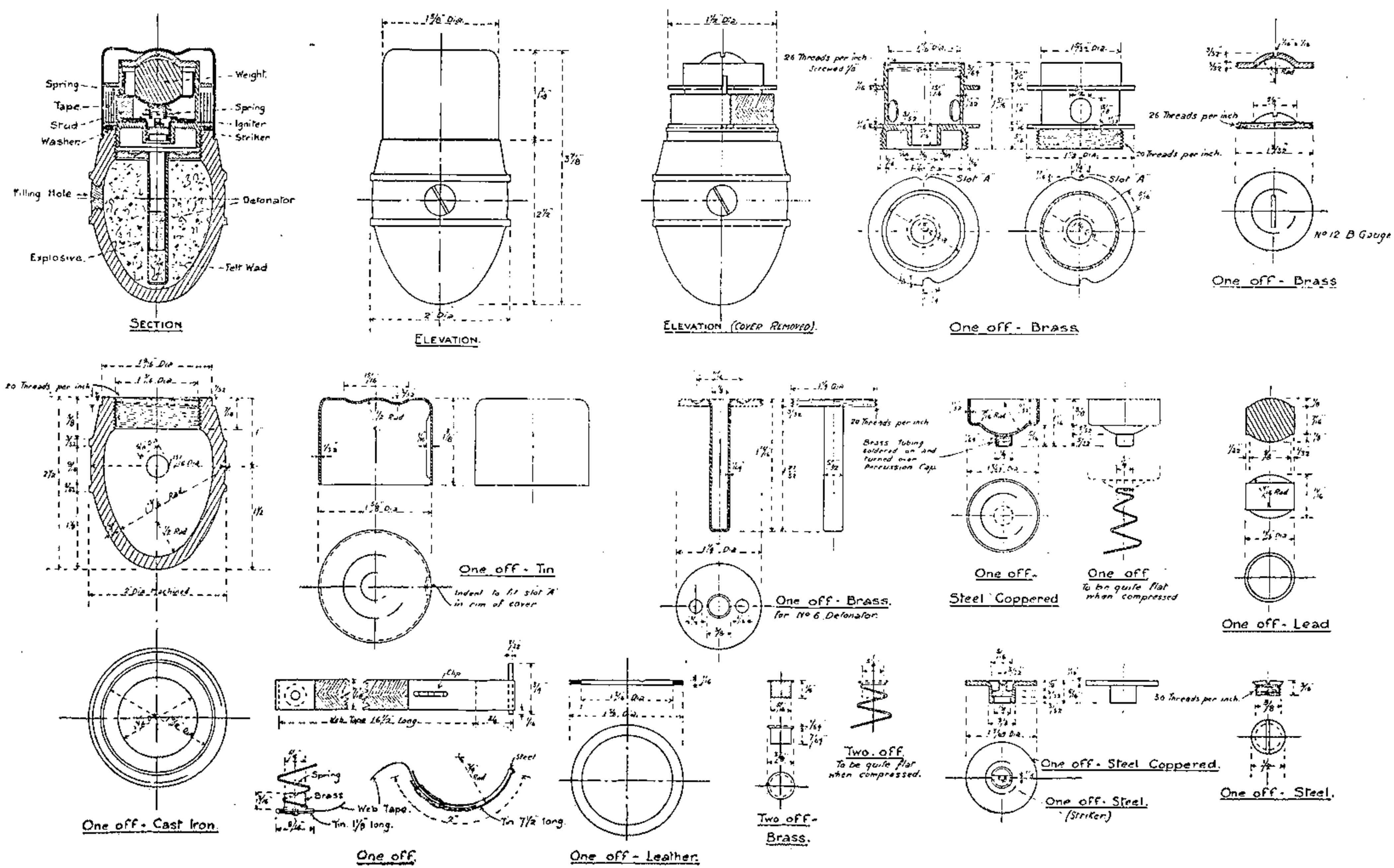


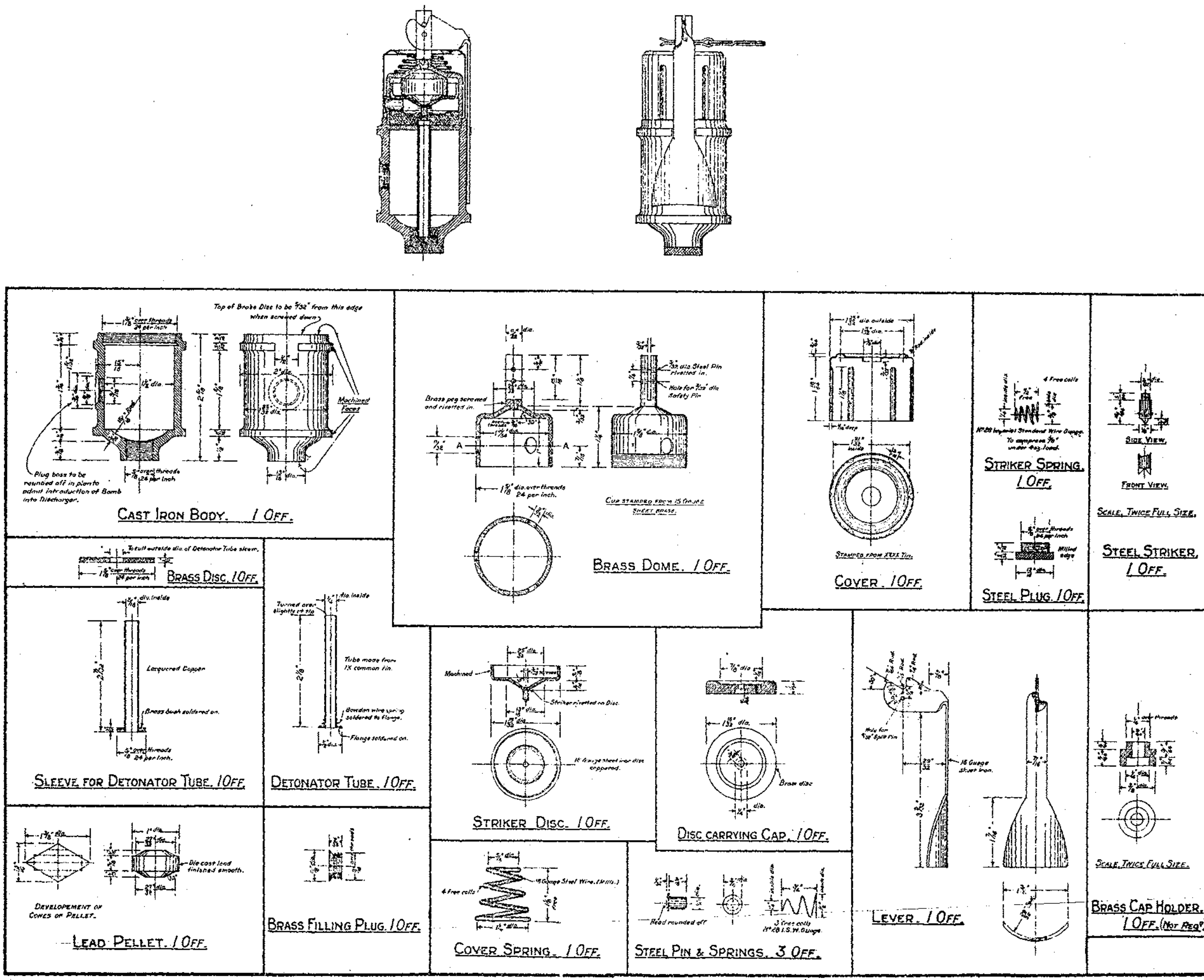
PLATE VI.

EGG PERCUSSION BOMB.

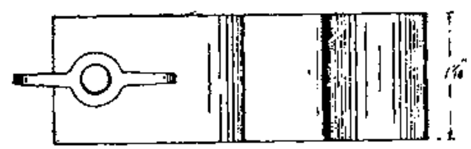


BELLAMY 'B' TYPE PERCUSSION GRENADE

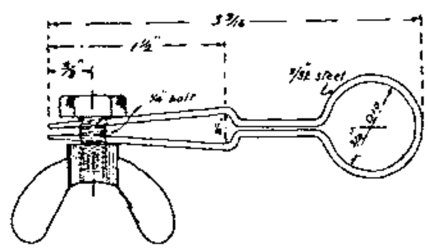
PLATE VIII.



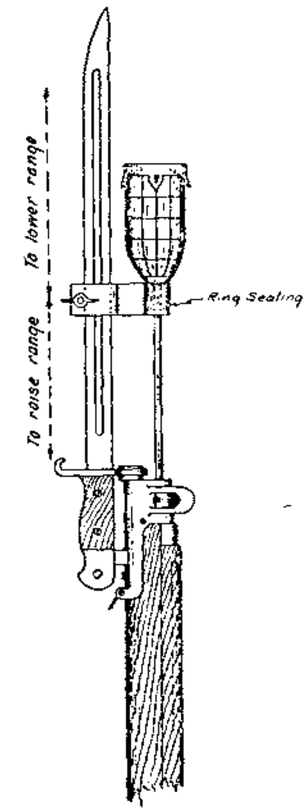
RANGING DEVICE FOR
NEWTON PIPPIN RIFLE GRENADE.
(XIIIth CORPS)



ELEVATION



PLAN



HISTORY OF THE 12th COMPANY ROYAL ENGINEERS.

(Continued.)

By LIEUT. M. R. CALDWELL, R.E.

THE Company remained in Komatie Poort until December 23rd, 1900, Major Graham Thomson becoming C.R.E. and Commandant Komatie Poort, as the C.R.E. (Lieut.-Colonel Foley) had proceeded home. The Company, meanwhile, carried out road-making, laying extra railway sidings and building platforms for new camps, hutting both for camps and hospitals, and water-supply. Much of the hutting was done by contractors and supervised by the Company. Several detachments were also out, carrying on much the same work.

The Komatie valley was a most unhealthy spot and nearly everyone in the Company was down with malaria sooner or later, some very badly, as will be seen from Appendix IIA. The animals, too, found the climate no more congenial and losses among them were very heavy, as is shown in Appendix IIB.

On October 10th Lieut. Pollard and the Newcastle Volunteers left the Company and proceeded to Pretoria.

On December 11th Captain Craven and 40 rank and file left for Barberton.

Move to Barberton.—On December 23rd the Headquarters of the 12th Company, consisting of one officer and 49 rank and file, moved to Kaapmuiden, where hutting was carried on for a week, the Company moving to Barberton, where Captain Craven's detachment was rejoined on the 3rd January.

On arrival at Avoca, *en route* for Barberton, it was found that the river was in flood and that the deviation had been washed away. Consequently nearly everything, including tool-carts, had to be transported across by an aerial line. This occupied two days (1st and 2nd January), the Company reaching Barberton the next day.

Here work was carried on on defences of all types, obstacles and land-mines, as well as defences being erected at Kaapmuiden, Hector's Spruit and Malalene.

The Company remained at Barberton until September, 1901, during which time various detachments were out, Kaapmuiden, Hector's Spruit, Malalene, Machadorp and Avoca being the chief.

Blockhouse Construction.—The Company, on arrival at Barberton, settled down to the construction of blockhouses, which became such a salient feature of the defences along the railways and at bridges and river-crossings for the " drives " or " round-ups " in the latter part of the war. A very large number of these blockhouses were built along the line from Komatie to Kaapmuiden and Barberton, and a considerable amount of work was done in erecting barbed-wire entanglements between them.

A very large amount of work was also carried out on hutments for barracks, hospitals and stables, as well as several diamond-drill borings.

The work during this period was very arduous, owing to the trying climatic conditions, malaria being even more prevalent than at Komatie.

There were also several small brushes with the enemy in the neighbourhood, and several alarms and " stand-to-arms," although the Company was never seriously engaged during this time. During this period Lieut.-Colonel Graham Thomson had been C.R.E., Barberton district.

However, on September 19th, 1901, the Company quitted the Barberton district after almost exactly a year, and were seen off by the G.O.C. (Major-General Stephenson), who made a speech to the men, expressing his appreciation of the work done while in the district.

The following letter was also received the day previous to leaving:—

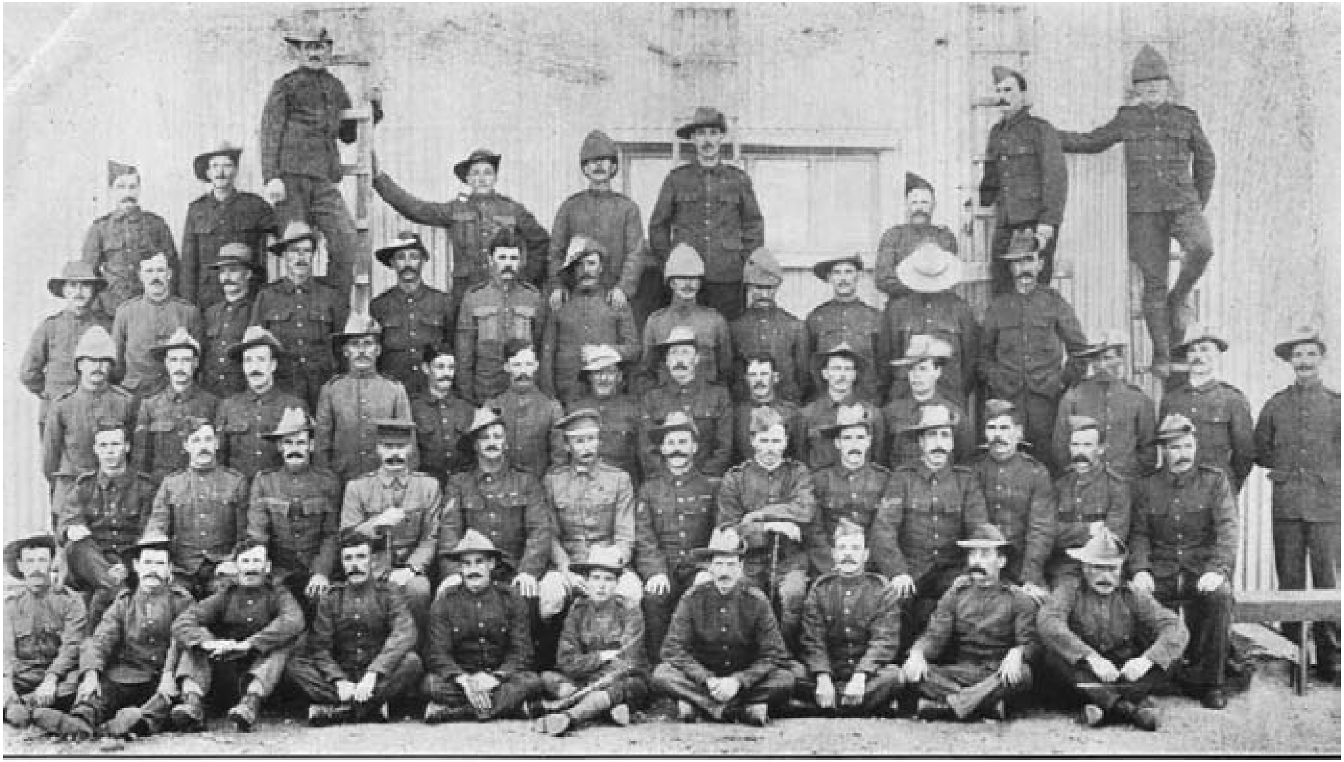
To :—

Major Graham Thomson, N.C.O.'s and Men of the 12th Co., R.E.

General Stephenson wishes to express his sincere regret at parting with the 12th Co., R.E. Although from previous association in the 11th Division he was fully aware of their high reputation, and had many opportunities of noticing their excellent spirit throughout the long marches from Bloemfontein to the Kapp valley, it is only during the past year that he has learnt to specially appreciate the soldierly smartness and devotion to duty of all ranks under very trying circumstances. The Engineer duties in this District have been extremely arduous and, owing to the prevalence of malaria, have had to be carried out under dangerous climatic conditions, yet the G.O.C. has never heard a word of complaint; both officers and men have shown a splendid spirit in sticking to their duty in spite of illness, and their ready resource and the thoroughness of their work have made the Barberton District probably the best-fortified in the whole Transvaal. In bidding good-bye to the 12th Co., R.E., General Stephenson ventures to wish all ranks the highest success, and a happy time under more healthy conditions in their new District.

(Sgd.) T. E. STEPHENSON, *Major-General*,
Commanding Barberton District.

Barberton,
18/9/1901.



Officers, N.C.O.'s, and Men who came out with the 12th Company in 1899, and were still with it at Harrismith in 1902.

12th Company in 1899

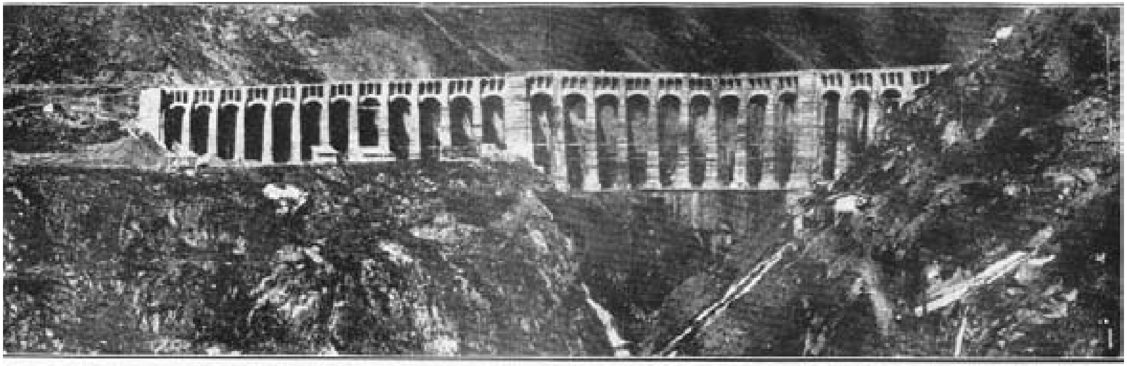


Fig. 1.

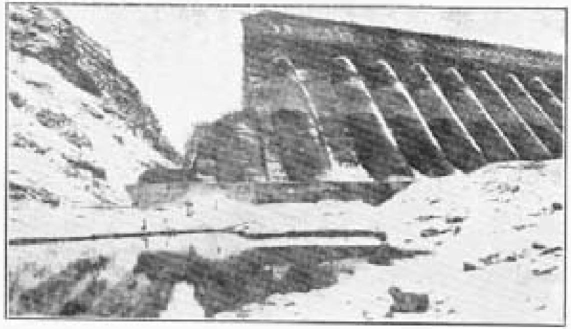


Fig. 2.

NOTES ON THE GLENCO DAM FAILURE

Harrismith.—Travelling by train *via* Waterval Boven, Pretoria, Elandsfontein, Standerton and Ladysmith, they arrived at Harrismith about 4 p.m. on the 24th. A small party under Captain Craven was left at Barberton to hand over to the 5th Company from whom the work at Harrismith was taken over. This detachment proceeded to Brandwater Basin on the 9th October.

On the 25th September a small detachment under Lieut. Nation left to join Colonel Vizard's Column, and proceeded to Olivers Hoek, where work on water supply and blockhouses was carried on until the 1st December, when the party returned to Harrismith.

The work while at Harrismith was chiefly blockhousing and other defence work on the line Van Reenans–Harrismith–Bethlehem–Basuto border; in all, about 60 miles. Between October, 1901, and the end of March, 1902, some 432 blockhouses were erected. A large amount of wiring was also done between the blockhouses and several sangars and redoubts were also built.

Tweefontein Disaster.—Several of the detachments came in for brushes with the enemy, one, which was with General Rundle's force blockhousing near Tweefontein, coming in for a fight on Christmas Day, 1901, when the Yeomanry camp was rushed by a strong party of Boers at 2 a.m., some 6 officers and 50 other ranks being killed and 60 wounded, and several pompoms and waggons lost. Several blockhouses south of Bethlehem were destroyed, but were very soon replaced by nearly double the number. Again in January several casualties were caused by snipers, who all the time continued to frequent the neighbourhood, among the casualties being two of the Company mules which were killed at Tiger's Kloof.

In spite of this, however, the blockhousing went on as fast as it could be pushed, and the following was received from Headquarters, Harrismith District:—

Copy of Telegram.

From C.R.E. Army.

To G.O.C. Elands River Bridge.

D.5136. 21st Jan. Progress of Blockhouses to Bethlehem has been very satisfactory.

To C.R.E.

The Lieut.-General, in communicating the attached telegram from the C.R.E. of the Army, desires at the same time to place on record the good and untiring work done by Lieut.-Col. Graham Thomson and the 12th Company R.E. since they have been in this district.

(Sgd.) L. E. KIGGELL, *Lieut.-Colonel,*
A.A.G. Harrismith District.

Elands River Bridge,
22nd January, 1902.

On March 14th two of the native boys employed by the Company were seriously wounded in an attack on Fort Davidson.

During March a considerable amount of damage was caused to bridges and drifts by the rivers flooding. A collapsible and portable boat was found most useful on these occasions, a ferry being formed with its help on April 1st, when the 14th Hussars and a regiment of Yeomanry were taken across Elands River at Majoors Drift by Lieut. Nation's detachment.

During the month Captain Craven's section was constantly under fire during the construction of the Brindisi-Bethlehem line of block-houses. A large amount of hutting was also erected in the Harrismith district, mainly for hospitals, remount depôts and veterinary hospitals.

Peace Signed.—On May 31st, 1902, Peace was signed at Pretoria, the official announcement reaching the Company next day.

On June 3rd, Corporals Allardyce and Shaddick were sent home as unit representatives in the forthcoming Coronation reviews, etc.

During the month work was continued in the district, a dam being built for water supply purposes. Some difficulty was experienced, however, owing to the rising of the river and bursting of the dam. A bridge over the Wilge River was also built.

Review Held.—On June 28th a review of all troops in the district was held, those taking part being the 3rd Dragoon Guards, 1st Battalion Imperial Yeomanry, a Battery R.F.A., a section of mountain guns, 12th Company R.E., the Grenadier Guards, 1st and 2nd Battalions Black Watch, East Yorks, South Staffords and Manchester Regiments. This ended about a fortnight of sports and general festivities celebrating the coronation.

On July 16th the first batch of Reservists left for home, and the work of sending off the Reservists and men whose time was up was carried on thenceforward as fast as possible.

APPENDIX I.

ITINERARY OF MARCH—BLOEMFONTEIN TO PRETORIA.

1st May—Bloemfontein to	Karee	22	miles
3rd ,,	Brandfort	14	,,
5th ,,	Vet River	22	,,
6th ,,	Smaldeel	8	,,
9th ,,	Welgelegen	14	,,
10th ,,	2 miles N. of Rietspruit Station	19	,,
11th ,,	Geneva siding	15	,,
12th ,,	Kroonstadt	14	,,
22nd ,,	Horning Spruit	21	,,
23rd ,,	Rhenoster River	16	,,
24th ,,	Vredefort Rd. Station	15	,,
25th ,,	2 miles N. of Grootvlei Station	12½	,,
26th ,,	Taibosch Spruit	17	,,

27th May	Vereeninging	10½ miles
28th „	Klip River	21 „
29th „	Germiston	15 „
31st „	Johannesburg	10 „
3rd June	Leeuwkop	12 „
4th „	Zwart Kop	14 „
5th „	Pretoria	8 „

The 12th Company thus did 20 marches in 36 days, covering a total distance of exactly 300 miles.

APPENDIX IIa.

12th Company, Royal Engineers (24/9/1900 to 19/9/1901).

ADMISSIONS TO HOSPITAL—KOMATIE VALLEY.

Strength of Company on arrival at Komatie Poort (including Volunteer Section and Lieut. Elsner, R.A.M.C., attached) was 6 officers and 167 rank and file.

	N.C.O.'s and Men.		*Officers.*	
	Actual Admissions.	*First Time.*	*Actual Admissions.*	*First Time.*
October	8	8	–	–
November... ...	23	23	1*	1*
December ...	39	38	2	2
January	23	13	–	–
February ...	14	6	–	–
March	15	8	–	–
April	28	14	3	3
May	55	32	4	3
June	25	8	2	–
July	28	3	–	–
August	14	–	–	–
September ...	5	1	–	–
Totals ...	277	154	12	9

* Lieut. Elsner, R.A.M.C. (attached).

Invalided :—34 men, 1 officer (2nd-Lieut. Reid, served only at Machadorp).

Died :—3 men.

Killed on railway :—1 man.

Since arrival at Harrismith, 30 rank and file have been invalided and 2 died out of those who were in Komatie Valley.

The above casualties refer to men who actually served in the Komatie Valley. Men who did not serve at Komatie Poort are not included, nor are any men of the First Volunteer Section under Lieut. Pollard.

APPENDIX IIB.

12TH COMPANY, ROYAL ENGINEERS.

RETURN OF DEATHS OF ANIMALS IN THE KOMATIE VALLEY FROM 24/9/1900 TO 19/9/1901.

Months.	*Horses.*	*Mules.*	*Remarks.*	
September, 1900 ...	–	1		
October, ,, ...	–	7	1 destroyed	Included in totals.
November, ,,	5	7	2 horses destroyed	
December, ,, ...	3	16		
January, 1901 ...	2	12	1 mule destroyed	
February ,, ...	2	1	1 mule destroyed	
March, ,, ...	–	2	Destroyed	
April, ,, ...	–	1	Destroyed	
May, ,, ...	2	1		
June, ,, ...	–	–		
July, ,, ...	–	–		
August, ,, ...	–	–		
September, ,, ...	–	–		
Totals ...	14	48		

Number marched into Komatie Poort :—

Horses, 19. Mules, 72.

APPENDIX IIIA.

HONOURS WON BY THE 12TH (FIELD) COMPANY, SOUTH AFRICA, 1899-1902.

Officers.

Major A. Graham-Thomson ...	Mentioned in Dispatches,	4/9/01
	Brevet Lieut.-Colonel,	29/11/00
Captain A. L. Schreiber* ...	Distinguished Service Order.	
	Mentioned in Dispatches,	29/11/00
Lieut. (afterwards Captain) A. J. Craven	Mentioned in Dispatches,	8/4/02
	Brevet-Major,	26/6/02
Lieut. R. H. MacDonald ...	Mentioned in Dispatches,	4/9/01
Lieut. J. J. H. Nation	Mentioned in Dispatches,	4/9/01

Other Ranks.

C.S.M. C. Skinner	Distinguished Conduct Medal.	
	Mentioned in Dispatches,	17/6/02
21691 Sergt. J. T. Hughes ...	Distinguished Conduct Medal.	
	Mentioned in Dispatches,	17/6/02
Sapper W. A. Gilham	Mentioned in Dispatches,	17/6/02

* The Editor regrets that in the June issue of the *Journal* the name of Captain (now Brig.-General) Schreiber, D.S.O., was wrongly spelt.

Those who did the march from Bloemfontein to Pretoria and Komatie Poort received the Queen's Medal with Clasps for "Cape Colony," "Orange Free State," "Johannesburg," "Diamond Hill" and "Belfast."

For the second period of the War, those who were with the Company received the King's Medal with Clasps, "1901," "1902."

APPENDIX IIIB.

N.C.O.'s AND MEN OF THE 12TH (FIELD) COMPANY WHO WERE KILLED OR DIED, SOUTH AFRICA, 1899–1902.

22084	Driver F. Wakefield	... ...	24/4/00
26398	Sapper J. Burt	... ...	17/5/00
23721	„ R. Bromley	... ...	2/7/00
5801	„ J. Lawson	... ...	23/7/00
318	Driver F. Pearce	... ...	1/10/00
27773	Sapper J. Sawnders	... ...	14/4/01
8224	„ R. H. Wilson	... ...	29/11/01
20032	Corporal W. Bartlett	... ...	14/12/01

CHAPTER III.

From this time the Company remained in Harrismith until 1905, employed on general R.E. work on cantonments and barracks in the neighbourhood.

Return Home.—On March 19th, 1905, the Company left Harrismith for Home, being told that they were going to be sent to Aldershot.

On March 24th they embarked on the S.S. *Dunera* at Capetown, and arrived at Southampton on April 14th, disembarking the next day. Here there was great disappointment when the news was learned that, instead of Aldershot, Fermoy in Ireland was the Company's destination. This place was reached late in the evening of the 16th, the Company being sent to Moore Park.

Moore Park, Fermoy.—There were at this time no men in the Company who had not been abroad at least four years, many having been in South Africa for five and a half years.

They were quartered in the mansion which had been the old family seat of the Earls of Mountcashel, but had been purchased a short time before by the Government. The estate, some 900 acres in extent, was situated on the River Funshion and was well suited for training.

The Company was employed on the usual peace-time company, brigade, and divisional trainings, and under the Division Officer for works, road-making, etc. They also had no small work each year in preparing camps for training and manœuvres.

In 1908, on the formation of the six Divisions at home, the 12th and 38th Companies were allotted to the 6th Division, the head-quarters of which were at Cork.

In December, 1908, a fire occurred at Moore Park and the mansion was almost entirely burnt down, leaving practically nothing but the walls standing.

There being no water laid on, the only method of dealing with the fire was a chain of buckets from the river, which, of course, proved quite inadequate.

The fire originated near the main staircase, in consequence of which many men had exceedingly hurried exits by means of knotted sheets from windows, etc., and were able to save practically nothing! They must have presented a somewhat motley appearance, an officer describing them as follows:—"It was quite the exception to see any of them properly dressed! I distinctly remember seeing one man wearing an officer's Wellington boot on one foot and a carpet slipper on the other! Many others were on a par!"

As they were now practically without accommodation, two huts were hurriedly removed from Clogheen and re-erected at Moore Park, and, having been reclothed and equipped, the Company once more reassumed its normal appearance.

In 1908 and 1909 the Company prepared camps at Aglish, in Co. Waterford, for divisional trainings which were carried out there.

In the spring of 1909 and 1910 the Company were assembled under canvas at Moore Park, having been somewhat dispersed under D.O.'s during the winter, owing to lack of accommodation.

It was at about this time that C.Q.M S. Fletcher transferred to the old balloon section which afterwards became the Royal Flying Corps. Fletcher subsequently obtained a commission, and, during the war of 1914–18, rose to the rank of Brigadier-General.

In 1910 the 17th and 59th Companies from the Curragh and 33rd (Fortress) and 38th from Cork came up to Fermoy for the Field Works course. Experiments in crossing wire entanglements were carried out on a large scale under the supervision of Major Godfrey-Faussett from the War Office.

In the autumn of 1910 Irish command manœuvres took place in the Wexford area, the 5th Division fighting against the 6th.

In the spring of 1911 the 12th and 38th Companies, after doing pontooning at Baltray on the Boyne (a tidal river) near Drogheda, prepared the camp for, and took part in, the large review of troops in Dublin on the occasion of the visit of H.M. the King, after which they returned again to Moore Park, and carried out similar annual trainings, etc., until 1914 arrived, bringing with it something in the way of variety!

(To be continued.)

PROFESSIONAL NOTES.

EXPLANATORY NOTES ON THE ACTIVATED SLUDGE PROCESS.

The Purification of Sewage and Trades Waste by an entirely aerobic process, free from objectionable odours, has always been the ideal method which sanitary engineers and chemists have had before them, and it has at last been rendered possible by the Activated Sludge Process.

The Aeration of Sewage, by blowing air through it, was often attempted, but it was found to require an altogether excessive time and volume of air, and the result left an effluent which needed to be further treated on filters.

The Activated Sludge Process consists not merely of aeration or agitation of the sewage, but the combination of both, with the retention in the tank of the sludge, indigenous to the sewage, but activated by the process of aeration.

Hitherto, with any sedimentation or septic tank process, retention in the tank induced anaerobic conditions, a bad smelling effluent, and a worse sludge of so little fertilizing value, that the problem of sludge disposal often became more serious than that of purifying the liquid contents of the tank.

Activated sludge is built up by aeration, gradual at first, the more or less purified liquid being drawn off and its place taken by more sewage, until about 25 per cent. of the tank contents consists of activated sludge. This proportion is then maintained and the surplus sludge can be drawn off and will be found to be innocuous, to settle rapidly, and contain valuable fertilizing properties, so that the Activated Sludge Process not only yields a pure effluent, but without further cost it also completely changes the character of the sludge and converts it into a valuable asset.

The Process of Purification.—The crude sewage is first rough screened and its detritus settled out. The light organic matter is retained, aerated and agitated until it is in a fine state of subdivision, and will pass through the fine screen. It is then mixed with activated sludge and aerated for the necessary period, passing through the circuit of the aeration tank until it is finally discharged into the settlement tank fitted with a special inlet. Here the sludge rapidly settles and a proportion of it is withdrawn by means of air lifts for further use whilst the surplus passes to sludge beds or tanks for de-watering and drying. Before, however, the activated sludge is returned to the aeration tank it is usually re-aerated, *i.e.*, air is blown through it in its concentrated state, as it flows back from the settlement tank to the sewage inlet.

Trades Wastes and the periods of aeration they require vary enormously, but sewage containing trades wastes, if alkaline, can be purified without any difficulty.

Existing Tanks Can be Used.—Tanks which have been sufficient for ordinary sedimentation or septic liquefaction will be ample for the complete treatment of the sewage by the Activated Sludge Process, when properly equipped.

No Filters or Other Bacteria Beds are Required as a stable effluent of almost any degree of chemical and biological purity can be obtained by a few hours' treatment in the aeration tank, followed by about one hour's settlement in another tank. The whole process is one continuous operation requiring very little labour and, whereas bacteria beds required from 4 ft. to 10 ft. of fall, 4 in. to 10 in. is now sufficient, or the effluent can be raised and discharged at a higher level as part of the process.

REPORT ON WORKING OF SEWAGE DISPOSAL PLANT (ACTIVATED SLUDGE SYSTEM) AT CHILWELL FOR THE PERIOD 1/2/23 TO 1/2/24.

Installation.—The plant was installed by Activated Sludge, Ltd., and commenced working on 25th January, 1923. The work was done in a thoroughly efficient manner, and the firm gave all assistance and advice necessary until the process of activation was complete, and the system in working order. Their representative has also paid periodical visits since, and has expressed himself satisfied with the working. An abridged description of the plant appears in Appendix A.

Initial Outlay.—The capital cost of the installation was as follows:—

(*a*) Construction of tanks	£1,261	approximate figures
(*b*) Supply and erection of plant ...	£3,077	
	£4,338	

The cost of (*a*) was considerably increased owing to unforeseen difficulties in keeping the excavations free from water. The firm's engineer afterwards stated that it would be possible to design a shallower pattern of tank for use in ground known to be heavily water-logged, and thus reduce excavation.

Chemical and Other Tests.—Samples of the crude sewage, the activated sludge, and the effluent were frequently analysed at the commencement, the latest of these tests being made on 6th June, 1923, the results of which are shown on an annexure to this report.* Mr. Gaul, of Manchester University, who carried out this test, remarked that "the purification effected is very satisfactory both from a chemical and also from a bacteriological point of view." Since the above date the effluent has remained clear, and it has not appeared necessary to obtain further analysis.

Routine tests are made as follows, and records kept :—

(1) daily for percentage of sludge,
(2) daily for nitrification.

Inspections and Visits.—During the year the installation has been inspected by :—

The D.A.D.H., Northern Command, on 4th May, 1923, who made certain criticisms and suggestions on minor points, which have been attended to.

The District Inspector, Ministry of Agriculture and Fisheries, Grimsby, on 13th April, 1923, who stated : "I was agreeably surprised at the nature of the effluent, and if all the effluents reaching the rivers in this country were as good, our pollution troubles would soon end."

Deputations from several public bodies, including the Medical Officer to the Notts County Council, have also visited the plant.

Machinery.—The three compressors (Reavell's, driven by motors of the English Electric Co.) have proved entirely satisfactory, and repairs during the period have been negligible.

No renewals of diffusers have been necessary during the period.

The ejectors have worked satisfactorily, and only on one occasion, at a time of exceptional storms, were unable to cope with the flow. They have been fitted with counters, thus enabling an exact record of the quantity of sewage dealt with to be kept.

An alternative supply of compressed air has been arranged from the Power House, by making use of a disused steam main, thus enabling the compressor house to be closed during non-working hours, and minimizing the risk of failure.

Maintenance Staff.—The supervising electrical and mechanical engineer is responsible to the Division Officer, R.E., for the running of the plant. The foreman of the heating and ventilating department is the immediate supervisor, and it is to him that the present satisfactory state of the installation is largely due. Under him there work one full-time attendant at 48 hours per week, and a second attendant at an average of half-time. The arrangement by which compressed air is supplied from the Power House during non-working hours, and at week-ends, makes it possible to work the plant with this staff. If, however, the local compressors had

* Appendix "B."

to be worked continuously, shift-working would be unavoidable, and three men would be essential. The firm stated, in reply to enquiries on this point, "We think it advisable that you should have a man at the compressor house continuously. If, at the end of six months, you find two men sufficient, you can then reduce."

From the above it will be evident that, if a plant of this nature were contemplated at a station where no alternative supply of compressed air exists, it would be necessary to estimate for a sufficient staff for continuous, or practically continuous, attendance. In such a case the best solution would appear to be to employ a "whole-time" attendant, who would be provided with a quarter close to the compressor-plant, and a day-worker in addition.

Disposal of Sludge.—When the percentage of sludge in the system reaches from 20 to 25 per cent., the sludge from the settling tank is drawn off by means of air-lift pumps into shallow lagoons to dry. At this stage it is in the form of a thick black liquid. This operation takes place, on the average, once a week, and the quantity drawn off each time is in the neighbourhood of 6,000 gallons. The lagoons are dug about 15 in. deep, and have an area of, roughly, 260 sq. ft. each. It has been necessary to dig nine only up to date, thus occupying only a very small proportion of the ground available for the purpose, and leaving ample for the future; as a matter of fact, the earliest of these lagoons still soaks the water away almost as well as it did at the beginning.

The sludge is run into the lagoons to a depth of 9 in., and after remaining for 24 hours, the water has soaked away, leaving a black paste. This paste dries up to a solid crust about an inch thick, the drying period varying with atmospheric conditions, but seldom being more than a week. The dried sludge is then taken off with a shovel, and the lagoon is ready again for its turn.

Up to date the dried sludge has been taken away by neighbouring farmers as an experiment. We shall perhaps learn their opinion as to its manurial value after this season's cropping. The amount taken away during the twelve months may be roughly estimated at 170 tons, but no exact record has been kept.

Cost of Treatment.—An analysis of the costs for twelve months' working from 1st February, 1923, to 1st February, 1924, is given in an annexure to this report.* It should be noted that the figures given therein include power for lifting the sewage into the tanks by means of ejectors, from a depth of 15 ft. But for this, the cost per 1,000 gallons would be appreciably less than 10·89d., though it would be difficult to dissect the figures with any approach to accuracy.

* Appendix "C."

Effects of Oil.—The presence of oil, especially if of a tarry nature, adversely affects activation, and the greatest care should be taken that no excess of heavy oil is used in urinals. The strictest supervision in this matter is necessary if the smooth running of the process is to be maintained.

Conclusions.—The results of a year's working are considered to show that the process is a very efficient one. It is especially suitable for a station where the space necessary for land treatment is restricted. The whole process is noticeably free from smell and flies, and this applies even to the dried sludge when stacked before removal. No definite defects have come to light in connection with the plant. and no particular improvements have suggested themselves.

APPENDIX A.

Description of Plant.

Population on which capacity is based	2,000
Estimated dry-weather flow per day	50,000 gallons
Maximum capacity per day	500,000 gallons
Average volume treated per day (to date) ...	103,490 gallons

Dimensions of Tank, etc.

1. Disintegration tank—12′ diam., 7′ 9″ deep.
2. Three aeration channels, 54′ long, 4′ 6″ wide, 7′ 9″ deep.
3. Settlement tank, 15′ × 15′ × 19′ 3″ deep, with hopper bottom, fitted with Clifford inlet.
4. Sludge return channel, 54′ long, 2′ wide, 7′ 9″ deep.

The walls and floors are of Portland cement concrete, 1 : 6. The floors are rendered with P.C. mortar, 1 : 3, well trowelled. The concrete in the walls was well trowelled against casings; after removing the casings it was decided that rendering was unnecessary, the surface being free from air-holes. Thickness of floor, 12″; external walls and walls under hydrostatic pressure, 12″ thick; longitudinal partition walls, also the transverse baffle walls, are 6″ thick.

Specification for Air-Compressing Plant.

1. Rotary type compressor, direct coupled to electric motor, capable of delivering 150 cub. ft. of free air per minute against a pressure of 10 lb. per sq. in.
2. As No. 1, but motor of variable speed type having a range down to a speed of one-third.
3. As No. 1, but against a pressure of 4 lb. per square inch.
4. Air receiver, 75 cub. ft. capacity, and tested to 25 lb. per square inch.

APPENDIX B (1).

ANALYSIS OF CRUDE SEWAGE.

Nature of sample ...	... Crude sewage
Date received ...	... May 31st, 1923
Date of report ...	... June 6th, 1923
Laboratory number	... No. 7 Chilwell
Description of sample	... Pale yellow liquid, containing a moderate amount of solids in suspension: slight smell.

Nitrogen as:

Free and saline ammonia	1·2
Albuminoid ammonia	1·5
Nitrites	*Nil*
Nitrates	*Nil*
Nitrites and nitrates	

Oxygen absorbed in:

4 hours	
3 minutes	9·2

Suspended solids

Percentage purification, calculated on the 4-hour figure

APPENDIX B (2).

ANALYSIS OF ACTIVATED SLUDGE.

Nature of sample ...	... Activated sludge
Date received ...	... May 31st, 1923
Date of report ...	... June 6th, 1923
Laboratory number	... No. 8 Chilwell
Description of sample ...	... Winchester quart of liquid, containing sludge

The sample is very similar to those previously sent. A microscopical examination reveals the presence of only a few protoxos.

APPENDIX B (3).

ANALYSIS OF FINAL EFFLUENT.

Nature of sample	... Final effluent
Date received ...	... May 31st, 1923
Date of report ...	... June 6th, 1923
Laboratory number	... No. 9 Chilwell
Description of sample	... Clear, colourless liquid, containing a trace of sludge in suspension. No smell.

	Parts per 100·00
Nitrogen as:	
Free and Saline Ammonia ...	·6
Albuminoid Ammonia	·08
Nitrites	Faint
Nitrates	
Nitrites and Nitrates	·30
Oxygen absorbed in:	
4 hours	·5
3 minutes	
Suspended solids	
Percentage purification calculated on the 4-hour figure	94·5

APPENDIX B (4).

ANALYSIS OF NEW SEWAGE AND FINAL EFFLUENT.

Nature of sample ...	New sewage and final effluent
Date received	May 31st, 1923
Date of report	June 6th, 1923
Laboratory number ...	Nos. 7 and 9 Chilwell
Description of samples ...	See chemical analysis sheets

BACTERIOLOGICAL COUNTS.

Number of bacteria growing on gelatine peptone broth, when incubated for three days at 21° C.

Raw sewage	2,700,000
Effluent	13,700
Percentage reduction ...	99·5

APPENDIX C.

ANALYSIS OF COSTS.

SEWAGE DISPOSAL WORKS—CHILWELL.

Period: February 1st, 1923, to January 31st, 1924.

	£	s.	d.
Direct Operating Charges			
Labour, civilian	186	6	11
Power, electric	598	7	3
„ steam	451	6	9
Stores, water	3	5	4
„ oil, grease, etc.	14	10	11
General Standing Charges.			
Machinery and Plant—			
Depreciation	204	0	0
Repairs and renewals	16	11	10
Storage tanks, etc.—Depreciation	62	5	11

	£	s	d.
General Standing Charges—continued.			
Quartering—Rental value, W.D. property	59	0	7
Repairs	39	9	5
Rates	2	5	0
Barrack Services—Barrack furniture, utensils, etc. ...	1	13	4
Engineer's salary (proportion)	35	4	6
Caretaking and custody—Police	7	15	8
Administrative Charges.			
Military—Officers	29	6	4
Stationery, Army Forms and Books	3	3	7
Total ...	£1,714	13	4

Gallons treated (12 months)	37,773,870
Cost per 1,000 gallons	10·89d.

Note.—It is to be observed that the Chilwell Army Ordnance Depôt is largely a factory, but partly residential. The residential population is 450 and the factory population, who are there 8 hours per diem, about 1,000–1,200. There is a laundry operating in the factory which consumes a large quantity of water.

As regards the plant being worked to only about 1/5th of its capacity, it should be explained that rainfall is only partly separated from the sewage and that, as much of this rainfall is foul, allowance in the capacity of the works had to be made to meet heavy rainfall together with prospective additional sewage.

These factors render it somewhat uncertain as to how the running expenses would compare with those of an installation in a purely barrack area, but the comparison would probably be much in favour of the latter as laundry water and factory waste water constitute a more difficult sewage to treat than that of a purely domestic nature.

SHORT NOTE ON THE PUNJAB HYDRO-ELECTRIC SCHEME.

1.—Shortly after the Armistice the attention of the Punjab Government was drawn to the possibility of generating power in bulk on a sufficiently large scale to supply the whole of the Eastern Punjab, from a large bend on the River Sutlej near Bhakra, a site already selected for the construction of a large irrigation dam in connection with the "Bhakra Irrigation Scheme," a project for which had just been completed.

2.—In October, 1919, the services of Bt. Lieut.-Colonel B. C. Battye, D.S.O., R.E., who designed and constructed the Simla Hydro-Electric Scheme prior to the outbreak of war, were obtained on deputation for this purpose.

3.—The site eventually selected was surveyed during the following cold weather and an elaborate census of the horse-power already installed in the province prepared

4.—This work included an investigation of two alternative sites for a small subsidiary power scheme for some 6,000 kw. to supply power urgently needed in connection with the Simla Water Works, the electrification of the Kalka-Simla Railway and the construction of the abovementioned irrigation and power projects on the Sutlej.

5.—A low-head site on the Sutlej was eventually selected at Nangal and a preliminary project report prepared in detail.

6.—The following year a complete report on the whole scheme was prepared; this was finally submitted to Government in June, 1921.

7.—The four volumes dealing with the Main Sutlej River Project were eventually published and copies were presented to the Institutes of Civil and Electrical Engineers in London, and to the American Societies' Library in New York.*

8.—This work was carried out by the following officers under the superintendence of Lieut.-Colonel Battye:—

Major R. N. Aylward, D.S.O., M.C. (late R.E.), who was responsible for the subsidiary projects and estimates for temporary equipment.

Major G. H. Hunt, M.C. (late R.E.), who was responsible for the survey work and civil engineering.

Lieut. A. Guthrie, R.E., for the electrical work; and Mr. B. K. Sibou, late of the Thomason College, Roorkee, who prepared the census and revenue estimates.

9.—The above report recommended the formation of a Punjab Hydro-Electric Commission, in order to co-ordinate the various interests of the province connected with development of electrical power in bulk. An Advisory Board was formed in June, 1922, and has been mainly instrumental in getting the Uhl River project surveyed and worked out.

10.—In April, 1922, the Punjab Government decided to proceed with the Nangal Subsidiary project; a Hydro-Electric Circle was formed, with Lieut.-Colonel Battye as Superintending Engineer, to construct the Nangal Scheme, with the assistance of the same staff as before, except Major Aylward, whose services had in the meantime been re-engaged to carry out a Hydro-Electric Survey of the Punjab as a whole. Major Aylward formed a Hydro-Electric Survey Division, which was placed under the above Circle, and has in the last two years completed a survey of the water-power resources of the Punjab. He is now writing a report which it is hoped shortly to submit to Government. This survey includes an area extending to 50 miles outside the political boundaries of the Punjab proper, and has revealed the existence of over one million horse-power capable of commercial development as soon as a market exists for it.

* See Appreciation, *R.E. Journal*, June, 1924, p. 267.

11.—During the preparation of the final report on the Nangal project, two of the most important Government Departments, who had promised to use power, fell out of the scheme, rendering it unproductive. During the discussion which followed Major Aylward discovered the site of the Uhl River Hydro-Electric Scheme in Mandi State. After considerable further discussion it was decided to drop the Nangal Subsidiary Scheme altogether and concentrate on the preparation of a detailed project for the Uhl River Hydro-Electric Scheme, which would replace both the Sutlej and the Nangal Schemes as a primary development, the Sutlej Scheme being postponed till after the Uhl River one has been loaded up.

12.—It should be explained at this stage that the Sutlej Project dealt with some 3,300 cusecs, through a fall of 320 ft. necessitating a two-mile tunnel, expensive headworks (the latter complicated by the existence of the proposed Bhakra dam), and two miles of 10 ft. pipe-line, the latter making speed regulation rather difficult and thus militating against the scheme as a primary development, but not as a second, if run in parallel with existing stations.

13.—Power was to be transmitted throughout the eastern half of the Punjab, from Delhi in the south to Lahore and Lyallpur in the north, at a pressure of 132 kilo-volts.

14.—The scheme was laid out for the development of 80,000 kw. at first in one station, but capable of expansion in two more similar stations after the completion of the Bhakra dam, to a total of 240,000 kw. The project was estimated to cost some 735 lacs, to start with, extending to a total of 1,100 lacs, eventually, for the full preliminary development of 80,000 kw.

15.—The Nangal Project involved the handling of 2,000 cusecs, two miles of canal for the same and a 32 ft. drop.

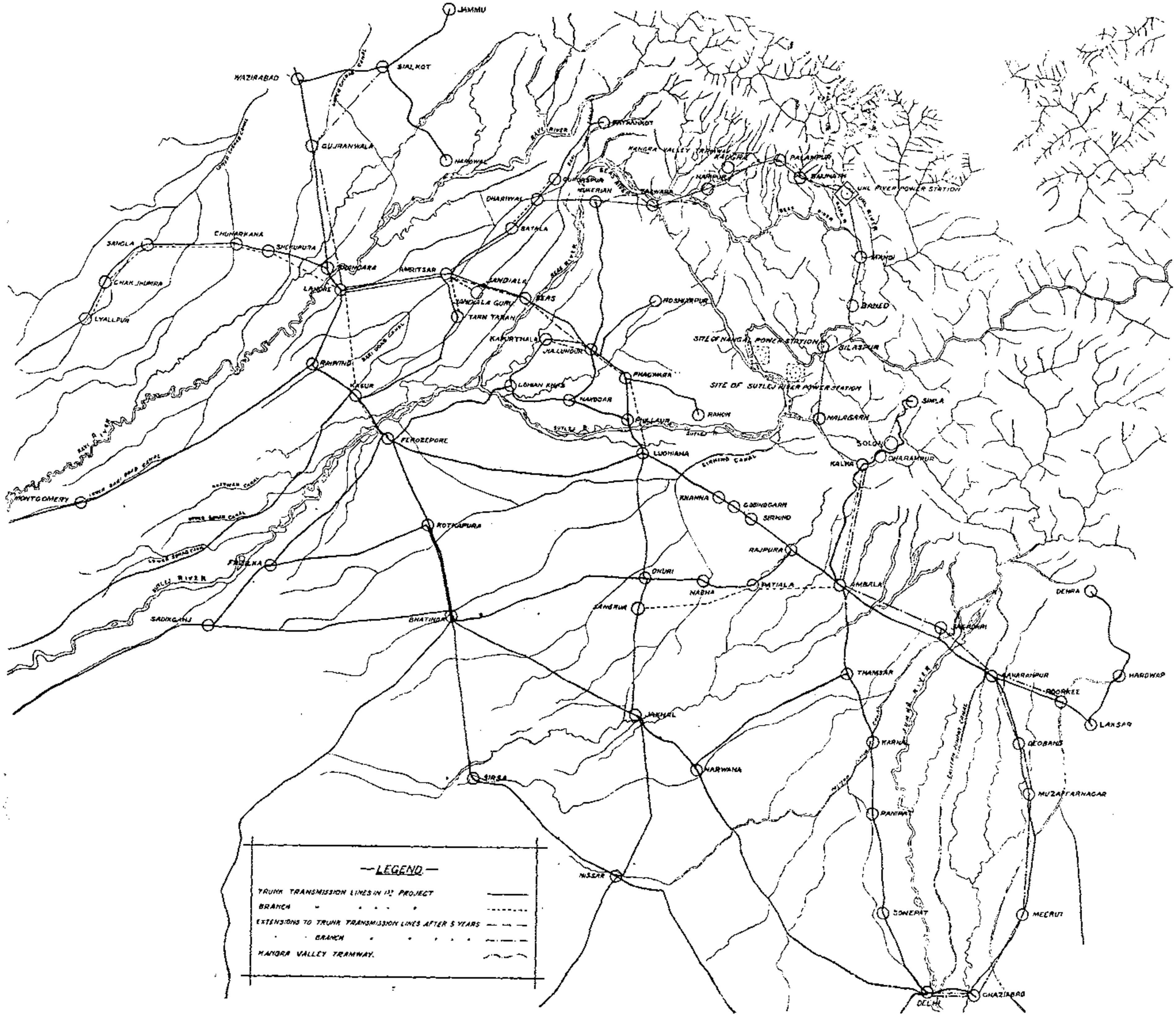
16.—The Uhl River Project, situated much further up in the Himalayas, contemplates a fall of 3,000 ft. in two stages of 1,800 ft. and 1,200 ft. respectively, $2\frac{1}{2}$ miles of tunnel and the handling of only 600 cusecs, eventually. The latter scheme, however, necessitates longer transmission lines in the mountains and the construction of 84 miles of metre-gauge railway to serve the site of the power station, and incidentally the Kangra valley and district, which is urgently in need of railway communications.

17.—The Uhl River project was surveyed during the cold weather of 1922–23, and a detailed project worked out last summer.

18.—This project has since been submitted for scrutiny to three committees specially formed for the purpose, one to deal with the railway proposals, a second with the civil and hydraulic engineering features and a third with financial and revenue aspects of the scheme.

19.—The report has now been completed and published in four parts. The above committees have completed their scrutiny and their reports are embodied in Part I.

THE EASTERN PUNJAB AND U.P., SHOWING THE UHL RIVER HYDRO-ELECTRIC SCHEME.



20.—The report is now about to be examined by Messrs. Merz and McLellan in London, and if their report is as satisfactory as those of the local scrutiny committees, it is probable that the project will mature and work start this autumn.

21.—The scheme involves the supply, to start with, of 26,000 kw extending by stages to 111,000 kw., supplying the whole area in the Eastern Punjab, from Delhi to Lahore, Lyallpur and Sialkot.

22.—A map showing the scope of the scheme is attached.

23.—Promises have been received for sufficient power to pay working expenses and interest charges from the second year of operation, while the normal growth of industry will enable it to meet the depreciation and sinking fund charges as well as a net return varying from 6 to 10 per cent. after the fifth year of operation.

24.—The scheme, inclusive of the railway, is estimated to cost approximately 563 lacs, to start with, extending by degrees to a maximum of 1,145 lacs, when the whole capacity of the site (111,600 kw.) is utilized. The report on the Uhl River Project was carried out by the same staff as that used for the Nangal Scheme, except that the services of Lieut. A. Guthrie, R.E., who was ordered home to Cambridge just before the surveys commenced, were replaced by those of Captain H. A. Kenyon, M.C., R.E., who has been in charge of the transmission lines and electrical side.

25.—If the project matures there will be opportunities for the employment of several engineer officers during the period of construction, which is expected to extend over 3½ years to start with, and an additional three years after that, on extensions consisting of a dam and the development of the lower head.

ELECTRIFICATION OF MILITARY STATIONS IN INDIA.

VERY considerable progress has been made in recent years in carrying out the Government of India's policy of electrification.

This provides for the electrification of the lines of British troops and of all hospitals. The complete scheme, of which approximately 3/5ths is completed or in hand, is estimated to cost approximately 2¼ crores of rupees (£1,500,000).

Electrification of stations in the plains provides not only for the electric lighting of barracks and other buildings, and for street lighting, which is often undertaken on behalf of Cantonment Committees, but for the provision of electric fans and electrically operated trains of punkahs, where these latter can be conveniently and economically installed in place of fans.

At certain frontier stations perimeter lighting has also been provided.

The demand for electric power for other than domestic purposes is not at present great, but is growing. Motor-driven pumps, motor-driven compressors in ice factories and electric-drive in workshops have been installed in some cases.

The total number of stations electrified is 36. In addition, the hospitals only, or certain individual groups of buildings, are electrified at 16 other stations.

At those stations where it can be arranged to obtain a satisfactory bulk supply of energy from an outside source, *e.g.*, a municipality, an electric supply company or the P.W.D., the Military Engineering Services are only required to provide for transforming and conversion, where necessary, for distribution and, of course, for the internal wiring. In a few instances a distributed supply has been provided by the outside agency.

There are, however, 39 power stations operated by the M.E. Services, 29 of which are for station supplies and the remainder for hospitals or for other minor individual purposes.

The amount of plant installed in a station power house which, of course, depends on the size of the station, varies from about 100 kw. to 450 kw., excluding the smaller electrified frontier stations. At the largest station the connected load is over 600 kw. and the consumption, in 1922–23, was over 800,000 units.

A very great variety of plant has been installed. Standardization is, of course, out of the question, though it has been found possible to introduce it to a limited extent. A similarity of practice is at all events aimed at.

At most stations the distribution is D.C., 440 volt, 3 wire. Some of the smaller stations are 220 volt, 2 wire, and at a few stations, where a H.T. supply is taken from a Company, an A.C. supply is installed, whilst in other cases the Company H.T. supply is converted to D.C. for distribution.

MILITARY ICE FACTORIES.

There are ten ice factories operated by the Military Engineer Services. These, which have a total capacity of 24 tons, are all at frontier stations. The largest individual factory has a capacity of seven tons. One-ton plants are mostly installed. There are, however, two 4-ton plants.

MILITARY WATER SUPPLIES.

The majority of cantonments have their own independent water supplies, but with water, as with electric power, advantage is taken of municipal or other outside sources of supply, where these are available and satisfactory, to so obtain the military supply or to have a joint supply.

The independent military supplies and the military or partially military worked joint supplies are very varied in character, from rivers, from dams, from wells, from boreholes, some pure at source and some very impure. A great variety of engineering work is therefore involved, and the pumping plant is even more varied and less standardized than the electric power station plant.

The military pumping stations total 77.

R. OAKES.

ELECTRIFICATION OF HIS MAJESTY'S MINT, BOMBAY.

TILL recently the Mint was driven by steam-power plant, most of which was old, unreliable, and uneconomical. It was therefore decided to replace it by electric motors. A 3-phase electric supply at 5000 volts was available from the Bombay Supply Co. A sub-station with static transformers to step down to 400 volts was installed, and current at this pressure is delivered to the A.C. motors which have been installed throughout.

Full specifications for all the plant were prepared by the Mint, and were issued for tender to selected firms who had branches in Bombay. The tender of Messrs. Metropolitan Vickers was finally accepted. The plant was delivered to the Mint, and the firm supplied an erecting engineer to superintend generally: the actual erection of the whole plant was carried out by the Mint, including the foundations, building work, lining up motors and shafts, etc.; the Mint also undertook all steel work for brackets, ladders, railings, etc.

The machines in the Mint are of many kinds, but the determination of the sizes of motors required was facilitated by the fact that similar plant at the Calcutta Mint was already driven by electric motors. The arrangements for drive adopted are as follows: The general workshop, die department, cutting machines, small coining presses, and other plant not taking much power are driven by squirrel-cage induction motors of sizes up to 15 h.p. In order to avoid the heavy expense of re-arranging the extensive slow-speed overhead shafting and pulleys, back-geared motors with fabric pinions were chiefly used for this work, and have proved quite satisfactory. Motors over 3 h.p. have oil-immersed star-delta starters with overload and no-volt trips. The air pumps working the large coining presses are each driven by a 60-h.p. plain slip-ring induction motor. The rolls are driven by similar motors, the adjusting rolls having motors of 20 h.p., the medium rolls motors of 40 h.p., and the breaking-down rolls motors of 150 h.p. All slip-ring motors have oil switches with overload and no-volt trips for the stators, and liquid starters for the rotors. The 40-h.p. and 150-h.p. motors have fly-wheels, and ohmic resistances are permanently included in their rotor circuits to permit of fly-wheel effect being utilized.

Silent chains are used to drive some of the smaller rolls. Worm-gearing is employed for the larger rolls, *e.g.*, each 150-h.p. motor is mounted on one bedplate with its fly-wheel and worm-gear which runs in oil and reduces the speed from 580 r.p.m. to about 28 r.p.m in a single reduction: this gear stands about 7 ft. high; it makes a compact and efficient job.

A main switchboard mounted in a central position receives current from the sub-station through three 3-core 0·4 square inch cables, and controls the feeders to departments. The feeders proceed to distribution boxes to which the motors are connected.

The power factor of the plant is low on light loads: extra charges for energy are made for a low P.F., while a rebate is given if the P.F. is over 80 per cent. Two 3-phase static condensers made by B.I. and Helsby Cables have therefore been installed to improve the P.F., having capacities of 57 and 116 K.V.A. respectively; they can be connected individually by oil switches to the bus bars of the main switchboard, so that 57, 114 or 171 K.V.A. can be used. They have been most successful, and it is usually possible to keep the P.F. near to unity. It is expected that the savings will cover the cost of the condensers in quite a short time.

The plant is working very satisfactorily. The horse-power installed is about 740. One engineer looks after the whole electrical plant, and has two men to oil and clean, etc., whereas the steam plant required about 30 men. Detailed figures of relative running costs are not yet available, but the savings are considerable.

R. E. STACE, *Major, R.E.*
Mint Master.

THE EMPLOYMENT OF ROYAL ENGINEER OFFICERS ON INDIAN STATE RAILWAYS.

AN officer writing at the end of the year 1923 says that, with the exception of the Khyber Railway (of which a separate account was given in the June number of the *R.E. Journal*), there was not much new railway construction in hand in India.

Many officers of the Corps, however, were engaged on open-line work. Colonel Sir Danvers Waghorn was a member of the Railway Board, Colonel H. E. C. Cowie was temporarily attached to the Board as Chief Engineer and Major F. H. Budden was in the statistical branch on special duty, inaugurating a vast new system of improved figures. Six Lieutenant-Colonels and three Majors were Government Inspectors.

Colonel H. A. Cameron was agent of the Eastern Bengal Railway, having recently returned from leave, during which Colonel G. R. Hearn had been acting for him. Lieut.-Colonel C. Walton was senior deputy agent of the North Western Railway and Major W. F.

Mathews was acting Chief Engineer of the Oude and Rohilkund. Among retired officers, Major-General Sir Henry Freeland was agent of the Bombay, Baroda and Central India Railway, Brig.-General Sir Charles Magniac of the Madras and Southern Mahratta, and Lieut.-Colonel W. R. Izat of the Bengal and North Western.

Major W. Macrae and Captain H. de L. Panet had just completed the Bombay-Karachi Connection Survey from Ahmedabad to Radhanpur; gradients and sandhills defeated them in their attempts to improve on the previous alignment along the north of the Rawn of Cutch, between Radhanpur and Badin.

Major R. N. Burn, Deputy Chief Construction, N.W. Railway, was relaying the Kasur Lodhran branch (picked up to supply Mesopotamia and other places during the war) with an 80-mile realignment between Pakpattan and Mailsi to suit the new Sutlej Canal system. His duties, besides, embraced the Khyber construction, various surveys and conversions, examination of schemes to improve the capacity of sections, and so on.

Major M. T. Porter had just become Deputy Chief Engineer, Southern Section, N.W. Railway. A deputy's charge on the N.W. Railway is approximately four districts of 500 miles each; extensions, remodelling of yards, improvements of water supply, 125 miles of track renewals come his way and, if lucky, he may have a lay-out of large shops, or a gradient improvement, or a large bridge that is overstressed, or the control of a meandering river thrown in to keep him busy between budgets and retrenchment programmes.

Major H. L. Woodhouse was looking after the permanent-way of the N.W. Railway and had a creosoting plant at Dhilwan, turning out 300,000 sleepers annually. The stores balances of Indian railways have of late become the butt of the managements, so that a permanent-way officer's energies are devoted to the elimination of obsolescent types, in addition to the economics of supply and distribution of materials. Concrete sleepers also are being tried.

The traffic departments claimed Lieut.-Colonel C. S. M. C. Watson and Captain G. Walton.

There were no R.E. officers in the locomotive or carriage and wagon departments, it being the precedent for them to undergo a locomotive course, but for reasons unknown, not to remain longer in those departments.

Captain H. H. E. Gosset was personal assistant to the Chief Engineer, N.W. Railway, and was looking after the large engineering staff of officers, permanent-way inspectors, inspectors of works, clerks, etc., down to time-keepers and tracers.

The responsibilities of executive work in India have increased considerably. The assistant engineer grades are being filled more and more by Indians who, to say the least of it, require more encouragement and supervision than the older generation

Captain R. E. Gordon had recently been attached to the signal department and was employed on the new lay-outs of yards that required remodelling.

The War is responsible for a hiatus in the number of R.E. officers taking up railway work, but it is good to observe a few junior officers coming on, like Waghorn, Panet, Dawes and Biddulph, and it is hoped that others may shortly be appointed.

The 25th Railway Company, Royal Bombay S. and M., were employed during the past year in construction and rapid plate-laying through jungle country.

NOTES ON THE GLENO DAM FAILURE.

On 1st December, 1923, the reinforced concrete power dam at Gleno, in Northern Italy, failed, causing great destruction to life and property in the valley below. A description of the dam and the result of the investigation into the causes of failure appeared in the *Engineering News Records* of the 31st January, 1924, and of 20th March, 1924, but, as many lessons can be learnt from failures of structures, a *résumé* of the articles is given below for the benefit of those who have not had the opportunity of reading the description themselves.

The Gleno dam, built after the war and only recently completed, was a reinforced concrete structure of multiple arch type resting on a gravity base of stone masonry.

The dam was about 800 feet long, and on most of its length ranged from 80 to 100 feet high, but in the narrow central gorge the height was about 160 feet. The gravity base filled the gorge and gave a horizontal base to the cellular or multiple-arch concrete super-structure which stretched across the valley. *Fig.* 1 shows the completed dam looking upstream.

The multiple-arch superstructure consisted of semi-cylindrical arches, 26 ft. 3 in. in span between centres of buttresses and inclined 53 degrees to the horizontal.

The type of construction can be understood from *Fig.* 2, which shows the upstream face of the dam after the breach had occurred.

From an analysis of the design of Dr. A. Stucky, of Basel, made by drawing pressure lines and computing stresses on horizontal sections, no abnormal conditions were found. Taking inclined sections, slight tensile stresses were found to exist in the buttresses near their up-stream edges, but these could not be considered serious. The maximum horizontal shear was below 60 lb. per square inch and the maximum diagonal shear about 70 lb. per square inch. Failure therefore does not appear to have been due to faulty design.

In the examination of the constructional methods used there appear to be many faults.

Nothing was done to prepare the surface of the foundation rock to receive the structure. No steps were cut, nor was the surface roughened to receive the bond. The rock surfaces are described as so smooth that mortar could not adhere.

Although the specifications called for cement mortar, much of the masonry of the gravity base was constructed in lime mortar, of lime burnt near the site by the builders. The upper portion of the base was constructed in cement mortar. The concrete of the cellular superstructure was of poor quality, the gravel aggregate was not washed and the concrete in the structure was porous. The concrete was mixed by hand. Nothing is said of the proportion of cement to aggregate used, but the conclusion may be drawn that the mixture used was very weak in cement.

The reinforcement used was inadequate, that in the buttresses was scrap netting used during the war for protection against hand grenades. The bond of the concrete to the steel was injuriously affected by large stones thrown into the concrete during construction. As a further proof of the low strength of the concrete is the fact that the reinforcement generally stripped quite clean.

The faults in construction may be summarized as follows: (1) Failure to cut footings in the rock for the buttresses of the dam, (2) Use of improper materials and lack of inspection of materials, (3) Poor mixing and lack of inspection of the concrete, (4) Use of unwashed aggregate, (5) Lax inspection in pouring the concrete, (6) Failure to ram the concrete in the forms, (7) Generally incompetent direction and supervision.

Failure occurred about six weeks after the reservoir had reached its full level and is attributed to buttress shear, owing to the weakness of the material used in construction.

Even before the accident the buttresses probably contained shear cracks indicating incipient failure. There may or may not have been causes inciting the failure, such as the leaching out of the lime mortar from the masonry base causing settlement or the slipping of the masonry base on its foundations, either of which would have increased the already serious stresses in the buttresses to a fatal degree and brought about destruction.

The absence of efficient specifications or the neglect to follow such specifications if they did exist during construction was the true cause of the disaster.

D.K.E.

MEMOIRS.

MAJOR-GENERAL SIR GEORGE KENNETH SCOTT-MONCRIEFF, K.C.B., K.C.M.G., C.I.E., M.I.C.E.

BY the death of Sir George Scott-Moncrieff the Corps has lost a very distinguished servant and a greatly-valued friend and comrade, a fine officer and an eminent engineer, whose life was one of whole-hearted loyalty and unstinted industry in the service of the Crown, and of the Corps which ever held a foremost place in his pride and affections.

He was born in India in 1855, second son of Major Alexander Pringle Scott-Moncrieff and Elizabeth Coventry, his wife, and was a grandson of Robert Scott-Moncrieff of Fossaway, and nephew of that distinguished engineer, Sir Colin Scott-Moncrieff.

At the time of the mutiny of the Bengal Army in 1857, Major Scott-Moncrieff being absent on duty with the 44th Bengal Infantry, his wife, a woman of great courage and determination, escaped with her three children from Purulia, Chota-Nagpur, to Calcutta. His father died in 1865, and from shortly after that time till 1913 his mother lived in the family dower-house, Elie Castle, in Fife.

George Scott-Moncrieff was educated at Edinburgh Academy and at the Royal Military Academy at Woolwich, entering the Royal Engineers in 1873, and leaving Chatham in 1876.

His first employment was on the Thames Defences at Gravesend, chiefly on railway and jetty work, for landing heavy guns. He designed a large T-pier in the Thames at Shornmead.

In December of the same year he proceeded to India, and in February, 1878, was appointed Assistant Engineer in the Indian Public Works Department on the Swat River canal and employed on the design and construction of several large masonry works, aqueducts and bridges.

The year 1878 gave him his first chance of active service, in the Afghan campaign, in which he was present at the capture of Ali Musjid, and throughout the operations did a lot of important work, including the construction of twenty miles of the road from Cabul to Peshawur.

When Sir Sam Browne's force marched down from Afghanistan in June, 1879, a mass of R.E. stores were collected at Jellalabad, and transport having broken down, hundreds of little rafts were constructed, under the orders of the C.R.E. (the late General Sir Frederick Maunsell), from *mussaks* and telegraph posts, and were

MAJOR GENERAL SIR GEORGE KENNETH SCOTT MONCRIEFF
KCB KCMG CIE

floated down the Cabul river to Dakka, each under the charge of two sappers. The night before the work was finished the men of Jellalabad, furious at losing the loot, attacked the fort, but made no impression. Scott-Moncrieff was one of the four or five subalterns kept by the C.R.E. for this work, and when it was finished they embarked on the last raft and made the passage to Dakka in about eight hours, through extraordinarily interesting scenery, partly through a gorge with vertical cliffs about 1,000 ft. high on either side, and, high up on one side, like pigeon-holes, could be seen the caves that Buddhist monks had burrowed for themselves in the cliff, the only access being by ropes from far above.

For his services in this campaign Scott-Moncrieff was mentioned in dispatches, and received the medal and two clasps.

From December, 1880, to October, 1882, he was stationed at Jutogh, near Simla, where he designed and erected many new barracks, hospitals, and other buildings, and constructed some new roads. In 1882 he became Executive Engineer of the Lucknow Division, building new barracks there also.

Appointed Deputy Consulting Engineer for Guaranteed Railways, Lucknow, in April, 1883, he was selected, after six months in that appointment, to be Personal Assistant to the Engineer-in-Chief of the Sind-Peshin State Railway, and the next year we find him in charge of the Quetta Survey Division, laying out the line from Quetta to Garkai (33 miles). After that he was Executive Engineer of the Nari Division of the Sind-Peshin Railway, which included two large bridges, sixteen smaller bridges and a tunnel.

In 1885 he was promoted Captain and invalided home, and in 1886 his marriage took place. His wife, Helen Morin, youngest daughter of Robert Moubray of Naemoor, was a lady of great charm, and had been the friend of his boyhood. The marriage was one of abiding affection, and of closest mutual interest and sympathy. Of the happy home life we may not speak, but that it was bound up with his love for the Corps appears from the words of the eldest of their six daughters: "The 'Corps' has always been to me a symbol of all that is greatest and best and most worthy of loyalty."

In 1886–7 he was employed at Colchester, but in the latter year he was given command of the 12th Field Company, and held it till December, 1891. At the Curragh he carried out the remodelling of the drainage of the barracks. The company was at Aldershot during the later part of his command.

In 1893 Scott-Moncrieff was promoted Major, and appointed Instructor of Military Engineering at the S.M.E., remaining till December, 1898, in that appointment. During this time he published two volumes on *Structural Design*, and a splendid book on *The Water Supply of Barracks and Cantonments*. These became text books of the course. He was the originator of the *R.E.*

Field-Service Pocket-book, a work of which he was justly proud. He had previously written an excellent pamphlet on *The Frontier Railways of India.*

In 1892 he became a member of the Institution of Civil Engineers, his sponsors at his election being Sir Guilford Molesworth and Sir Colin Scott-Moncrieff. In 1917 the Institution conferred on him Honorary Membership, a distinction which he greatly valued. The records of the Institution show his ability and the variety of his engineering interests, by his useful intervention in the discussions on the Water Supply of Liverpool, Stresses in Masonry Dams, Road Construction and Maintenance, and again on Wind Pressures and Stresses Caused by Wind on Bridges.

On leaving Chatham he returned at once to the P.W.D. in India and was given charge of important work on arterial roads on the Frontier. There he got into touch with leading Mahommedan *maulvis*, and through them created a considerable interest in the Bible, copies of which, in Pushtu, he distributed.

In 1900, at the special request of the Viceroy, who had been impressed by his ability, he was sent in command of the Royal Engineers with the Indian Expeditionary Force for China. He took part in the relief of Pekin and in the actions at Peitsang and Yangtsun, was mentioned in dispatches, awarded the C.I.E. and given the China medal.

In 1901 he was promoted Lieut.-Colonel, and on his return to India was appointed Chief Engineer of the N.W. Frontier Province and Secretary to the Chief Commissioner, but in 1901–2 we find him again on active service with the Waziristan Expedition. He received the medal and clasp.

Of this period one of his brother officers writes: "What I noticed about Scott-Moncrieff was the strength of his religious convictions. He never started the day, however early, without reading a portion of the Scriptures. He had great physical energy and endurance. After long days in the saddle, or on foot, he would tackle correspondence or any business which came along till quite a late hour of the night."

In 1904, being made Bt. Colonel, Scott-Moncrieff reverted finally to Home service, and was appointed C.R.E. at the Curragh, where he was held in high estimation by General de Courcy Morton and given every opportunity for improving the work of Field Companies with cavalry and infantry.

He was known also as a good man to hounds, with a great heart for a big bank. An officer writes: "I commanded a field company at the Curragh when Sir George Scott-Moncrieff was C.R.E. there. He struck me always as being the ideal C.R.E., equally at home in soldiering and engineering, and obviously a power with the G.O.C. and Staff. He saw to it that we got plenty of jobs both on

"Works" and in Brigade and Divisional trainings, but was by no means a believer in all work and no play. We never had any difficulty in getting leave for hunting. He was out himself often with the Kildares, and we used to chaff him on the number of times he had 'crashed' on his top-hat, saying that he did not seem to think that he had a good day unless that had happened.

"It must have been due to him that we got some excellent experience of bridging expedients with the 3rd Cavalry Brigade (General M. Rimington), at Lusk and at Bannow. These manœuvres finally took the form of squadron and horse artillery competitions across wide tidal inlets, with a pretty heavy current. Each squadron and battery was directed by Rimington to a point where stores were laid out and had to get horses and men across, using catamarans, hay-bale rafts, extemporized boats, etc. The contests were most exciting and interesting." The same officer bears witness to Scott-Moncrieff's keenness for engineer reconnaissance and also to the excellence of his winter lectures to officers and men of the companies.

On the 1st October, 1906, he was promoted Colonel and posted to the War Office as A.D.F.W. In 1907 he was awarded the C.B. The officer quoted before speaking of this time also says: "I owe him a very valuable bit of experience (when I was still O.C. Field Company), in connection with the installation of the Cavalry School at Netheravon in 1907–8. It consisted in the moving from Bulford and re-erecting at Netheravon a number of huts, buildings and stables, also installing a water-supply and sewerage scheme by sapper labour, supplemented by infantry working parties in the earlier stages and civilian labour later on. It was really a contract, and we did the job with a considerable saving on the estimate."

In August, 1909, Colonel Scott-Moncrieff was made Chief Engineer at Aldershot, with the temporary rank of Brigadier-General. There he remained, again making his mark by the excellence of his work and administration till, in September, 1911, he was selected by the Army Council for his last appointment, Director of Fortifications and Works. He was promoted to Major-General in October, 1912.

The incidence of the war and his own proved fitness for his great charge caused the tenure of his appointment to be extended till February, 1918, when he had to make way for Sir P. G. Twining and finally retired.

For his services in the war he received the K.C.B., the K.C.M.G. and the medal. He has himself written full accounts of the work carried out in his office during this strenuous time. It must, therefore, only lightly be reviewed in this memoir. It is not too much to say that Scott-Moncrieff's cool and balanced judgment, his ability and experience, together with his extraordinary industry, were of vital importance to the War Office during the course of the war till he handed over. A part of the work was closely affiliated to that of the Quartering Branch of the Q.M.G.'s Department, and those who were in that Branch can gladly bear witness to the cordial and kindly relations which throughout were maintained, and to the ready assistance and advice always available in the office of the D.F.W.

An officer, serving under him at this time, being also his intimate friend, writes :—

> "It was during these fateful years that we were almost hourly in contact and no one will ever know how much work he got through and how his indomitable spirit and absolute dependence upon God for everything sustained him through untold pressure and deep family sorrow.
>
> He was usually surrounded by members of his staff and others waiting for interviews or 'decisions' and he was always alert and quick to decide whenever questions were referred to him.
>
> His judgment was sound and definite and once given was 'carried through.' There was no time for hesitancy and his wide knowledge and experience of all engineering questions and official routine instilled confidence into his staff, whom he absolutely trusted and who had the fullest confidence in their Chief."

His connection with the Institution of Civil Engineers was one of great avail at this crisis, and he was able to draw in the power of a number of civil engineers and to secure the services of many of the leading contractors.

His own accounts of the work are recorded in a series of articles contributed to the *Times Engineering Supplement* in the early part of 1919. Later on he published in *Blackwood's Magazine* (to which he was a frequent contributor) reminiscences of his association with Lord Kitchener before and during the war. There is also in the present number of the *R.E. Journal* an article of his on the hutting problem of the war, which gives in detail the work from the aspect of his office, and shows the magnitude and interest of the service.

The supply of engineering stores to the armies in the field gave him much urgent thought and necessitated visits to France.

The illness of his wife and her passing away in November, 1916, the result of terrible injuries received more than a year before, by being knocked down by a motor-car, brought crushing anxiety and sorrow upon Scott-Moncrieff, at a time when his work in the great war was at its heaviest, and saddened and aged him.

On his retirement he joined the Board of Messrs. Macdonald Gibbs & Co., and, in connection with "English Oilfields," set to work on the development of the shale oilfields near King's Lynn. This work he continued till, in 1921, failing health obliged him to curtail his activities. His great sorrow, and the ceaseless work and devotion to duty of the years of the war, had weakened his vitality and his medical adviser now warned him that his heart was badly overstrained, and that, unless he took the greatest care, he must not expect his life to be prolonged for many months. Characteristically he accepted the verdict with a smile, saying that he hoped to be able to work till the end should come. He was always ready.

To his friends he seemed to be getting better, and there was no slackening of his religious work or in his Corps interests.

His loss will be specially felt by the Central Committee of the R.E. Old Comrades' Association and by the Charitable Fund, of both of which he was chairman.

He took an active part in the reconstitution, under the Royal Charter, of our Institution, of which he was elected one of the Vice-Presidents; and was deeply interested in the development and improvement in the *Journal*.

His fellow-members of the Councils and Committees of the Corps will unanimously testify not only to his unfailing good-humour and courtesy, but also to the innate generosity of his views, especially in dealing with personal matters. He seemed to bear the whole world in affectionate remembrance. The sterling quality of his advice and of his opinions made them always acceptable, while the deep tones of his voice, and the ready smile and humour behind his somewhat serious aspect, weightily impressed his hearers.

The end came suddenly in Poland, whither he had gone in the interests of the Society for promoting Christianity among the Jews.

A brother officer writes: "Thus he died as he would have wished, working for the cause of the Saviour Whom he had consistently served all through his life. Deeply religious, he was no narrow sectarian, but a true exemplar of the gallant and happy fellowship to which so many of our greatest Anglo-Indian soldiers and civilians have belonged."

When duty had brought him home to England, he was welcomed on the Boards of the Church Missionary Society (of which he was a Vice-President, and a very active member), and of the British and Foreign Bible Society.

He was the author of *Eastern Missions from a Soldier's Standpoint*, and for fourteen years he compiled the monthly Missionary Leaflet for the Officers' Christian Union, embracing a view of practically every missionary operation in the world. Even in the stress of the world-war he never failed to produce a comprehensive epitome of the missionary activities of the Church of Christ, in itself a monument of research and industry.

He leaves to the Corps and to his many friends a memory fragrant with loyal service, kind words, unswerving friendship, tireless industry, and a record of high principle fulfilled in every interest of his life.

F.G.B.

COLONEL WILLOUGHBY DIGBY MARSH.

COLONEL W. D. Marsh, who died at Thomas Town, Co. Kilkenny, on 19th May, 1924, in his 93rd year, was the oldest surviving officer of the Corps, with which he was connected for nearly 75 years, 40 of which were on the active list.

He retained the use of all his faculties almost to the end, though latterly troubled by failing eyesight. He was a keen fisherman and killed his last salmon a few years ago, unaided and with a foot of snow on the ground.

Born in 1831, the eldest son of Rear-Admiral Digby Marsh, he was educated at Blundell's School, Tiverton, and entered the " Shop " at the age of 15. He passed out Head of his Batch and was gazetted 2nd-Lieut., R.E., on 19th December, 1849, being promoted Lieut. in 1854, 2nd-Captain 1858, Captain 1864, Major 1872, Lieut.-Colonel 1874, Substantive Colonel 1885, and placed on the retired list in 1889.

Colonel Marsh was unlucky in missing the " Crimea " and the " Mutiny," spending those eventful years in the West Indies, where he was stationed from 1852 to 1857, at St. Vincent, Trinidad and Barbados. At the last named place he served through a severe epidemic of cholera, which carried off many of the inhabitants and of the Garrison.

At various stages in his career he was employed on " Works " at Woolwich, Chatham and London. He was also an Instructor in Survey at Chatham from 1861 to 1865, and attached to the I.G.F.'s Office from 1865 to 1870. His eyes suffered much at this period from the bad lighting of his office, but after a period of rest and attention they recovered.

From 1875 to 1884 Colonel Marsh was at the " Shop," first as Professor of Military Drawing and later as Secretary and Treasurer, being " Acting Governor " on several occasions. This long spell of duty at the R.M.A. caused him to be well known to a very large number of the officers of the R.A. and R.E. commissioned during those years; one of his pupils was the Prince Imperial.

His last appointment was Colonel on the Staff, C.R.E., in Ireland. Whilst holding this appointment he was made a J.P. owing to the disturbed state of the country. It does not appear, however, that he was ever called upon to read the Riot Act or to call out the military.

Shortly after leaving the service in 1889 he settled down in Kilkenny.

Colonel Marsh had a wonderful memory. With his elder sister, who is still living, he saw his brother (afterwards killed in the Crimea) carrying the Colours of the Duke of Wellington's Regiment at the Duke's funeral. He was a contemporary and intimate friend of General Gordon, and loved to recall incidents in the latter's career.

COLONEL WILLOUGBHBY DIGBY MARSH

Colonel Marsh was an artist of very considerable talent as well as a skilful carpenter and a good shot and fisherman. He was a devoted Christian, courteous, considerate and always anxious to help everyone around him; a gentleman in the best sense of the word, he will be long remembered by all who had the privilege of knowing him.

He leaves two surviving sons and one daughter, married to the Hon. H. A. Shore.

COLONEL GEORGE ANDERSON CARR.

COLONEL George Anderson Carr, who died on 20th March, 1924, was one of the pioneers of electrical science in the British Army. Born in 1857, he was the son of William Carr, Esq., of Nymans, near Crawley, Sussex. He was educated at Uppingham and the Royal Military Academy, Woolwich. He obtained his first commission in the Royal Engineers in August, 1876, and after two years of instruction at the School of Military Engineering, Chatham, he was posted to the Submarine Mining Service, with which he was employed at Chatham, Sheerness, Portsmouth and Pembroke Dock. In 1883 he was appointed Assistant Instructor in Electricity at the School of Military Engineering and in 1886 was transferred to the School of Submarine Mining, which was just being reformed at Gillingham.

He was promoted to Captain in 1887 and in 1889 went to Bermuda for his first foreign service. He was recalled from there in 1892 to take up the new appointment of Chief Instructor at the School of Submarine Mining, Gillingham, and in 1896 was appointed Instructor in Electricity at the School of Military Engineering, having been promoted Major in 1895. In 1902 he was posted, on promotion to Lieut.-Colonel, as C.R.E., Cape Colony. Here he came in for the last few months of the South African War and received medal and clasp.

He retired at his own request in March, 1909.

Colonel Carr married, in 1888, the eldest daughter of the Rev. R. P. Hooper, of Hove, and had two sons, both of whom obtained commissions in the Corps of R.E.

The above is a short summary of a very active and useful life and a few words may be added to fill in some of the details. Like many other young officers, Carr passed easily through his various courses and examinations without any special distinction, but when posted to the Submarine Mining Service he found employment which was entirely congenial, and well adapted to his special qualities and character. Possessed of a remarkable capacity for clear and accurate thinking, he added to this an infinite capacity for taking pains. With him nothing was ever half-done; if he started any job he threw himself into it whole-heartedly. In his new work he found himself in company with a little group of officers who were laying the foundations of a new application of science to military purposes. Chief among these were Major R. Y. Armstrong, R.E., Lieut. P. Cardew, R.E., and Lieut. (now Major-General Sir R. M.) Ruck, R.E. Under these officers it fell to Lieut. Carr to carry out many detailed experiments, to elaborate electrical apparatus, and to devise methods of testing which could be readily applied in the rough and tumble of military work. He was the first to suggest the fitting up of standard test rooms at military defence stations so arranged that the position of all firing and testing apparatus would be identical in each station.

He was Secretary of a special committee in 1880 which reported on the patterns of apparatus in use for searchlights, which laid the foundations of that branch of the military service.

As an Assistant Instructor and Instructor in the Electrical School, S.M.E., he was responsible for the instruction of military telegraphists, and for the instruction in signalling of all ranks.

As an instructor and lecturer he was at his very best. He not only had the habit already referred to of clear thinking, but the capacity of putting his thoughts in logical sequence and expressing them in clear and simple language adapted to his audience. He was for many years the examiner in electricity at the Royal Military Academy.

In connection with his various appointments he held for different periods an *ex officio* position as Member of the Royal Engineer Committee, and was at one time Secretary. This committee worked through sub-committees, which investigated and often originated proposals for changes in the construction or use of all military engineering stores and appliances. Carr was a member of all the electrical sub-committees and was often called on to act as Secretary or for special work, such, for instance, as the standardization of patterns and sizes of screw threads in use throughout the Army. He attended as a member of this committee the early trials of Marconi on Salisbury Plain, and at Poole in 1895, and formed a personal friendship with Signor Marconi.

He became an associate member of the Institute of Electrical Engineers in 1882 and served on the Council of that Institution in 1895–96. He was admitted to full membership in 1896.

To those who knew him well he was a most interesting companion, as he had read and studied much and generally took some original and often illuminating view on any controversial question. Though interested in games and playing those he took up well, he only treated them as a recreation. But perhaps his most marked characteristic was a deep-seated modesty as to his own qualifications. He never put himself forward for any of the appointments he held, or asked any favour as to employment. It was perhaps unfortunate both for himself and for the Army as a whole that his period in the rank of Lieut.-Colonel should have been spent in the comparative seclusion of Cape Colony, so that he dropped out of the running for a senior appointment in England.

Major-General Sir Richard Ruck, K.B.E., C.B., C.M.G., writes:—As I was closely associated with Colonel Carr in the early days of submarine mining, I should like to say a few words in support of your appreciation of his work and character.

The Corps of R.E. was very fortunate at that time in possessing officers of the type of Colonel Armstrong, Major Cardew and Colonel Carr, men of first-class intelligence combined with real scientific ability and an absorbing devotion to their work.

These officers, with one or two others, were (as you remark in the case of Colonel Carr) the pioneers of electrical science in the British Army, Colonel Carr being, I think, pre-eminently the instructor and perfector of the electrical methods and appliances which were not infrequently in those days of a makeshift nature.

In common with all who were associated with Colonel Carr, I had the greatest possible respect for his sense of duty, knowledge and ability, and one could not wish for a more loyal and careful assistant.

His work in connection with the electrical side of submarine mining was invaluable, and his general career one of great utility to the Corps to which he was proud to belong.

W.B.B.

COLONEL HUGH MONTGOMERIE SINCLAIR, C.B., C.M.G., C.B.E.

COLONEL H. M. SINCLAIR, late R.E., died suddenly at Barming House, Maidstone, on the 10th July, 1924. The fifth son of Canon William Sinclair, who was formerly a captain in the Madras Cavalry and afterwards rector of Pulborough, he was born in 1855 and was educated at Malvern and Repton and at the R.M.A., from which he passed into the Royal Engineers, gaining the Pollock medal, in February, 1874. After short tours of service at Chatham, Dover and Aldershot he went to Cyprus on its occupation by the British in 1878 and remained there for eight years, during the last five of which he was private secretary to the High Commissioner. He served in Ireland from 1886 to 1888 and then went to the Staff College, from which he graduated with honours in 1890. From 1890 to 1892 he was employed at the War Office and then obtained the appointment of D.A.A.G., North Eastern District, which he held until 1895. He was again at Aldershot in April, 1895, and from there he went as C.R.E. to the Ashanti expedition, for which he received the Star and Brevet of Lieut.-Colonel.

He served in India from 1896 to 1899 and then became A.M.S. and A.D.C. to Lieut.-General Sir George Luck, Commanding in Bengal, but threw up the appointment a year later to take part in the South African war, where he was employed on transport duties, graded as A.A.G. He took part in the operations in the Orange Free State, February to May, 1900, in the Transvaal east and west of Pretoria, July to October, 1900, including the battle of Zillikats Nek, and in Cape Colony, South of Orange River, and was mentioned in dispatches. He returned to India for two years, was C.R.E. Woolwich 1902–3, A.Q.M.G. Western District till 1907, A.A.G. Southern Command (1907–8) and Chief Engineer Scottish Command until he retired from the service in February, 1912. In 1906 he married Rosalie Sybil, second daughter of Sir John Jackson. He received the C.B. in 1910.

Colonel Sinclair settled near Maidstone in 1912, but on the outbreak of the Great War he was appointed Commandant of Railways and Roads Training Centre at Longmoor and held the command until the end of 1919. He received the C.M.G. and military C.B.E. as rewards for his services. During the last years of his life Colonel Sinclair entered keenly into the religious work of his village and of the Rochester Diocese, and he will also be gratefully remembered for his share in the work of the R.E. War Memorial Committee, in which he was Chairman of the Monument Sub-Committee, and devoted much time to the selection of the site for the R.E. Memorial, the preparation of the Roll of Honour and the work in the Kitchener Chapel in St. Paul's Cathedral, where the Corps is presenting the altar and providing a niche for the Roll of Honour. It is not the least regret of those who were associated with him in this latter work that he has not lived to see it completed.

COLONEL HARRY D'ARCH BRETON.

COLONEL HARRY D'ARCH BRETON, late R.E., whose death took place at Rochester on Friday, 19th July, was the son of the late Captain W. H. Breton, R.N., and was born at Bath in 1851. He entered the Corps in 1871, and during his 33 years of service he was employed for over 14 in the I.G.F.'s office at the War Office, including nearly five as Assistant I.G.F. (1899 to 1904). He was not fortunate enough to see any active service and had only one tour of foreign service, which he spent at Saint Helena, as a Captain (1876–1881). He retired in 1904 and settled at St. Margaret's House, Rochester, where he threw himself heart and soul into municipal activities. In 1914 he became mayor of the ancient city, so well known to all members of the Corps, and he was still Mayor of Rochester when we held our Memorial Service in the Cathedral in 1919. Throughout all the anxious years of the War his services to the Borough were untiring and invaluable, and no small strain upon a man no longer young. His last years will be chiefly remembered for his efforts on behalf of the ex-Service men. He was an example of the grand type of old English gentleman, courteous to all, a good companion and universally popular.

BOOKS.

EAST PERSIA: A BACKWATER OF THE GREAT WAR.

By Brigadier-General W. E. R. Dickson, C.M.G., C.I.E. (Edward Arnold & Co. 15s. net.)

Generally speaking, a book written by an R.E. officer on engineering subjects is interesting. When to these subjects are added solved problems in Strategy, Transport and Administration, then such a book becomes absorbing, and such a book is General Dickson's *East Persia: A Backwater of the Great War.*

General Dickson's account of this "backwater" has already been favourably noticed in the Literary Supplement of *The Times*, which draws attention to the fact that the Government of India, with its G.H.Q., frequently displays the faculty of fitting round holes with well-turned round pegs. In this case there was appointed, as I.G.C. of the L. of C. in East Persia, a soldier who was experienced as an Engineer, as a Staff Officer, and as a linguist in Persian and Russian.

The book is a "workshop record" of the conversion of a loose net (called the "East Persian Cordon") into a close-meshed sieve (called the "East Persian Line of Communications"), which was designed to intercept Turco-German emissaries (*en route* to intriguing in Afghanistan) as well as to continue the throttling of the traffic in rifles between the Persian Gulf and the N.W. Frontier of India.

The future historian will no doubt grumble that this same "workshop record" is unworkmanlike in that it omits to state the *years* of the happenings. For instance: he will be unable to ascertain when General Malleson's Mission went to Meshed, or when the author went to East Persia, or when the great road was begun and when finished, or when the Quetta railway was pushed on to Persia. This failure to indicate the *years* in which events occurred is one of the commonest (and, one may say, the most exasperating) of faults in all the unofficial histories of the many theatres of the war.

Before the mid-period of the war, our line of approach to the South-East corner of Persia, *i.e.*, Seistan, was a veritable "pilgrim's-way" from the railway terminus at Nushki (which is about 100 miles south-west of Quetta) across about 300 miles of desert lying to the south of

Afghanistan. By dint of the superhuman energy of its Engineer-in-Chief, the railway had been pushed on across this desert to within 100 miles of the Persian border when General Dickson took over charge as I.G.C. in E. Persia, and it was finally carried through to Duzdap, from which point General Dickson made his great road which stretches 600 miles to Meshed, in the north, and runs parallel with the western boundary of Afghanistan and approximately 80 miles from it. From Meshed to Askabad, 170 miles to the north-west, a good carriage-road had been made by the Russians. This road also came within General Dickson's L. of C., which, therefore, was 870 miles in length, or about the distance from Boulogne to Vienna, or from Karachi to Landi Kotal (at the top of the Khyber).

This mere recital of distances would not impress the mind without such considerations as the nature of the country (deserts, quagmires, shifting sand and stony ranges), the difficulties of climate (terrible heat and appalling sandstorms in many sections, and icy blizzards in many others), the lack of *personnel*, skilled or otherwise, and the want of "straw" for the "bricks." Added to these great obstacles was the need to evolve, and to evolve at racing speed, order out of the chaos which the inception of our first efforts in East Persia occasioned. How a "man of mettle" may "grasp" such "thistles" in the path of progress General Dickson tells in simple, clear and modest language, much of which is devoted to giving credit to the whole of his loyal band of workers, from the late Colonel Mark Synge (a Napoleon of Supply and Transport in wild regions) down to the M.T. driver, who postponed his own comfort and demobilization so as to motor General Dickson on his final and farewell tour before giving over command.

From the point of view of the R.E. reader, it is rather unfortunate that there are no descriptions of the methods adopted for the crossing of ravines and streams, whether these were negotiated by Inglis bridges, steel girders, arched masonry, or suspension work.

However, what we lose on the Engineering we gain on the Transport, a subject which is dealt with in a novel and interesting way. The first principle, as it occurred to General Dickson, and as it was developed by Colonel Mark Synge, was that the Troops and Services were "consumers," and the Transport was the "producer," of a commodity called "transportation energy." The unit of "transportation energy," applicable to consumer and producer, which was selected by these two officers was the moving of one ton, once a week, over a distance of one mile, and it was designated "WTM." As it would seem like pilfering to reproduce, in a review, the working of this scheme, which is adequately explained in the book, it will suffice to say that the WTM of a camel worked out at 6 tons, and that of a Ford van at 46 tons, after allowing for rest and repairs. By compiling, and having at hand, a sort of "ready-reckoner" table, showing the needs of the various arms, and units, in tons, and showing also the various distances and the WTM value of the classes of transport available, it was easy to answer, with speed and accuracy, the conundrums from G.H.Q., and to deal with varying demands of the L. of C.

General Dickson completely justifies his action in expending money on hutting the troops, etc., on his L. of C.—an expenditure which was hysterically condemned by ill-informed newspapers, but an expenditure which saved the whole of the Force from serious losses, when death and disease lurked in the Persian " billets," which these same newspapers would have had our men inhabit—.

One of the most important points brought out in the book is the establishment of excellent relations between the Persians, of the whole of the lengthy locality, and our own people. This admirable result was due to the irreproachable behaviour of the troops themselves and to the faultless tact of all our officers, who were always just in their firmness and wise in their toleration. The effect of such relations on the trading between East Persia and India has already been considerable, and, especially as the imports from Bolshevist Russia have dropped by 80 per cent., it seems most likely that the whole cost of our occupation of East Persia will be recouped by our increased trade in the very near future.

General Dickson saves his book from being merely a serious record by many " human " touches and by humorous stories of Oriental guile and simplicity. Not many of us have had an invitation-card marked " Hanging and throat-cutting at 4 p.m. on the Execution Square."

G.P.C.

THE ARMY IN INDIA, AND ITS EVOLUTION, 1924.

(Superintendent, Government Printing, India.)

As specified in its prefatory note, the principal purpose of this admirable work of reference is to provide a contemporary account of the reorganization of the Army in India since the Great War, and to describe the essential features of this reconstructed army.

The book is also intended for the information of the general public, and for use in promotion examinations, and although it has been compiled officially, and with the authority of the Government of India, it is not wholly a formal " Official Publication." Consequently, the author, or authors, adopted an attractive and simple method of compilation which has created that most desirable of qualities, " easy-reading."

The first chapter, which is entitled " Historical Retrospect," is a text-book in itself, and an interesting text-book, free of laboriousness and of unnecessary statistics. Nevertheless, the sources of its information are " weighty authorities," so that it is all thoroughly reliable.

It is not possible, in the space at disposal, to do full justice to even one of the many chapters, or to say that any of these is better than its fellows, when all are excellent.

The book is made up chiefly of four Parts, of which the following is a brief summary :—

Part I contains the above-mentioned " Historical Retrospect," and recounts the lessons of the Great War, and the details of the subsequent reorganization and of the Administration and the High Command.

Part II provides separate chapters for the respective descriptions of all the links of the Army-chain, *e.g.*, Staff, British Cavalry and Infantry, Royal Artillery, Royal Engineers, Indian Cavalry and Infantry, and the Ancillary Services, as well as describing the Indian State Forces, and the Supply of Officers.

Part III is devoted to the Royal Air Force in India.

Part IV deals with the Finance of the Army and of the Royal Air Force in India.

But these main portions of the book do not exhaust its wide information or its interest, as there are no less than 21 Appendices, all of which are very neatly arranged. One of these will be studied many times by officers of every branch of the Service, as it contains a startling contrast between ancient and modern forms of transport, as shown below :—

A Force of 4 Divisions (with animals only on half-rations) requires a daily lift of 900 tons. Such a lift would require one or other of the following alternatives :—

Type.	*Number required.*	*Radius (miles).*	*Road-space (miles).*
Broad Gauge Trains ...	1	—	—
Light Railway Trains ...	3	—	—
3-ton Lorries	300	30	6
3-cwt. Lorries (pneumatic cord tyres)	600	40	16
Ford Vans	2,500	50	42
A.T. Carts	3,150	10	13
Camels	45,000	10	126 (single file).

Naturally, the chapter on the Royal Engineers (including the Sappers and Miners, and the Engineering Services) will appeal most to the readers of the *R.E. Journal*, and particularly to those who contemplate an Indian career, or even a tour in India. The diagrams showing the new systems of R.E. chains of command (at Head Quarters and in the four Commands) are reproduced in the Appendices, and have already appeared in the *Supplement to the R.E. Journal*.

G.P.C.

INDIA: A BIRD'S-EYE VIEW.

By the EARL OF RONALDSHAY, P.C., G.C.S.I., G.C.I.E. (Constable & Co. 1924.) Price 18s.

WHAT every intelligent traveller in a country first desires is an immediate bird's-eye view of it, pending the slowly-acquired knowledge of Experience.

But this "viewing" must not be what the guide-book uses, namely, a mere glance accompanied by a catalogue of the visible "prominences." It must see *into* the material things, and must discern the spiritual in the tangible, and yet it must not cause the eyes to tire, or the brain to ache.

Possibly some such idea urged Lord Ronaldshay to write this admirable book, which is warmly commended to every officer whose career is, or is to be, in India.

Lord Ronaldshay, who was recently Governor of Bengal, has not only travelled far and wide in Asia, but he has written half a dozen other books on the East, and is probably the best-informed of all our writers on India.

In the first place, this book is literature, and, for this reason alone, it is a joy to read. Furthermore, its many indications of wide culture and sound research will appeal to all scholars. Its only blemish is that the attractiveness of the chapter-headings tempts the reader to "browse" (as one does in a library) instead of reading in orderly sequence, and thus appreciating the later "references." But even such "browsing" will soon show the reader that this comprehensive, but compact, book will readily engage the close attention of the soldier, as well as being of the utmost interest to the "Indian-Civilian" and the English-Statesman.

For instance: Every military officer, and especially every R.E. officer, in India, has frequent dealings with natives of all classes and religions, and must exercise considerable circumspection so as to avoid offending the caste-prejudices and the religious susceptibilities of his local co-workers, subordinates and social acquaintances. A careful perusal of Lord Ronaldshay's accurate descriptions of the races, creeds and customs of that "difficult" Empire will save even a new-arrival from most of the troubles which beset the Great Endeavour, *i.e.*, the "Bridging of the Gulf."

The author's broad-minded appreciation of Mahommedan and Hindu architecture does not dim his keen perception of the ornate *minutiæ*, and these together interpret to him the minds, beliefs and environment of those wonderful designers of a remote past. Again, in his treatment of any of the distracting "policies" of India, whether it be the "forward" policy of a frontier, or the "self-determination" policy of a Bengali-irredentist, or the Akali-policy amongst the Sikhs, he sees all of the little when describing the big, and he also provides sufficient data to enable a reader to form a policy for himself.

The graphic account of the N.W. Frontier of India, its history, its geography, and its ever-present military and political problems, are extraordinarily interesting.

G.P.C.

PERFORATED MAP. AN AID TO NIGHT OPERATIONS.

By Captain T. J. Edwards, The Somerset Light Infantry (Prince Albert's). Gale & Polden. Price 1s.

The importance attached to aids in night operations in future wars is stressed by General Sir George Milne, in a foreword, and this invention is an effort to assist such operations without the use of special gear. The principle of the perforated map is that a map or enlargement should be prepared for each night operation, the details being pricked through the paper according to conventional signs.

The system was adopted by the author's battalion for patrolling in Macedonia, and proved valuable.

Without practical experiment it is hard to judge its efficacy, but the system would seem to be one which would require considerable training on the part of the users.

The idea is worth investigation, and, as the notes have been prepared as the result of practical experience in war, even if the whole system is not accepted, valuable hints as to the preparation of sketches for night marching will be gained from a study of the pamphlet.

W.P.P.-W.

ANALYTICAL MECHANICS.

By EDWIN H. BARTON, D.SC. (London), F.R.S., F.R.S.E., F.INST.P., F.P.S.L., Professor of Experimental Physics, University College, Nottingham. and sometime Examiner in Physics to the Universities of London, Birmingham and Manchester. Published by Longmans, Green & Co., 39, Paternoster Row, E.C.4. Price 21s.

THIS book of 21 chapters and 578 pages is a treatise on statics, particle and rigid dynamics, and there are useful chapters on mechanism, strains, hydrostatics, hydrokinetics and elasticity. Nearly the first half of the work is devoted to dynamics, and the treatment is to some extent novel, inasmuch as the theory of rectilinear and orbital motion is tolerably extensively developed as a branch of kinematics, that is, without reference to the laws of motion. There is much to be said in favour of this procedure and little if anything at all against it.

Kinetics and the Newtonian theory are not introduced until the XIth chapter, which opens with an interesting historical review, and extracts from criticisms on the Newtonian philosophy made by eminent mathematicians. Euler's equations are explained in Chapter XIV, and their important applications clearly developed; no mention, however, is made of Lagrange's equation or of theories of constrained motion and small oscillations.

Within the limits that the author has set himself, statics has been tolerably completely dealt with, the theories of forces in three dimensions, attraction and potential centroids are quite adequately treated.

There are but two short chapters on hydro-mechanics.

The examples have been chosen with great care, those following the various chapters are mostly from the London B.Sc. Pass Exam.; but there is an extensive collection of miscellaneous and much harder examples from the London B.Sc. Honours Exams.

The collection would be improved if some examples on tops and gyroscopes were added in a subsequent edition. Mathematical acrobatics have been avoided.

The study of the book requires a knowledge of the calculus; the treatise is intended to meet the requirements of University students, and is more than sufficient for the B.Sc. Pass Exam., London, in fact it contains a great deal of the knowledge required for the six papers of the Honours Exam. in mathematics at Oxford, Cambridge and London Universities.

Within the limits which the author has set himself, the information given is tolerably complete; Dr. Barton has preferred to omit certain parts of mechanics altogether rather than to deal inadequately with them.

A complete outfit of works on mechanics, including hydro-mechanics, would cost the student certainly over £10, whilst this treatise which contains a great deal of the subject matter of well-known standard works, costs but 21s.; the average student will probably find its purchase an economy and sufficient for his needs. The author is to be congratulated on having produced a very valuable all-round treatise at (in these days) a reasonable price. I can recommend its acquisition to any R.E. officer who, having a fair working knowledge of the calculus, desires to improve his knowledge of mechanics, or, having but few books, requires a handy volume for reference.

J. M. WADE, *Lieut.-Colonel* (B.Sc., London).

WHERE TO SEEK FOR SCIENTIFIC FACTS.

By A. B. EASON, M.A. (Cantab), A.M.I.C.E., A.M.I.E.E. W. Rentell & Co., Ltd. Price 1s.

THE object of this pamphlet of some 40 pages is "to indicate where people may find—(1) Lists of books on various science subjects, (2) Books or journals and proceedings and bulletins of learned and scientific societies; (3) Indexes of literature and publications and papers on technical and scientific subjects; (4) Abstracts of technical papers." It is intended "to help people from spending a long time in searching for information," and is little more than an index of catalogues and similar publications, such as the *Catalogue of British Scientific and Technical Books*, 1921 (compiled by the British Science Guild) and of libraries where the books may be found. In a list of periodicals on *electrical* subjects, the only list of periodicals given, we notice mention of our distinguished contemporary, *The Sapper*. For some unknown reason contributions dealing with electrical subjects do not often come our way, and it is perhaps deservedly that the name of the *R.E. Journal* is not mentioned.

F.E.G.S.

MR. A. H. DYKES, M.I.C.E., M.I.E.E., has sent us a paper on "Electricity Supply in War-time as Affected by the Improvements in Heavy-oil Engines," written by himself and W. T. Townend, R.N., and published under the auspices of the Diesel Engine Users Association, 19, Cadogan Gardens, S.W.3. They call attention to the tendency to replace the existing smaller local stations by large capital stations, serving by means of high-tension feeder cables very large areas, and point out how impossible it is to camouflage such stations against air-raids if the power is obtained by the use of coal. Their conclusion is that the only practicable way is to provide a certain number of underground stations driven by heavy-oil engines. The project of the design of one of these stations is worked out in great detail, for which we must refer our readers to the pamphlet itself, a copy of which is being placed in the Corps Library.

EARLY in the present month Messrs. John Murray will publish a new book by Major E. W. C. Sandes, D.S.O., M.C., R.E., entitled *Tales from Turkey* (Price 5/-). Those who are acquainted with his earlier book *In Kut and Captivity with the 6th Indian Division* and with his articles in the *R.E. Journal*, of which we are promised another, describing the Siege of Kut, will welcome the appearance of this new volume, which is reported to contain tales of adventure, intended to describe the strange people of a strange land—the Turks of Anatolia—with a few remarks on other nationalities found in Turkey.

MAGAZINES.

THE JOURNAL OF THE ROYAL ARTILLERY.

OUR readers will learn with interest that the Council of the Royal Artillery Institution has decided to follow the example set by the Royal United Service Institution and ourselves and to publish its journal in future quarterly instead of monthly. The first quarterly number is notified for publication on 1st October.

REVUE MILITAIRE GÉNÉRALE.

(*April*, 1924.)—*The Peninsular War.* By Commandant Grasset.—The writer considers that a study of Napoleon's strategy in face of the national rising in Spain in 1808 may afford valuable lessons for the present day. It is hardly realized that, with her organized militia as well as a regular army, Spain then possessed what almost amounted to obligatory service. When the imperial troops invaded the country they soon found that they were in the presence of a nation, not, indeed, prepared for war, but provided with the essentials of a national army. Their position, therefore, in face of the national rising, resembled that of any European army which might now be occupying a country which has not yet completed its mobilization, but is animated by strong national feeling and hatred of the foreigner, which has arms and a respectable number of trained reservists or militia, or societies for military training. It is of considerable interest to trace the Spanish efforts to organize their forces in presence of the imperial armies, and to note the defects in the strategical action of the latter in spite of the fact that they began with many factors in their favour. In this number is described the inception of the rising in the North of Spain. (*To be continued.*)

Our North African Races in the New Army. The article by Lieut.-Colonel Clément Grandcourt is continued.—In this number he develops his argument in favour of the professional soldier and points out his economic advantages, considers the administrative and legislative measures required to attract recruits, ensure a fair proportion of re-engagements, and secure the continued loyalty of the old soldier after his discharge. He then discusses organization, which must differ in Tunis from that in Algiers. (*To be continued.*)

The Military Apprenticeship of the Italian Army. By Albert Pingaud.—French domination in Italy awoke the martial spirit in a nation which for three centuries seemed to have confined its energies entirely to the arts of peace. It was not until 1806 and 1807 that Italian troops were admitted into the "Grand Army." The participation of one of their divisions in the campaigns in Prussia and Poland represents their *début* in the political arena of the world, and their experiences therein form the subject of this article.

Attack of the 10*th Colonial Division in September,* 1915. The conclusion of the article by Commandant P. Janet.—At 1040 hours the 6th Corps (second line) advanced behind the colonial division, but, adhering strictly to their orders not to aid the latter in their task (they were to leap-frog the colonial division when the latter reached the Py), the leading brigades halted in rear on approaching the firing-line. Two groups of artillery sent forward failed to get into touch with the infantry and remained inactive. In the evening the Germans brought machine-guns into action, and for two hours opened a bombardment with gas-shell. The action was resumed next morning, but the favourable opportunity had been lost, and in this sector the German second position was nowhere breached. The causes of the failure are then discussed. Briefly they were the short aim of the French artillery, due to bad weather and breakdown of communications, absence of effective immediate reserves for the first line, the deaths of the divisional commander and of his two brigadiers, the mud, want of training in open warfare, and absence of accompanying artillery owing to the mules being killed. There was no lack of bravery and dash on the part of the troops.

Was it a Mistake to Withdraw the Belgian Army on Antwerp?—A short rejoinder by Capt. Kuntz to Colonel Nuyten's article under the above heading (*R.E.J.*, June, 1924) which was written to demonstrate the fallacy of Capt. Kuntz's previous arguments in reference to Belgian strategy. The editors accept no responsibility for the opinions expressed.

Military Chronicle of Economic Questions. By Pierre Bruneau.—The appointment of General Debeney to the head of the staff will ensure the study by French Staff officers of economics, a course which he introduced when Director of the *Ecole de Guerre.* The increasing use of agricultural tractors gives cause for anxiety, in case it should lead to a reduction in the effectives of the infantry, which was recruited mainly from the agricultural population during the late war. General Debeney's reflections on this subject are worthy of study.

The financial and economic recovery of Germany is due in a great measure to the energetic action of General von Seekt, Chief of the Reichswehr, which should be closely examined. His aim is to support his new army formations by restored economy and healthy finances, while in the *Reichsministerium* he is preparing for the mobilization of the whole German nation, a tradition which General von Falkenhayn bequeathed to his successors.

(*May,* 1924.)—*Infantry in Trench Warfare.* By Commandant Padovani.—This article is divided into three parts, Part I dealing with the defence, and sub-divided into (1) organization of the ground, (2) normal life in the sector, (3) the enemy's attack, (4) outline of regimental defence orders. Part II deals with the offensive, and is subdivided into (1) characteristics of the attack on a fortified position, (2) preparation of the ground (to facilitate launching and maintaining the attack), (3) preparation of the troops, (4) dispositions for the attack, (5) attack orders. Part III is devoted to the actual execution of the attack.

The Peninsular War. The article by Commandant Grasset is continued.—The Spanish rising now spread to Saragossa. Marshal Bessiéres, who was commanding the French troops in the North of Spain, was aware of all these movements and took what steps he considered best to counteract them, reporting at the same time to the Emperor, who was at Bayonne engaged in drawing up a new constitution for Spain. But Napoleon, who allowed little initiative even to his marshals, sent his own orders based on reports three or four days old and constantly changing. Bessières was forced to disobey these, and thenceforth Napoleon, recognizing the necessity, contented himself with issuing general instructions, leaving to his lieutenants on the spot the responsibility for deciding on the best means for achieving the ends he had in view. (*To be continued.*)

Our North African Races in the New Army. The conclusion of the article by Lieut.-Colonel Clément Grandcourt, dealing with the question of *cadres*—officers and N.C.O.'s—both European and native, bringing out the difficulties experienced at the present day in obtaining them satisfactorily, investigating the reasons for this, and suggesting remedies. The necessity for enlisting into the ranks of the native army a certain number of European privates is regretted. It is objectionable to place privates of the ruling race under native N.C.O.'s, and the writer would retain only the number required for special services which cannot be, or ought not to be, entrusted to natives. In fine, the problem of the native army is infinitely more delicate and complex than is generally realized, and must be approached with prudence and caution.

Military Chronicle of Economic Questions. By Pierre Bruneau.—This month the high cost of living is referred to. Attempts to reduce prices in the army were made by introducing the *Société Coopérative Militaire*, but some of the advantages enjoyed by this establishment have had to be withdrawn in view of the complaints of private traders. The Society, however, works well in the occupied territories. In the Ruhr it has been necessary to forbid German merchants to demand higher prices from the Allies than from Germans, and in Mayence the G.O.C. has appointed a mixed commission to regulate prices.

Books. Amongst the books reviewed the following appears to be of general interest :—

Mémoires du prince Louis Windischgraetz, translated by Capt. Chomel de Jarnien. (Payot.)—The writer, who belongs to an old Hungarian family, held a high command at the front, was then Minister of Supplies, and later an Envoy Extraordinary. Admitted to all the political and fashionable circles of the Dual Monarchy, his quick intelligence, ardent temperament and energetic personality enabled him to exercise great influence on the tragic events of the last years of the Empire. His style is blunt, as that of one who has nothing to hide and nobody's feelings to consider. He criticizes Count Burian, and accuses the great General Staff of incapacity, while praising the excellence of the soldier, but in so doing discloses the virus of the pan-German Junker. He blames the General Staff for having sent an ultimatum to Serbia instead of promptly bombarding Belgrade, and, evidently a great admirer of the Germans, contrasts the disorder and slackness of the Austro-Hungarian staff with the method and order of the German. The book clearly reveals that which was wanting in the Empire of the Hapsburgs and prevented it from becoming a great nation. The Empire was not betrayed by blind fate, but met its death because it lacked unity and national discipline, and its officials patriotism and a sense of duty.

A. R. REYNOLDS.

REVUE MILITAIRE SUISSE.

(1924. *Nos.* 4 *to* 6 *inclusive.*)

COLONEL GROUARD'S article entitled *Le haut commandement et l'état-major* is continued and concluded in the numbers (4 to 6) of the *Revue* under notice. The importance of the subject under discussion is brought out in a striking manner in the article by Colonel Grouard, who is a fearless critic; he shows that, although the Great War was eventually won by the Entente Powers, there were occasions, and many of them, when victory was placed in dire jeopardy, owing to a failure on the part of politicians, and others, to apply the true principles of organization in connection with the arrangements in relation to the G.H.Q. and superior staff provided for the conduct of the war. Colonel Grouard gives in outline the principles upon which the staff of an independent Army should be organized; he also points out that it is the general in chief command who should personally dictate the plan of operations and that to the staff falls, in the first instance, the responsibility alone for collecting the information and data required by the general to enable him to sketch out his plan of campaign. After he has given his decision in relation to this plan, naturally, it is then the duty of the staff to take up the work of developing the same in detail, and of preparing and distributing the orders necessary to give effect to the general's intentions. These two functions are, however, not independent, and emphasis is laid by Colonel Grouard on the need for a Chief of Staff being completely familiar with the ideas of his general; indeed, the two should maintain the closest relations and should be at work incessantly elaborating the details of the plan of campaign. Dealing with the subject of command, Colonel Grouard thinks that normally an army should contain not more than four corps, together with one cavalry division, or even two such divisions, and the necessary army troops. In the case of a force of larger dimensions than here stated, a sub-division into armies, and maybe larger formations, becomes necessary; it may even become desirable to create separate and independent commands. Where the force is so large and the theatre of operations so extensive as to require an organization consisting of groups of armies, the principle to be employed in constituting the several groups is that each group shall be self-contained and so composed that a distinctive task or mission can be assigned to it; standardization in the composition of armies and groups of armies is neither desirable nor possible from a practical standpoint. Discussing the position which should be assigned to a Chief of Staff, Colonel Grouard suggests that there should be at G.H.Q. an officer of high rank and recognized ability in the position of *un véritable commandant-en-second;* he could appropriately bear the distinctive title of *major-général* and under him there should be a *chef d'état du major-général*, as was the case in Napoleon's time. In 1914 there was a *major-général* in France, but he was not vested with sufficient authority; his activities were limited to the direction of the operations of the French "Armée du Nord-Est." Colonel Grouard further rightly objects to the arrangement under which one general-in-chief has sometimes been called upon, in the capacity of a representative of the Minister, to *control* another general in chief command. Where an officer is supposed to be possessed of such outstanding abilities as to justify very large responsibilities being placed on his shoulders, he should, it is urged by Colonel Grouard, be given the *military command* over the other generals whose operations are to be supervised by him.

Having sketched out the principles upon which a G.H.Q. should be organized, Colonel Grouard next examines how matters would have worked in France had these principles been properly applied during the early stages of the Great War. He recognizes that the mobilization and the concentration of the French Army were carried out in a perfect manner, but he has some hard things to say of the operations constituting the opening phases of the Great War: the offensive in Alsace was, he thinks, *une absurdité;* the offensive in Lorraine, *sans être aussi complètement inepte, était des plus dangereuses;* other criticisms are also made. Colonel Grouard gives his views as to the manner in which the French Armies should have been employed on the outbreak of war: the First and Second Armies, which were to operate in the Vosges, should have both been placed under the direction of one of the generals commanding and, indeed, in order that the operations in the Eastern frontier should be properly co-ordinated, a commander-in-chief should have been designated with a view to exercising command over all the troops which might have to operate on the line Belfort–Toul. The Third and Fifth Armies should similarly have been combined under a single general for operations on the line Verdun–Mézières, whilst the Fourth Army should provisionally have been held under the direct orders of the G.Q.G. Colonel Grouard attributes the early successes of the Germans in 1914 mainly to the faulty organization in the command of the French Army when hostilities broke out. The want of co-ordination which is apparent in the operations of the Entente Armies in the initial phases of the war he traces to this cause, and to it he also ascribes the creation of the situation of which advantage was taken by the Germans, who were able, in consequence, to take up and hold a position at Rheims and also to seize St. Mihiel, positions which they retained up to the time of the final advance in 1918.

Dealing with the staff, it is suggested by Colonel Grouard that a G.H.Q. staff should be constituted in two sections, one mobile and the other stationary; with such an arrangement, the mobile section could, without any dislocation of the work, conveniently accompany a commander-in-chief to the battle area. Colonel Grouard touches upon the general situation in 1915, and refers to the opposition raised, at the G.Q.G. at Chantilly, to the dispatch of an army to the Balkans; he thinks that the views held at Chantilly were too narrow and, in the particular circumstances, the staff at G.Q.G. was not in a position to form unbiased opinions and therefore was not in a position properly to grasp the essentials of the problems confronting the Entente Powers; nor could it be expected, placed as it was, to formulate a general *military policy* on sound lines. The opposition of G.Q.G. to the dispatch of an army as reinforcements in support of the Serbians led to the loss of much valuable time; and, finally, when the decision was taken—a decision which Colonel Grouard thinks was right—to adopt a course of which G.Q.G. did not approve, a serious mistake was made in placing the *Armée d'Orient* under the Generalissimo in France.

The constant friction of one kind and another which seems always to have been present in connection with the conduct of the war can be traced almost entirely to the circumstance that correct principles were continually being ignored in the arrangements made in relation to *le haut commandement et l'état-major*. The changes which took place at the French Ministry of War and in the chief command of the French Army are duly recorded by Colonel Grouard, who comments on the causes that led thereto. Commenting upon the supersession of General Joffre, whose period of command extended over the first 2½ years of the war, the Colonel calls attention to the fact that, in the first instance, the former had five French Armies directly under his own immediate command—it was during 1915 that the three groups of armies, the North, Centre and East, were formed—and expresses his disapproval of the arrangement, which, he considers, was extremely harmful, as the Generalissimo was thus prevented from concentrating his attention on those sections of the front which, from time to time, became of most importance. However, this arrangement was not, Colonel Grouard thinks, the principal cause of the early defeats of the Entente Armies, whose misfortunes he attributes almost entirely to the radical defects in the original plan of campaign and in the obscurity existing at G.Q.G. as to the true situation, factors which prevented the general-in-chief modifying the initial dispositions in time to place the Entente Armies in an advantageous position for meeting the German onslaught. After the removal of General Joffre, General Nivelle became Generalissimo, but did not possess the necessary qualities required for the post. The French War Minister, it is alleged, now began to interfere mischievously in the conduct of the war; had he been a military genius, the consequences might not have been serious. However, according to Colonel Grouard: "Ce qui s'est passé prouve que l'on n'avait pas d'idées nettes sur l'organisation rationelle, et cela tient à ce qu'on ne savait pas distinguer la stratégie de la politique militaire: la confusion dans les questions de principe entraîne forcément celles des procédés employés dans l'application."

General Nivelle's tenure of command lasted barely five months; he made way for General Pétain, whose first task was that of re-establishing order and discipline in the French Army. The choice of General Pétain for the position of Generalissimo proved a fortunate one; his great knowledge of the temperament of the French soldier, coupled with his firmness and tact, enabled him to restore discipline and thus to lay the foundations of future success. Of him, Colonel Grouard says, "il a été le véritable organisateur de la victoire."

The Caporetto disaster in October, 1917, created an extremely serious situation and resulted in both the French and the British Governments sending troops to Italy to stem the tide of the Austro-German invasion there. At the same time, a conference was held in London with a view to the better co-ordination of the operations of the Entente Armies. At this conference was sown the seed which eventually brought into existence the unification of command, under General Foch, of the troops in the western theatre of operations. However, the seed did not germinate immediately; withering breezes blew over it both from the Palace at Westminster and the British G.H.Q. in France. The German offensive in Picardy, launched on March 21st, 1918, was necessary to create the atmosphere in which the seed could take root and bear fruit. A conference was now held at Doullens, and on April 14th, 1918, it was announced that the British and French Governments had agreed to give General Foch the title of "Commandant-en-chef des Armées alliées," his command being confined to the troops operating in France. On the following day the Belgian king announced his adhesion to this arrangement and placed his army also under the orders of General Foch. Two days later the American President adopted a similar course. The story of the Great War, after the unity of command was established, is one of unbroken success.

In conclusion, Colonel Grouard expresses the opinion that for the conduct of a big war it is necessary to place the *general control* of the situation in the hands of a committee charged with the formulation of a military policy; the function of the committee should be that of allotting the necessary forces to each of the several theatres of operations and of defining the particular task assigned to each of the several armies. The province of military policy must not be confused with that of strategy; questions of military policy having been decided, one enters on what lies in the domain of strategy, the rôle of which is concerned with the handling of armies in order to bring about a battle or a series of battles. Whereas the problems of military policy require for their solution the joint knowledge of the politician and the soldier; on the other hand, strategy is exclusively the concern of the soldier. This does not mean, of course, that statesmen should not familiarize themselves with the problems and principles of strategy; indeed, it is desirable that they should do so, in the same way that soldiers aspiring to high command should make a study of political questions for a better understanding of their responsibilities.

M. Jean Fleurier's article, entitled *Une légende. La faillite de la* *fortification permanente pendant la grande guerre*, is continued (No. 5), the defence of Namur being dealt with in this part. Although the lessons to be derived from the defence of Namur are not so instructive as those provided by that of Liége, nevertheless there are two points which merit particular attention : (1) the short duration of the resistance put up by the Belgians at the former, and (2) the relatively small damage done to the Namur forts by the German artillery. The time gained by the hold-up of the invaders at Liége was profitably utilized by the Governor of Namur, who arranged for defence works to be constructed in the intervals between the detached forts ; the possibility of Namur being carried by a *coup de main* was therefore guarded against. The course of events caused attention to be turned to the idea of *fortification en profondeur*, but it was not fully developed at Namur ; an exterior system of defences was not provided beyond the line of detached forts, and infantry was not pushed out beyond the permanent defences with a view to hindering the bombardment of the forts, as was done, for instance, at Belfort. The second line of defences thrown up at Namur was practically concentric with the first line and no attempt was made to construct retrenchments on the "chord" of the front attacked. The number of troops in Namur were fewer than those in Liége ; the garrison of the former consisted of the 4th Division (say, 13,000 men) and 10,000 fortress troops. On the other hand, the French Army under General Lanrezac was within supporting distance of Namur and, indeed, had a *liaison* officer in the Belgian fortress. The garrison of Namur was increased by the addition of some of the troops who escaped from Liége ; unfortunately, they told pessimistic tales and on that account did not prove to be altogether a source of strength. On the material side, so far as the defence works were concerned, Namur was in a better condition than Liége to stand a siege, but the morale of the defenders proved disappointing ; moreover, there was a marked difference in the personalities of the two Governors, and this also influenced the two situations differently from the standpoint of staying power. In view of their experiences at Liége, the Germans approached Namur with great caution and made no attempt to take the place by a *coup de main*, but relied entirely on their heavy artillery, which was given full opportunity for making its weight felt : it was here that birth was given to the now celebrated phrase, "The artillery conquers ; infantry merely occupies." The advanced Belgian troops began to retire within the shelter of the Namur defences on August 20th ; the German bombardment opened on the following day and at 4 p.m. on the 23rd the order for the retreat was given by the Governor of Namur. It has to be remembered that at the date on which the Germans commenced their attack on Namur, the fortress was already practically isolated ; the Belgian Field Army had then retired towards Antwerp from the Gette ; the French Fifth Army was on the Sambre, in the neighbourhood of Charleroi, some 13 km. from the western forts of Namur. Further, the German First Army had already entered Brussels, thus interposing itself between Namur and the remainder of Belgium. A table is furnished in the original article in which are set out the dates on which the bombardment of the several forts began, those on which they surrendered, and, in some cases, the losses suffered. In conclusion, M. Fleurier expresses the opinion that Namur fulfilled its mission up to August 23rd; however, the surrender of the place was premature and thereby German troops, which should have been held fast at the Belgian fortress, were released for operations against Maubeuge, where they arrived on August 27th. The total casualties suffered by the Germans at Namur did not exceed 1,000 all ranks (about a third of these were killed). The Belgian artillery proved itself very inferior to the German artillery and was at once dominated by the latter. The fall of Namur was of considerable value to the Germans for propaganda purposes, and helped to create the legend as to the immensely destructive power of the German "super-cannon." Whereas the defence of Liége had had the effect of raising the morale of the Belgians, that of Namur, unfortunately, had that of distinctly lowering it.

W.A.J.O'M.

BULLETIN BELGE DES SCIENCES MILITAIRES.

(1924. Nos. 4 to 6 inclusive.)

THE account of the operations of the Belgian Army in connection with the defence of Antwerp is continued in Numbers 4 to 6 of the *Bulletin* under notice. The general situation in the sub-sector of the 5th Division as it existed in the afternoon of October 5th is outlined. Fortunately, the German infantry, which had gained a footing on the north bank of the Nethe, west of Lierre, did not show much enterprise. Had the Belgians had fresh troops and sufficient artillery, it is probable the enemy's position north of the river would soon have been rendered untenable. During the evening of October 5th the Belgians began preparations for a counter-attack for the purpose of driving the enemy from the north bank of the river. One of the chief difficulties of the Belgians at this time arose from the fact that, even during the daytime, the support given to the infantry by the artillery was of the feeblest kind, whereas at night, owing to the fact that the necessary equipment had not been provided and also to the circumstance that the gunners had not been trained for the purpose, the Belgian artillery could not come into action at all, once the light failed.

At 6.35 p.m. on the 5th, a report was received at Fortress Headquarters in Antwerp conveying information as to the movements of the enemy which had been obtained by an airman during a reconnaissance; *inter alia*, it was stated that the enemy had placed in position the bays of a temporary bridge at a point on the river 1,000 m. south-west of the steeple in Lierre. This information was passed on to the armoured-train and to the commander of Fort Broechem, and at 7.40 p.m. it was also communicated to General Paris, in order that his artillery might make an attempt to destroy the German bridge. However, it was already becoming dusk and it was felt that the guns could do no effective work; in consequence, no action was taken on the R.N.D. front.

A good deal of uncertainty seems still to have existed at Fortress Headquarters as to the dispositions of the troops in the 5th Division sub-sector. Certain enquiries on the subject were answered, but the information given was not altogether correct. Some misunderstanding appears also to have existed at General Paris's headquarters as to which units of Belgian troops had been placed under the British General's orders, and as to the positions occupied by them; this led to some unnecessary correspondence.

It was proposed to launch the counter-attack being prepared in the 5th Division sub-sector at 2 a.m. on the 6th; it was decided that, when the troops moved forward, a detachment of Engineers should make an attempt to destroy the temporary bridge south-west of Lierre. General Coveliers was placed in command of the troops detailed for the counter-attack. At the same time, General Paris was directed to hold his troops in readiness to join in the counter-attack; he was informed that, should it become necessary for his troops to participate, orders would be given him by Divisional Headquarters. It was now arranged that the Brigade and Regimental Commanders, whose troops were to take part in the counter-attack, should meet at the battle headquarters of the 17th Brigade, then east of Linth, in order to work out the details of the attack. At the hour fixed for the conference, the three Brigade Commanders concerned had arrived at the rendezvous, but all the Regimental Commanders had not put in an appearance; up to 9.30 p.m. no decision had been arrived at by those present—the three Brigade Commanders were still seeking information as to the dispositions of the troops under their respective commands. At this time, units were in many cases intermixed; in other cases, detachments had become completely isolated, and, generally speaking, the troops seem to have lost their nerve and the least bit of firing at once produced a panic. About the hour last named, a Staff Officer of the 5th Division present at the rendezvous reported to his headquarters that the Brigade Commanders had come to the conclusion that a counter-attack could not, in the existing circumstances, be carried out; however, should express orders be issued to them on the subject they would act according to their tenor. Three of the Regimental Commanders were still absent and the efforts made to get in touch with them had failed. A Staff Officer now volunteered to go in search of the Commander of the 2nd Carabiniers, who was in the neighbourhood of Lachenen. Leaving the 17th Brigade Headquarters in a motor-car, with headlights turned full on, he succeeded in his mission and took the missing Colonel back with him. Incidentally, it may be stated that the passage of the brightly-lit car had a most reassuring effect on the troops: all the dispatch-riders who had been sent with messages for the missing Regimental Commanders had turned back as they had been fired upon, and the idea had got about that the enemy had penetrated into the cover of the woods at Looverjik; this assumption was now proved to be erroneous. Eventually all the Regimental Commanders concerned arrived at the rendezvous and it was possible to draw up an appreciation of the situation, a copy of which (text given in the original article) was dispatched to Divisional Headquarters at 10.10 p.m.; it was, however, not received at Bouchout until 11.30 p.m. After the dispatch of the appreciation of the situation, the officers at the battle headquarters, east of Linth, continued to concert measures for the counter-attack and by midnight a plan had been agreed upon; the necessary orders were then drawn up. The Divisional Commander was duly informed as to the final decision arrived at by the three Brigade Commanders and was furnished with an outline of the scheme of attack worked out; this did not reach him until 1.20 a.m. on the 6th. The Divisional Commander, however, on the receipt of the "appreciation," had decided that a counter-attack must be made, and at 12.30 a.m. had sent a peremptory order to this effect to General Coveliers, directing him to attack on the line Ringenhof–Ander Stad—the latter was to remain in touch on his left with General Paris. At the hour last named, orders were also sent to General Paris directing him to join in the attack; he was to make a special effort to destroy the German bridge south-west of Lierre. At 2.5 a.m., on the receipt of the foregoing orders, General Paris sent a dispatch to Divisional Headquarquarters at Bouchout stating that the orders had reached him at too late an hour to enable him to take any action thereon. He added that he could do no more with the troops under his command than hold the trenches occupied by them, and that an independent force was necessary for the purpose of carrying out the counter-attack ordered. The inaction of General Paris, and, indeed, his conduct generally in relation to the operations, is much criticized by the author of the original article.

The dispositions for the counter-attack are given in the original article and the operations which ensued are described. During the attack, which was carried out in the dark, a ruse was adopted by the enemy on the part of the front where Colonel Tiechon (2nd Chasseurs) was in command; as if to warn the Belgians that the British troops had already reached the locality, German soldiers shouted "English! English!" Colonel Tiechon was entirely deceived by these shouts and moved forward to a brick-oven near him; as he turned the corner he was felled to the ground by three German soldiers who took him prisoner. The Belgian counter-attack was delivered with energy; however, after a temporary success in places it failed all along the line. This failure naturally increased the disorder already existing in the ranks of the Belgian troops.

In the meantime, orders had also been given to the Belgian 3rd and 6th Divisions, then operating in the 4th sector of Antwerp, to act on the offensive on their fronts in order to attract the enemy's attention to the westward of the Willebroeck Canal with a view to facilitating the operations of the 5th Division. At this time, the forts at Breendonck, Liezele and Bornhem and the redoubts at Letterheide and Puers were still intact. The Belgian offensive movement was met by a counter-attack delivered by the German troops at Larendries and St. Amand, and the Belgians had eventually to give ground in the 4th sector.

The first parts of an article entitled *L'Enveloppement à la guerre*, by Lieut.-General Baron W. de Heusch, appear in Numbers 5 and 6 of the *Bulletin* under notice; the object of the Baron is to restate the true doctrine of war. He points out that the far-reaching changes which have taken place in recent times in the equipment of armies necessitate a reconsideration of the deductions drawn from historical material so far as they relate to tactical methods. The great distance apart at which opposing forces come into contact on the battlefield is to-day, and, indeed, has been since 1870, a factor which has tended to transfer to the domain of strategy problems which formerly were considered properly to belong to the domain of tactics. Baron de Heusch feels that the full bearing of recent developments in the military art has not been clearly appreciated in dealing with strategical problems. He thinks that the Germans have confused ideas on the subject; not content with having produced von Clausewitz, they seem to see in their General von Schlieffen the inventor of a strategy superior to all others and throwing that of Napoleon completely into the shade, a strategy based on Hannibal's tactical manœuvre in the Battle of Cannæ, where the Carthaginian general enveloped both wings of the army led by the Roman Consul Varon. The Battle of Cannæ would be looked upon to-day as an incident of minor importance, an encounter in the nature of an engagement on a divisional front. Hannibal's enveloping movement was made against an inert unmanageable mass holding a relatively narrow front; on the other hand, the enveloping movement attempted by the Germans in 1914 in the initial phase of the Great War was directed against forces which were supple and extremely mobile, and which, moreover, were operating on a very widely extended front; they were, in consequence, in a position to carry out suitable manœuvres with a view to avoiding battle in a situation which might prove disadvantageous to them. Envelopment tactics derive their value almost entirely from the element of surprise, where it can be secured; more than anything else, it is surprise that has the tendency to destroy the morale of an army upon which an unexpected blow falls with suddenness and swiftness. But in these days, when the fronts of opposing forces stretch over a line of immense length, it is difficult to secure telling moral effects on a scale sufficiently large to be of military value; it takes, in these circumstances, a considerable time for combatants fighting on one section of a front to learn what is happening, or has happened, on another section of the front, literally thousands of yards away. For instance, it was quite late at night that even the King of Prussia and his staff learnt of the successful envelopment of the French right on the northern part of the battlefield of St. Privat (August 18th, 1870). Baron de Heusch suggests that it was not necessary for von Schlieffen to have discovered the outstanding merits of Hannibal's tactics at Cannæ in order to employ the talent of his German brain for the purpose of inventing a distinctive German strategy; there is no reason why he should not, with an equal probability of success, have based his invention on the tactics employed by Hannibal at the Battle of the Trebbia, where by other processes, such as the adoption of a ruse and the employment of light troops against the flanks of the Romans, he also managed to secure a complete victory. In the military art, history, Baron de Heusch points out, plays the important part of a great preceptor, and to it the military student must always turn when he seeks to confirm the correctness, or otherwise, of a theory which he desires to apply in practice. As an aid to the study of the problem of envelopment tactics, Baron de Heusch has, in his article, set out in outline the principal battles of the Napoleonic and succeeding periods: therein is shown the extent to which successes on the battlefield can be attributed to the employment of envelopment tactics.

Among other subjects dealt with in the numbers of the *Bulletin* under notice there is an account of the Russian invasion of Germany and Austria in 1914—it appears in the final part of Major Jobe's article entitled *Le principe de la bataille* (No. 4); the facts are clearly stated and the strategy of the Great War is briefly discussed. The first part of an article entitled *Le terrain et la guerre* is contained in No. 6 of the series; in it Major B. E. M. De Grox examines the question as to whether geographical considerations had any influence on the plan of operations of the Great War, 1914–18, and particularly so in the initial phase thereof.

W.A.J.O'M.

MILITÄR WOCHENBLATT.

25th October, 1923.—The leading article in this number is a review by General v. Kuhl of the ninth volume of the French General Palat's book on the war on the west front. The volume deals with the offensives of 1915.

After some half a column devoted to belittling the value of General Palat as a military historian and to ridiculing the sources from which his information is said to have been drawn, the critic proceeds to say that they should not be deterred from study of French military literature, which is "instructive in many respects and helps to correct judgment of our own operations." These often proved much more effective than hitherto they were inclined to believe. Palat shows that the French soldier was in no way better prepared for position warfare than the German. Also the munitions crisis in the German army does not seem to have been so threatening as in France. At what date this was the critic does not explain, but he proceeds with the extraordinary sentence: "If the Germans had known their opponent's situation in the autumn of 1914 and had undertaken just such a powerful offensive as at Verdun in 1916, but against a more suitable section than the Yser, then the French supplies of munitions would not have sufficed for an uninterrupted fight." The argument is typical.

The critic then deals at some length with the optimism of General Joffre in the winter of 1914–15, who is said to have scouted the idea of a second winter of war, for the Germans would be utterly worn out by the end of 1915. This serves the critic as an answer to those who reproach German G.H.Q. for their offensive in 1918. "War is inevitably waged in the element of uncertainty."

After a digression on the struggle between the conduct of the war by the military leaders and politics, the critic deals with certain of the battles of 1915. Palat is said to make some "interesting statements" concerning the gas attack by the 4th German Army at Ypres on 22nd April, 1915. "Already, by the beginning of 1915, it was learnt in France that the Germans were busying themselves with making a war gas." Von Kuhl then gives the full name, regiment, etc., of the German prisoner who, on the night of the 13th–14th April, made accurate statements about the gas cylinders, about the method planned for loosing off the gas and about the point of attack, yet the information was not sufficiently appreciated by either the French or British headquarters. So the German attack on the 22nd came as a surprise. According to Palat it could have been pushed as far as Dunkirk without resistance, if only German reserves had been ready at hand. Von Kuhl remarks that the situation recalls the events on 20th November, 1917, at Cambrai, where, too, a new weapon (tanks appearing for the first time in mass), secured an unexpected success for the English, who were not in a position to exploit it.

The German attack at Ypres upset and delayed the preparations for the great allied spring attack in Artois. The May attack by La Bassée and Arras again aimed at the break-through. After initial successes the worn-out French had to postpone the costly attack to the middle of June. The Cavalry Corps, which was to have exploited the success, was withdrawn, without effecting its object, behind the front once more. "Even the Corps Cavalry had found no opportunity of carrying out the instruction of the Army leader, General D'Urbal, which ran: 'It is a case of attacking at full gallop. The time of cavalry on foot is past.'" With the action of the British in the battle Palat is said to be but little satisfied. "French gave up the attack too soon, discouraged too quickly, as he generally was."

Von Kuhl then turns to the "renewed great attack by the British and French in Artois and by the French in Champagne" which began on 25th September, 1915. The secret of the forthcoming attack was badly guarded, the plan was soon in everybody's mouth. The effort to make the Germans think the attack was intended to be made in Alsace-Lorraine under General Dubail was futile. This time such a thorough artillery preparation was to precede the assault that it must succeed; but the hopes were not fulfilled. Palat admits that the offensive failed and that the small results gained were out of all proportion to the great losses sustained.

Palat concludes his observations by saying that "the year 1915 was the year of the great disillusionments. The first was the feeble conduct of the war by the Italians, from whose participation hopes of an early finish had sprung. The Dardanelles undertaking had failed. With difficulty were the British induced by the French not to withdraw their troops from Salonika. The experiences in the western theatre of war had shown that the enemy's successive positions could not be broken through at one go with the means then available. The heavy artillery and ammunition supply were not yet adequate. No one knew which method of attack should be used in future for the break-through. Was it better to attack on a broad front after long preparation, or was success to be won by a series of heavy successive assaults, leading to the using up of the hostile reserves?"

As Palat shows, the prospects of the German Higher Command for 1916 were thoroughly favourable in the West. But they had not freed their back for a great offensive in the West; in spite of brilliant successes in the East. "The attack at Verdun in February, 1916, had only a limited objective. That it failed was of extraordinary significance for the further conduct of the war. From all French contemporaneous and subsequent reports it is evident that the successful defence of Verdun raised the lowered self-confidence of the French Army and nation in a way never dreamt of."

10th December, 1923.—The value and virtue of private study form the subject of the leading article in this number. The writer begins by bewailing the fact that the Treaty of Versailles has abolished all the institutions at which the officers were prepared for the highest tasks of their profession. "The academies belong to past history." Their loss is deplored as they gave the officers—teachers and students—the time for systematic study. The training which they gave could, to be sure, only stimulate. The writer then gives an extract from General v. Freytag-Loringhoven's book of reminiscences to show that, as far as he possibly could, he tried to encourage officers to study, though without any striking success. In the Prussian Army, especially, training was directed exclusively to action, which, after all, is unquestionably more important than thought in the military sphere. Count Schlieffen is then quoted to show that their duties were so exacting and onerous that officers actually had no time for study. The writer then warns his readers of the danger, particularly at a military institution, of the students accepting, without criticism, everything that is given them. Another danger to which attention is drawn is dissipation of effort; the man who does not fix definite limits will wander easily from flower to flower and lose the much by pursuing the many. This does not mean, the writer continues, that the officer should confine himself to military studies alone, but unless he limits himself he will gain but superficial knowledge. This, then, leads to a quotation from a book written in 1820 by a Prussian officer of a eulogy of Scharnhorst, and a final exhortation to industry.

Other articles in this number include a review of the military political situation of Great Britain, with the usual complaint that we do not appreciate the danger to us of France's military hegemony; the American share in gas warfare; a bitter criticism of the exposures made by Count Robert Zedlitz-Trutzschler, former Court Chamberlain to the ex-Kaiser, a book which should make rather entertaining reading; and a review of an official brochure on the question of the responsibility for the war.

E.G.W.

MILITÄRWISSENSCHAFTLICHE UND TECHNISCHE MITTEILUNGEN.

Numbers for March–April, and May–June, 1924.

In the January–February number appeared the first part of a discussion on the supreme command of the Allied Armies of 1813. In the two numbers under review the discussion is continued and ended. Schwarzenburg's troubles, political rather than strategical, are interestingly described and the student of history will find each statement referred to the appropriate authority. The life of a staff officer of those days must have been a thankless one.

Two articles under review deal with the operations which resulted in the first siege of Przemysl in September, 1914. Previous articles on these operations were given in 1918: "The Defence of Przemysl, 1914–15" (G. M. Schwall) and "The Strategical Part Played by Przemysl on the Eastern Front" (by Major Stuckheil, 1923).

The first of the present articles—by Colonel Rudolf Fleischer (Inf. Regt. 6) begins in the January–February number with his promotion to the command of a battalion of 800 strong, formed from the remains of the three regimental battalions. His adventures on the retreat in which he loses half his battalion and finds them again, circles round Przemysl, where he sees German airmen, crosses the San, and, in a forced march, loses for good 25 per cent. of his strength, are graphically told. The retreat has made him determined, in any future reincarnation, to choose some other branch of the service.

The other article, by Major Stuckheil, describes the provisioning and preparing for defence of the fortress itself, whilst he records his impressions of the retreat of the 3rd Army to which Colonel Fleischer belonged.

The diaries and reports compiled during the defence were either lost in a balloon which was sent up from Przemysl in March, 1915, or were otherwise destroyed, and Major Stuckheil is careful not to claim entire accuracy for his account.

Przemysl lay, on mobilization, in the X Corps area and formed an area command, "Subrayon Przemysl." Five battalions, 1 cavalry patrol (?), 1 battery, Field Artillery, a fortress artillery regiment, and several companies Engineers composed the garrison of the moment.

The construction of additional strong points, intermediate works, obstacles, etc., etc., began at once, but it was not till the 20th day of mobilization that the Engineer staff was complete at the formidable figure of 300 officers, 2,200 tradesmen, 27,000 labour troops and 900 wagons of sorts.

A point strongly emphasized is the difficulties which resulted from the presence of the staff of higher commands in the fortress and the constant passage of troops and material to the front. *Contre-espionage* absorbed much time and attention.

The provisioning of the fortress went on uninterruptedly until the last moment, but the garrison was increased to 131,000 men and 21,000 horses, as against the pre-arranged figure of 85,000 men and 3,700 horses, and in consequence there were only 80 days' rations (or so) for men and about 70 for horses in the fortress when it was invested.

From the 12th to the 16th of September the crossings of the San at Przemysl were the scene of considerable confusion during the retreat of the 3rd Army. On the 16th Przemysl was informed that it was left to its own devices and was to hold out to the last, but it was not till the evening of the 18th that the field army was finally clear of the fortress area.

On the 19th, bridges and railway communication with the outside world were blown up and on the 23rd the investment was practically complete.

Good diagrams illustrate the articles and give the arrangements for defence and the strength of various arms at various dates.

Major Dr. Rendulię continues a study of the infantry tactics of the training manuals of European Armies. The comparison is interesting and gives an impression of general similarity of method, although minor variations are noticed.

The short account of the activities of German tanks in the war is finished. The historical part is not interesting. The main lesson drawn is the futility of employing tanks in marshy soil, after too long an approach march or against the technical judgment of the tank commander. Thus in the attack on Fort Pompelle, near Rheims, 15 tanks were employed in spite of an unfavourable report, and 10 were lost. Tanks in the counter-attack at Cambrai on the 11th of October, 1918, are credited with particularly useful work, whereas at Bapaume at the end of September three German tanks, the survivors of two sections (5 each), after an exhausting and unreconnoitred approach march, reached the appointed place only to be put out of action at once by the German artillery, which had not been warned of their advent.

Dipl. Ing. Fritz Heigl does not approve of the German word *tarnung*. He declares his preference for "camouflage," and divides it into :—

POLITICAL AND STRATEGICAL.

1. Spreading false or misleading information and camouflaging one's own messages.
2. Pseudonyms ; as, for example, the word "tanks."
3. Concealment of concentration and approach marches.

TACTICAL.

4. Smoke.
5. Camouflage against sound-ranging.
6. Camouflage of individual guns, tanks, ships, etc.
7. Camouflage of defensive works and of roads.

Under heading (1) the palm is offered to the Allies. A German N.C.O. prisoner is quoted as having lulled the French into false security before the German attack of May, 1918. A similar incident preceding the Canadian attack on the Vimy Ridge might have been quoted. The name "tank" is considered to have served a great purpose and the attention called to the French heavy tank by its name "Char de la Seyne" is contrasted with the indifference with which a name such as "Char 2 C" would have evoked.

The "passive" concealment of concentration quoted as the masterpiece is that before the German offensive of May, 1918 ; whilst, as an "active" concealment, Solomon's book, *Strategic Camouflage*, is quoted as evidence of successful German camouflage of whole divisions. The author feels, himself, a little doubtful, for he adds that, whether this wholesale camouflage of formations be true or not, it points the finger to the camouflage of the future.

Considerable space is devoted to camouflage against sound-ranging. The author is correct in saying that it is more or less impossible, except by such a volume of noise as accompanied an opening offensive on the Western front.

He advocates, and it would seem rightly, the placing of isolated guns or sections, for emergency, or normal, support and counter-battery work, while the remainder are held in reserve for the *pièce de résistance,* and shifted immediately afterwards. Dummy flashes are considered useful camouflage against flash-spotters. In my experience they were of little avail.

Two outstanding items of tactical camouflage are quoted. The camouflage of Montdidier Viaduct (as a group of lofty elms) by the French, and of a monument near St. Quentin as an observation post by ourselves.

In the May–June number there are, in addition to those recorded, articles on heavy gun and heavy load traction by four-wheel drive motor-carriages, and on the relative fighting strengths in aircraft in the world of to-day.

H.St.J.L.W.

HEERESTECHNIK.

(May, June and July Numbers.)

Dr. Ing. Becker concludes his description of the ballistograph. His experiments have shown that, although generally less precise than the Boulengé, the difference is very small and the comparatively insignificant weight makes it much more suitable for calibration on service. The instrument does not depend upon any direct action of projectile or shell-wave, whereas most methods do; and it can be used for any elevation. If heavier construction is allowed the ballistograph might certainly equal the Boulengé in precision and be equally valuable at artillery schools. Such matters as the rotation of the head of the shell round the line of flight, at any point in the trajectory, the effect of increase of elevation on the muzzle velocity, the angle of impact, etc., can all be photographically recorded, whilst by using two or more ballistographs each round of a series may be recorded at the beginning and end of its flight.

It is thought that the timing apparatus employed may have value for sound-ranging.

Captain von Giesecke describes the German G.S. limbered waggon 95, with its wheel-base of 1,460 mm. This waggon gave considerable trouble during the later stages of the war. There is a lot of iron in the model (as there is bound to be in limbered waggons), and the article asks the question as to whether a limbered waggon is really worth while. On the whole, the conclusion is, No.

Any waggon should start by having the normal wheel-base for the countryside in question, otherwise it has to break its own path and often has one wheel in a rut and the other on higher and unbroken roadway. The limbered waggon is much better across country and turns quicker—but the normal country waggon is easier unloaded and loaded, is much easier transported by rail ($\frac{1}{8}$ of the space packed on trucks), costs half the price, may be secured in large numbers on mobilization, and returned to farm use on demobilization, and employs much less iron.

The Austrians had, before the war, evolved a good and fairly general type of country cart which was of great value in the war.

The German protractor, circular in shape but with pieces cut away parallel from opposite edges (in order to fit the pocket) is described. The outer edge is graduated in millièmes, and co-ordinate measures (for the grid) and scales are added. It is interestingly different from our own.

Lieut. Arnold writes of a method of training artillery observers in one or two line observation on a sand model. Ordinary service instruments are used, and although there is nothing either new or important in the procedure, the article would repay study for one confronted with indoor training. The minor points, such as the blowing of puffs of smoke through an india-rubber tube up through a hole in the sand to illustrate the smoke of discharge or of burst, are well worked out.

The annual report of the German National Survey is reviewed. The department is considerably reduced compared with its pre-war establishment, but has carried out new first and second order triangulations, levelling and surveys at 1/25,000. There are stereo-photogrammetric and air-photo sections. The trig. records published in some 30 volumes are continued, etc. Perhaps the matter of greatest interest is the new 1/5,000 (12 inches to the mile) cadastrals. A 12-sheet series of Berlin and the neighbourhood at 1/50,000 has been published.

Special maps for air navigation have been discussed but have not been published because of the expense involved.

An investigation of the behaviour of invar wires (24 metres long) from 1905 to 1921 showed an annual growth of a 1/1,000,000th part of the length. But in 1921–2 they showed a shortening of ten times as much, possibly owing to a sea voyage. These figures will be of peculiar interest to British surveyors.

Pigeons and their habits, and their powers and limitations are discussed in an article which might repay study.

Professor Dr. Brunswig's book *Explosivstoffe* is reviewed at great length. In fact, the review by Captain Justrow finds place in five consecutive parts ending in the July number, but book and reviews are too technical for any but the expert.

The *Regional Geology of the Theatres of War*, which has been threatened for some time, is appearing in 13 volumes. Volumes 4 and 5—*Before Verdun* and *Argonne and the Champagne* are already published. Volumes 7 and 8, which will deal with *Picardy, Artois and Hennegau* and *Flanders*, respectively, will be of interest to soldiers, as will also the volumes on Macedonia, and South-east Macedonia and Asia Minor.

Volume II of *Der Grosse Krieg*, 1914–1918, has appeared and is reviewed by Major-General A. D. von Barries.

The period is from the spring of 1915, to winter 1916–17, and includes Falkenhayn's régime. He himself was replaced in August, 1916, but his policy and his undertakings had, naturally, to be carried through for a period, and the volume ends at the time when the third supreme command (Hindenburg and Ludendorff) began to make itself felt. There are nine parts, ranging from the general political and military factors to the operations on the western, eastern, Serbian and Roumanian fronts. Lieut.-General Balk is responsible for the western front.

Major von Wallenberg (political part) states that the political leadership, strong in the Entente countries, in Germany did nothing but hinder, forbid and disturb. Differences of opinion between v. Falkenhayn and Hindenburg are alluded to, and although Falkenhayn's measures appear to be freely criticized, he is well spoken of on the whole.

The "official" part of the July number is entirely taken up with an article on "Wireless." Ten well-reproduced diagrams in colour illustrate the text.

The following books, amongst others, are briefly reviewed :—

Coast Defence and Coast Fortification. Major Klingbeil. See July number.

The Sea War (Der Krieg zur See, 1914–1918). Volume 4. See June number.

H.St.J.L.W.

VOINA I MIR.

(*No.* 10 *continued.*)

E. Dostovalov, in *Landing Operations and Coast Defence,* discusses, with special reference to Russia and its coast-line on the Black Sea, how a country without a fleet, or with a fleet inferior to its adversary's, can successfully defend its shores. He states that the object of a country so situated must be to prevent an army landing on its shores and advancing into the interior. Even a weak fleet can do much towards this end by delaying the preparation and execution of landing operations, gaining time for the strengthening of coast defences and for the concentration of troops. New methods of transport introduced during the world war, facilitating the movements of large masses of troops, have made an essential change in the relative chances of the invader and defender. The aim of this article is to appreciate the data now available. The writer first deals with the question of transport of troops, and shows the enormous scale on which such operations were carried out : *e.g.*, one French transport fleet carried 2,152,622 men between France and the colonies. He then discusses the general character of landing operations and states that, from the attack by the Athenians on Syracuse in 415 B.C. to the operations in Gallipoli in 1915, the success of such operations has depended more than other war operations on accidental happenings, in many cases unforeseeable, and on the exceptional skill and determination of the leaders. Before considering the methods by which modern landing operations should be carried out, the experiences of the late war must be considered from the point of view of the struggle between a fleet and coast artillery assisted by aircraft. Owing to the perfecting of means of observation, bombardment of coast defences can now be carried out at a range of 40,000 metres or more. Increase in mobility and manœuvring power has enabled vessels to concentrate quickly. Small vessels which afford a difficult target are suitable for the attack of ports and of boats lying in a roadstead. Monitors can be used for operations in shallow waters ; armed with one or two heavy guns, they are adapted for the bombardment of coast defences where the shallows would prevent the use of larger vessels. Artificial fog is a useful auxiliary in certain types of attack, such as forcing narrows, and in attacks on harbours. Aircraft was little used in engagements between the fleet and coast defences, but they will undoubtedly play a large part in the future. Without aviation coast defence is blind.

The writer describes in detail the attempt to force the Dardanelles by the allied fleets and considers that these operations have once more emphasized the ability of coast defences to successfully resist an attack by sea unsupported by landings. The bombardment of the batteries in the Dardanelles showed the wonderful tenacity of batteries with turret mountings and of batteries in covered positions, whilst the unsuitability of batteries in open positions was demonstrated.

The writer describes the measures taken by the Germans for the defence of the Flanders coast and the English methods of attack by means of artificial fog and monitors. Experience has shown the necessity of increasing the size of coast artillery up to calibres of 16 or even 18 inches. It has confirmed the advantages of concealed and covered positions for coast batteries. It has shown that immobile coast guns are not only essential in certain cases, but must be further perfected in accuracy and range; heavy mobile artillery and a powerful air fleet will enable swift concentrations to be made at points on the coast where the fight between coast batteries and the fleet has already started. The part played by aviation on the Flanders coast is described and the writer gives his views as to the part aviation will play in the future. He considers it will not be possible for a country to undertake landing operations in the future unless it has command of the air as well as of the sea. A continuation of the article is to follow. In an appendix is given a list of the German naval guns with their ranges and distribution in groups which were used for the defence of the Flanders coast.

In this number of the magazine a section which comprises two articles is devoted to Aviation. The first article, "The Principles of Aerial Warfare," by V. Kolossovsky, treats of the subject of aerial fighting generally, and describes with illustrations the types of machines which would be used under varying circumstances. The second article, also illustrated, entitled "The Present Condition of Aerial Communication," by A. Shershevsky, describes the various type of passenger aeroplanes and dirigibles and their constructional requirements. He discusses the subject of aerial stations, the organization of an aerial route, the organization of meteorological stations and radio connections and, finally, the present development of the European aerial net and the future of aerial communication.

(No. 11.)

A well-illustrated article by Engineer Captain Hegel, entitled "Present Position of the Problem of Tanks," is of considerable interest. The author hopes that, by a study of the technical side of the question, conclusions may be arrived at as to the value and future significance of tanks. He divides tanks into three classes—light, weighing 3 to 10 tons; medium, of 10 to 20 tons; and heavy, of 20-60 tons. The German heavy tank weighed as much as 150 tons. Heavy tanks must be strongly armoured to withstand field artillery. Their task is to make a breach in fortified lines and open the road to infantry and light tanks. The task of medium and light tanks is the exploitation of success and the continuation of the attack. They must, therefore, possess great swiftness and renounce strong armament and protection. Under certain conditions such tanks must act in conjunction with cavalry, and it is possible they may partly replace that arm. Under cover of the heavy tanks will follow also special infantry tank tractors. These must be strongly protected but weakly armed and, like the British tank Mark IX, must be able to carry an infantry detachment of 50 men. Their object is to break through to the enemy rear and there to form centres of resistance. The division of swift light tanks into light and medium occurred during the war owing to the difference in the views of the English and French. Both countries constructed two splendid types of light tank, the Whippet A and the Renault, respectively. The English tank weighted 14 tons and was armed with three machine-guns, whilst the Renault weighed 6·5 tons and was armed with one machine-gun and one field-gun.

The swift tank must be as light as possible. Its outer dimensions are governed entirely by its armament. In the last war tanks could be armed with machine-guns only, because of the numerical inferiority of the German tanks, but in future such conditions will not obtain. A tank must be in a position to knock out an enemy tank, and this can only be done with the aid of guns. The Americans have armed their "Medium Tank" with a 6-pounder gun and one or two machine-guns. According to recent information, the French are trying to improve their Renault tank; it will be heavier and hold a crew of three men. They have also a scheme for constructing an ultra-light tank for one man only, and provided with Kegress chains. Generally speaking, the French and Italian tanks can be divided into two types, very heavy and very light, whilst the English and Americans have something between the two. The Americans propose to develop from their medium tank their swift tank of the future, whilst the English are improving their "Medium Tank D" to the same end.

Owing to the smaller vulnerability of light tanks, as shown by experience in the war, the evolution of tank construction, so far as heavy tanks are concerned, has come to a standstill. Italy, apparently, is chiefly interested in light tanks, but she has several examples of a heavy tank of 42 tons, the "Fiat Typo 2000." Germany has actually constructed two tanks of 150 tons. The French tank "Char de Rupture," of 60 tons, was constructed towards the end of the war and is a fine example of heavy tank construction. The maximum thickness of its armour is 5 cm., it can cross a ditch 5 metres wide and pass through water 1·5 metres deep. In England the Mark V remains the latest form of heavy tank, as no new developments were made after the end of the war. The American army has about 100 examples of the Anglo-American tank Mark VIII. The author describes this tank in detail, as being a type of an up-to-date heavy tank, and gives photographs of it. It is armed with two 6-pounders and seven machine-guns and its weight is 37 tons. The author then discusses the question of caterpillars, the most important part of a tank. He describes, with the aid of diagrams, Holt's chain and indicates its advantages and defects and also the German chain "Orion."

The Kegress caterpillar wheel has an india-rubber band and is, apparently, the best form produced up to the present time. This also is described in detail. The springing of tanks is then discussed.

The author lays down the following conditions as being essential for efficient action :—

Tactical mobility ; strategical mobility ; comfort for the crew.

As regards tactical mobility the chief requirements are that a tank should be able to cross a wide gap, to climb slopes of 45°, surmount vertical obstacles 1·5 metres high, to cross fords and shallow rivers and pass through walls and trees ; it is now demanded that tanks should be water-tight and able to travel in water, and to pass freely over areas covered with shell-craters. The modern tank satisfies all these conditions except those of water-tightness and ability to travel in water. Important experiments are now being undertaken by the French and Americans in this direction. There appears to be no difficulty in making a water-tight tank, but after going 100 km. no trace of water-tightness is left, as the continuous shocks and strains destroy any obturating material, even india-rubber. The first floating tank was the amphibious tank "La France," made by the French engineer Foenquinos. Many successful experiments were carried out with this tank in 1921–22 at Marseilles, with a crew of nine men and half a ton of baggage. Another example is that made by the Christie Company in America. It successfully crossed the Hudson in the autumn of 1922 in the presence of numerous officers and engineers. This tank weighs 6700 kilogrammes ; the author gives other interesting details about it and a photograph. There is also a photo of Medium Tank M 21, an American tank, which, owing to its great length and small height, is specially adapted for crossing shell holes.

As regards strategic mobility, one of the necessary conditions is rapid transport by its own power over great distances. During the war the French light tank was carried over great distances in a special lorry. Their "Char Schneider" of 14 tons was loaded on a special four-wheeled platform for towing. This system, if applied to great numbers of tanks, would require a large additional number of vehicles, with all their concomitant technical and tactical drawbacks. Since large numbers of tanks travelling long distances would speedily destroy any road surface some other method must be found. The solution of the question lies in the provision of "combined type" tanks, *i.e.*, tanks which are provided with caterpillars and wheels and can use them alternatively. There are at present two systems—the French "St. Chamond" and the American "Walter Christie." In the first, the wheels and caterpillars are entirely separate ; the former can be raised off the ground, leaving the tank supported on the caterpillar. The author gives a detailed description and plans of the tank Chenillette, and states that, according to rumour, it has been bought by the Spaniards and is being used in Morocco. In the Christie system there is only one transmitting system. The tank is provided with four double wheels and on them a caterpillar—the teeth of which fit into the groove between each double wheel—is fixed for movement across country. The caterpillars are supported in the middle by a pair of rollers on each side of the tank, which are lowered into position. The difficulty of steering when the caterpillars are in use, which involves independent movement of the off and near wheels, has been successfully overcome by an ingenious device which is described in detail. A full description and excellent photographs are given of each type of tank.

As regards "comfort for the crew," one of the most important points is the separation of the machinery from the crew in different compartments. Another point is good ventilation. The duties of the driver of the tank are very tiring and the operation of turning requires great exercise of strength. This matter is being remedied in the American Medium Tank M21 and in the English Mark D. Loopholes and slits for observation purposes are necessary · in the newest types of tanks (Mark VIII improved Renault) they are provided by means of swiftly-revolving steel plates pierced with slits for observation purposes. In conclusion, the author remarks that tanks are yet in their infancy. The question of strategic mobility deserves careful attention. He thinks that the English Medium Tank D, with its great speed of 30 km. per hour, its excellent springing and efficient chain, may obviate the necessity of having combined tanks; on the other hand, the latter would require far less petrol but demand exertions on the part of the crew in changing from wheel to caterpillar and *vice versa*, an operation which must be done under cover (in this respect the St. Chamond system has an advantage over the Christie). Speaking generally, there is complete obscurity amongst the Central Powers about the significance of this new arm, whilst in England and America, considering the present state of their development, there is a tendency to overestimate their value.

A.H.B.

THE MILITARY ENGINEER.

May—June, 1924.

American Roads.—The number of vehicles registered in the United States is estimated to reach 20,000,000 by the end of 1925. Under the Federal Highway Act of 1921, a connected system of main, inter-state and inter-county roads, comprising 6 per cent. of the total highways of the country, was selected to form the Federal Aid Highway System, its mileage approximating to 170,000. Up to March, 1923, 60,000 miles of this system had been converted to present-day requirements. It is hoped to complete the remainder in a ten-year programme.

Various materials are being used. Mention is made of gravel, concrete, bituminous concrete and brick roads, but the respective merits of each type are not compared. Problems of design and construction are being continuously investigated. The author quotes many interesting facts which have been established by research and experiment.

New Type Motor Lorry.—The Quartermaster-General is experimenting with an improved type of 5-ton lorry. The new type is a conversion of a standard four-wheel solid-tyred vehicle. A four-wheel flexible bogey replaces the ordinary rear axle, all six wheels being fitted with pneumatic tyres. The impact is reduced from 29,000 pounds to 7,000 pounds; the sub-soil pressure from $6\frac{1}{2}$ to 2 pounds per square inch. Trials are proceeding.

The Relation of Current to Tide.—Tidal movements may be classified as Progressive Wave, Hydraulic, or Stationary Wave types. The author gives an explanation of each and shows how the tide in any locality can be identified from a study of tide tables, and hence the direction and strength of currents at any time determined.

Use of Teleferica in the Italian Alps.—Teleferica, or Aerial Ropeways, were extensively used on the Italian front, where their principal applications were:—

(1) During active operations to provide a rapid means of opening communication with advanced troops, pending the construction of roads.

(2) To supplement road communication in winter, when conditions became difficult.

(3) As a temporary means of crossing gaps, where bridges had either been demolished or rendered impassable by floods.

Troops on Mt. Grappa were supplied by a line 3,500 metres long, with a carrying capacity of 8 tons every 30 minutes and a maximum load of 1,000 pounds. Lines were usually duplicated, power being supplied by petrol engines.

The Evolution of the Nautical Chart.—Work of the U.S. Coast and Geodetic Survey Department. A complete account of the methods employed in the production of a chart.

R.I.M.

CORRESPONDENCE.

AUSTRALIAN SHEEP RUN.

To the Editor, *R.E. Journal.*

DEAR SIR,

The two enclosed diagrams of devices used on a sheep run in South Australia may be of interest.

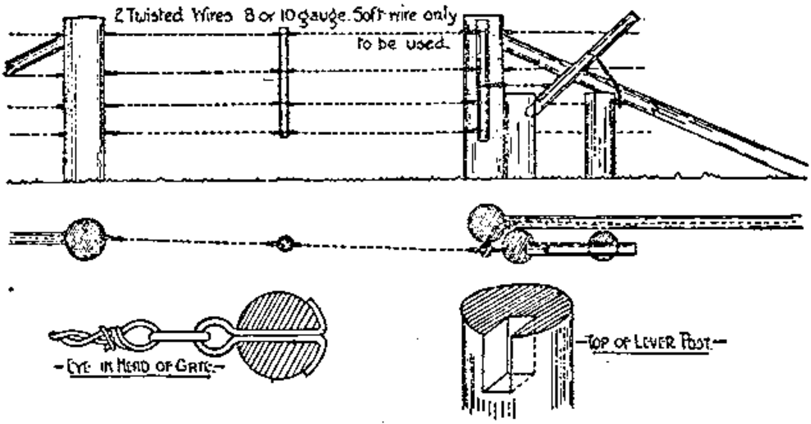
1. *Wire Gate.*—This is sometimes made 30 ft. in width for large mobs of sheep. The strands forming the gate are made of twisted soft wire, so that the gate, when opened, will lie on the ground without coiling up. The lever post is usually tied back to the strut of the gate-post, and the chain on the lever is often attached to this strut instead of being fixed on a separate post, as shown in the diagram.

2. *Wire Ties.*—These are used in the place of nails for attaching timber to timber, as in stockyard rails.

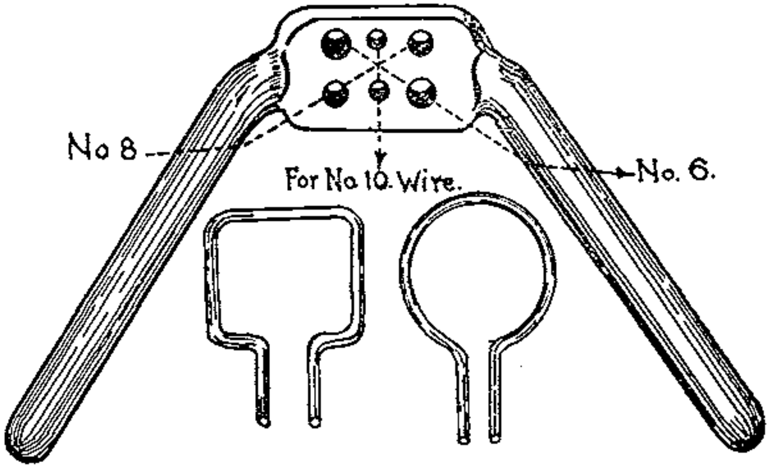
Yours faithfully,

R. U. H. BUCKLAND, *Major-General.*

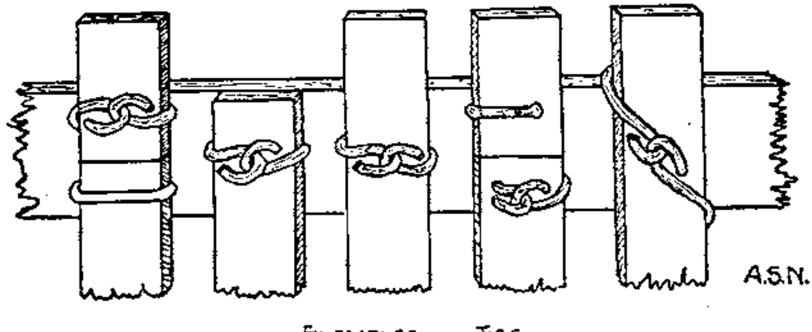
WIRE GATE - 20 FEET



-Twister for Making Wire Ties.-



-Before Tying.-



-Examples of Ties.-

The twister is made of steel or an old file or rasp, the holes in it being bored in pairs to take, say, Nos. 6, 8, and 10 wire. Ties for square and round timber are also shown. When the tie has been made, the ends are cut off and points hammered down as shown in sketch. The ends must not be corkscrewed.

WARMING AND COOKING FOR SMALL HOMES.

To the Editor, *R.E. Journal.*

SIR,

One of the institutions in which I am interested possesses an infirmary, which is a building, like many such, devoid of special design for its purpose and added on to from time to time without any regard to our modern ideas of economy.

The ruling body asked me whether I could give them my assistance in reducing the annual cost of heating their establishment, and possibly reducing their coal bill by utilizing the boilers and other miscellaneous heating appliances which seem to have accumulated from time to time without any definite policy.

Luckily, my answer was somewhat conservative and to the effect that, in my experience, the main economy in central heating was secured by reduction of labour in carrying coal, removing waste and keeping the place clean. But the reduction of the coal bill required some careful consideration.

I say luckily! Because on investigation I found that the establishment has a practically unlimited supply of unsalaried labour of old pensioners and other hangers-on; so the only items on which savings could be effected were reduced to coal consumption and periodical internal decoration.

I am indebted to my brother officers for two articles which have recently appeared in the *R.E. Journal* on central heating. I turned to these again with redoubled interest and absorbed much wisdom from their perusal.

But I could not find all I wanted; so I turned to the open market and made enquiries amongst my friends who had centrally-heated houses, and amongst the catalogues of firms professing to install central heating according to the latest modern developments.

I give the results of my enquiries for such as they are worth, not because I think they should be a model on which to base other similar schemes, but in order to provoke discussion and eventual enlightenment on a question which I humbly think has been a good deal neglected from an economic point of view.

The question of central heat production is going to have a greater importance than is generally attributed to it by the general public, which is content to view its public buildings, beautifully warmed in winter, and occasionally its private houses equally comfortable, as accomplished facts without enquiring how the desired result has been attained or whether it can be improved either in efficiency or economy.

When I was in Canada, some little time ago, I heard of a scheme for supplying heat to groups of houses in townships on exactly the same principle as water or electricity is now supplied. Now that I am in France, I find that there is a scheme on foot to erect superior grade mechanics' houses on disused bastions of the defences of Paris and to supply them from central stations with water, light and heating at a fixed rental to include all these conveniences.

So the central heating scheme is before us and it behoves us to study it just as we have studied the supply of gas, electricity and water.

After a good deal of investigation and, possibly acting in accordance with my own prejudices, I decided on the low-pressure hot-water system. I may mention that I had long experience of the hot-air system as applied in three different countries and I did not like it. So the pipeless system did not enter into my calculations.

When I use the word "heat" I imply that the temperature in the room or building under consideration is to be raised to and maintained at between 60° and 65° Fahrenheit, with an outside temperature of 30°.

This I assume to be the average problem to be dealt with in England and the Lowlands of Scotland.

Radiators are now made of any pattern to suit the fancy. Many catalogues can be found in the trade which give very full information on this subject. A favourite method in England appears to be to install these under the window-sills, so that any leakage of air from outside should pass over the radiator and so be warmed as it enters the room. This system is apparently favoured by the Paris scheme. But it has its dangers in very severe weather, and it is not much liked in Canada, where an incautiously opened window might suddenly have the effect of cracking a radiator.

When the building to be heated has more than one story, the number of square feet of radiator surface in the second and third story, etc., can be reduced and allowance must be made for the heating surface of the communicating piping.

Now, 1 sq. ft. of radiator surface will heat 50 cub. ft. of air space per hour, roughly, so that 1,000 sq. ft. will heat 50,000 cub. ft. of air space per hour.

It requires 144 British thermal units to heat 1 sq. ft. of radiator surface per hour.

Coke broken of suitable size and good grade produces 8,500 B.Th.U.* per lb.

Therefore 1,000 sq. ft. radiator requires $\frac{144,000}{8,500}$ lbs. = 17 lbs. of coke per hour, assuming first-class stoking and absolute unwasted combustion, Add $\frac{1}{3}$ for mains' losses, cooling and imperfect stoking, say 23 lbs. per hour altogether.

So for 24 hours' heating of 50,000 cub. ft. of air-space we require 23 lbs. $\times$ 24 = 5 cwt. of coke.

Or, to put it in more convenient figures :—

1 cwt. of coke will heat 10,000 cub. ft. of air space per 24 hours.

The quality and gauge of the piping for a large scheme can be specified with any exactness to please the designer, but in small schemes, as a rule, one has to be content with the local supply available and the limitations to which the workmen are accustomed.

One installation which proved very satisfactory had one-inch piping

* Theoretically, 1 lb. of coke will produce 12,000 B. Th. U., but it depends on the pattern of the boiler, the draught in the chimney and manner of stoking as to how much of this heat is wasted and how much is absorbed by the water in the hot water boiler. The figure 8,500 is only applicable to the best boiler work and for the average house it would be safer to estimate for only 6,500 B. Th. U. being available per lb. of coke burned.

throughout ground floor rooms and passages, and two-inch piping running along the skirting-boards of the first floor, connecting a correspondingly reduced number of radiators in the rooms with a final outlet into the open air of one-inch piping.

I have taken coke as the basis for my calculation. The corresponding figures for anthracite or for good steam coal are: 10,000 B.Th.U., so that 10,000 cub. ft. of air space require 90 lbs. per 24 hours for heating purposes.

It is possible that at some future date gas, and even electricity, may be utilized for heating purposes. So I venture to give the connecting link in B.Th.U.

One cub. ft. of gas produces 450 B.Th.U.

One therm of gas=100,000 B.Th.U.=30 Board of Trade units of electricity and 1,000 Watt hours=$1\frac{1}{3}$ H.P. hours.

I do not pretend that my calculations give anything more than a very approximate estimate of the fuel consumption and I am inclined to the belief that they rather overstate the requirements for an average British winter. It must be remembered, however, that though the winter may be mild it may last for a long time, like the one just concluded, so the estimate has to cover the possibility of a very severe winter or a long comparatively mild one.

So much for my figures and calculations! But I have failed entirely in collecting data for working out the size or design of the furnace and boiler required to produce the results I have endeavoured to work out.

Would one of your contributors favour me with some information on this subject?

Trade catalogues give illustrations of boilers and furnaces producing a given number of B.Th.U. per hour, but I have learned by experience to be somewhat sceptical of these designs and their promised performance.

My attention was next directed to the modern economical devices for supplying hot water to small houses and the latest developments in cooking ranges.

There is a very useful pamphlet prepared under the auspices of the London County Council, discussing the developments to be sought in superior artisans' houses, as well as in those for humbler members of the working population.

There seems to be a general consensus of opinion that hot-water circulations dependent on the boiler attached to the kitchen range use up 30% of the fuel allowance. They have this further disadvantage that the water is not really hot (180° Fahr.) unless the dampers are drawn out for that special purpose, and if there happens to be cooking going on at the same time when hot water is required, the oven suffers from robbery of heat or else the whole system is run at great pressure and so hastens its deterioration.

Some years ago I abandoned the kitchen range system for hot-water circulation in Government quarters and put in a separate furnace and boiler in connection with the existing cylinder, cutting out the old saddle boiler from behind the kitchen range.

The drawback of this system I found to be that nobody but the gardener could contrive to bank the fire so that it would last throughout the night. This proved a great inconvenience, as it meant having the gardener on duty at ten o'clock every night. Otherwise the system proved to be economical and the furnace, being omnivorous, got rid of a good deal of kitchen refuse which in ordinary country houses would have been devoted to fattening the pigs.

Certain gas companies have, in the last few years, been advocating their gas water-heaters with what they call a Thermostat installation.

Opinions differ as to the efficacy of these. In the first place they are expensive in first cost, and the gas companies are not always willing to let them out for hire.

There were some of these on show at the Exhibition in Olympia last March and I extracted the calculations from the experts in charge, who wanted to put me off with the bald statement that the cost was 3d. per bath of 20 gallons. But it took, so far as I can recollect, 20 minutes to prepare the water for circulation, after which time it was continuous.

I then tried the several Geyser companies that were exhibiting their wares. These are certainly a great improvement on the terror of former years, but they are expensive to install for more than three taps. These experts again tried to put me off with the 3d. per bath of 20 gallons.

On checking the calculations of my friends I found that they based their results on the London County Council specification of gas producing 500 B.Th.U. per cubic foot and costing 8d. per therm.

Personally, until I am convinced by better arguments to the contrary, I am in favour of the Thermostat water-heater.

If the pipes are nicely laid and exposed where wanted they supplement the central heating of a small house. If the house is already sufficiently warmed, it would, of course, be better to insulate the pipes, except in the linen cupboard, in which the cylinder should find its home, and in the bathroom itself, when the circulating water should have a by-pass to warm the towel rack.

The gas-heater can be turned off in summer and only lighted when actually wanted.

Having accepted the gas water-heater, we now turn to the kitchen range itself.

My own proclivities are in favour of gas cooking and I would gladly see the kitchen range and consequent sweeping of chimneys abolished.

But would our attendants, on whom our comfort in declining years so greatly depends, view the subject in the same light?

Poor things! They do suffer from the heat of the kitchen in summer-time, and it is no doubt a severe trial to have to cook in parts of July and August. But how long does the real summer weather last? Three months, with luck four, and during the remaining eight months of the year there is much comfort and consolation to the worker in a cheery kitchen fire.

So I fear the kitchen fire must remain till a new generation of assistants arises and we must go to the expense of a gas-cooker for use in summer and to supplement the kitchen range.

Now I have got to the subject of ranges I have to make a further confession of faith. It is that the kitchen range of the average British

12-room or 10-room house is an exaggerated anachronism. Why need it be so large?

Why need it be built into a cave in the wall so that whenever anything has to be put right a bricklayer as well as a stove-setter has to be employed?

Why not introduce everywhere the Canadian cooking range, standing like a table away from the wall with the stove-pipe running up out of reach, so that the operator can walk round it and keep it clean?

Such a stove as I have in my mind stands on legs, so that the paving on which it is set can be kept religiously swept and there is no harbour for black beetles and mice.

Many firms in London make and stock these ranges, but they are not often met with in middle-class houses.

The County Council pamphlets above alluded to recommend these ranges for artisans' houses, and the only objection so far encountered by me in course of discussing their introduction to workmen's houses is that children might possibly run up against them and burn themselves.

It was in vain for me to protest that these ranges have been in use in Western Canada for many years without serious diminution in the rising generation. I was still met with the rooted conservatism in favour of buried ranges where the cook has to put her head under the arch of the chimney-piece to see what is going on and stands in her own light.

One more grumble and I have done. Many of us, in our declining years, are martyrs to gout, rheumatism and arthritis. Are not these ailments in a great measure traceable to the prevalence of hard water?

Water-softeners are obtainable in the market at a certain price. The cost is considerable, but I am confident that the rising generation of house-builders has only to press their efficacy on the public to render them sufficiently popular, so that the price, which is now almost prohibitive, may be brought within the compass of a modestly-furnished purse.

Some of us of the old guard manage to hang on to a good old age in spite of gout and rheumatism, but if these latter ailments could be exorcized even by a little, our declining years would be made the happier and we would go down to our graves in a spirit of thankfulness to those who have contributed to our comfort.

J. A. FERRIER.

TIDES.

To the Editor, *R.E. Journal*.

DEAR SIR,

May I offer the following criticisms on the correspondence entitled "Tides" in the June number of the *Journal*.

Not being acquainted with Mr. Louis Stromeyr's theory, which, he remarks, renders a gravitational field of force as a plenum of energy, and so prevents him from looking to attraction as an explanation of the tides, makes one diffident about criticizing his idea of tidal causes, which is based on that theory. However, his letter strikes at the roots of so much that one has become accustomed to take for granted that I venture to bring forward some reflections on the modern view of the constitution of matter, for without a fairly good idea of "matter" we shall probably fail to discover the reasons underlying the effect that matter has on matter.

These reflections tend to confirm one's belief, in my opinion, in the theories of Newton and Laplace as to tidal action, the equilibrium theory of the former and its extension in the dynamical theory of the latter.

As I understand Mr. Stromeyr's letter, he firstly criticizes tidal theories, which take into account lunar attraction, and which are therefore not admitted by him. He then briefly states his own conclusion, but without supporting data, perhaps that is contained in his "gravitational theory," with which I am unfortunately not acquainted.

We find Mr. Stromeyr repudiating the existence of the force of attraction that mass has on mass; he says this still implies "action at a distance." Men of science admit that the exact mechanism by means of which mass attracts mass is not understood; this largely because the constitution of matter itself has not yet been fully determined. Much, however, is now known about matter and something about space.

Mr. Stromeyr only makes a slight reference to electrical matters, but since the modern conception of matter is that its structure is electrical, I shall here probe somewhat deeper into this field.

The atom, the old-time basis of matter, has now itself been sub-divided. It is known to comprise one or more electrons, the units of negative electricity, which have a definite mass value of about $\frac{1}{1850}$ of that of a hydrogen atom, and besides, a nucleus of positive electricity, which has so far evaded isolation.

Some of the properties of this elusive positive nucleus are known, and others are in the process of coming to light. Its mass, for instance, appears to be much greater than that of an electron.

The arrangement, or configuration, of the electrons and positive nuclei, is probably the factor determining the atom and its properties. The electrons, there is little doubt, are usually, if not always, in a state of some type of orbital motion.

The different effects of mass in motion and mass at rest are well illustrated by the powerful water jet through which a sword will not pass, and by the smoke vortex ring which passes through a smoke cloud as if an individual structure.

Bearing in mind the dissimilarity existing between the positive and negative "ultimate particles," may we not justly conjecture that the electrical inter-actions between two atoms of matter may cancel out?

Consider two identical atoms, electrically neutral, that is, each with its normal constitution of positive and negative "particles" of electricity, and these in normal motion.

The indications are that the electrons particularly inhabit the surface layers of the mass, anyhow they are comparatively easily dissociated from the mass.

The first effect between two atoms would then be a mutual repulsion between the nearest electrons in each. One might then suspect an opposite reaction on the remainder of the atom, resulting in an attraction of mass for mass. Such a reaction would account for attraction, such as exists in the force of cohesion, where small masses are in intimate contact, also for attraction between planets, where large masses can act over greater distances.

Having considered the possibilities in this way, even though it may not be a completely true explanation which I have hazarded, I conjecture that an explanation proving that mass does attract mass will be arrived at by some such reasoning. It is not surprising that mass attraction cannot be explained at present, seeing that our knowledge of the constitution of matter is still incomplete.

Now as to "space," which, Mr. Stromeyr says, a "field of force" cannot occupy, but which "energy" can occupy, if I understand his meaning, such a differentiation seems to me impossible, having due regard to the meanings of the terms "force" and "energy." The word "occupy" is ambiguous, but I will not make a quibble on that. Space, of course, is a medium through which various transverse waves can be and are propagated at a finite velocity, that is to say, in the interval of time between the generation of the wave and its reception, the medium is in a state of wave strain, and therefore a seat of energy.

It can be shown also, that prior to the wave being propagated, space may be in a condition of static strain, and therefore a field of force.

Consider a wireless transmitting aerial; with the initial charge of the aerial wire, space is "lifted" into strain, ready to propagate its strain in the form of a wave, immediately the stress is suddenly removed.

While the charge is "held," strained space is a field of electrostatic force.

Near a magnet we have strained space as a field of magnetic force.

A mass of matter, having a mechanical force applied to it is a field of mechanical force, and so on.

We say nowadays that ether permeates all space, but what is ether?

We don't know all about it, but it is certainly something which can be set into vibration at the enormous frequencies of X-rays, light waves, wireless waves, and so on.

It is also something in which certain currents of electricity, known as dielectric currents, can be made to flow, though unwillingly. Or, put into other words, it is something which appears to contain positive and negative electrical particles, which can be displaced and so become currents of electricity in space during the time interval of displacing. In considering the wireless aerial, we had, first, the electricities displaced forming an electrostatic strain; this strain in righting itself gives rise to displacement currents of electricity in space, which in their turn give rise to electromagnetic space strain, which again gives rise to further electrostatic strain, and so the wave is passed on.

Compare the static condition at the crest of a water wave and dynamic condition half way between crest and trough.

Perhaps a working hypothesis would be to imagine the ether of space to consist of positive and negative electricities in a neutral and immaterial configuration. What constitutes the difference between electrostatic and electromagnetic force in space has yet to be explained—some difference in the motions or positions of the electric particles, perhaps.

Now, as to Mr. Stromeyr's query on antipodal currents, does not the *Encyclopædia Britannica* explain the causes for these, under the heading of tides? I refrain from reproducing the arguments.

As to Mr. Stromeyr's final conclusion, I am able to believe that a distortion of both earth and water is set up which possibly gives rise to a wave of strain, but I think these effects would be due to attractions by the moon and sun, and cannot be solely due to the earth's rotation.

Something besides mere rotation is required to explain the generation of this wave.

E. D. CARDEN, *Major*, R.E.

DEPÔT BARRACKS, YORK,
18th June, 1924.

TROUBLES OF AN OFFICIAL HISTORIAN.

THE MINES AT HILL 60, 17TH APRIL, 1915.

To the Editor, *R.E. Journal*.

SIR,

May I again ask your assistance in compiling the official history.

I should be very much obliged for any information that would help to clear up the mining situation at Hill 60, on 17th April, 1915. The Army, Corps, Divisional and Infantry accounts agree that three mines (or six mines in pairs) were fired at 10 seconds interval; the artillery opened when the first mine was fired, the storming party advanced directly after the third explosion.

The diary of the C.R.E., 5th Division, says: "for this operation see the diaries of the 59th Field Co., R.E., and the 1/2nd Home Counties Field Co." The 59th Co. diary contains nothing on the point; that of the 1/2nd Home Counties Co. speaks of three mines fired by the 171st Co., R.E., and of finding R.E. for the storming party and consolidation. The diary of the 171st Tunnelling Co., only formed on the 9th April, states that it loaded *two* mines, not three, with 2,700 lbs. black powder and fired them. Some other unit apparently made the galleries and the third mine.

The 28th Division, which preceded the 5th Division in the Hill 60 sector, is believed to have initiated the mining scheme when it took over from the French, who lost the Hill on the 10th December. There is, however, no mention of mines in its diaries, except that the 1st Northumbrian Field Co. has an entry of an officer being wounded "returning from the mines."

I am now compiling the volume on 1915 (France) and should be glad of any details of R.E. doings in that year. The R.E. war diaries contain very little, as members of the Corps were too busy doing work to have time to write about it.

Your obedient servant,

Audit House,
Victoria Embankment, E.C.4.

J. E. EDMONDS.

WAR PHOTOGRAPHS.

THE Imperial War Museum, Imperial Institute Road, South Kensington, S.W.7, to which address its quarters have now been transferred from the Crystal Palace, contains a very complete pictorial record of the War, comprising upwards of 100,000 official and unofficial photographs depicting scenes and incidents of interest to the three Services in all theatres of operations during the period 1914–1919.

In addition, the Museum possesses very extensive records in the form of maps, charts, aerial "oblique" and "vertical" views, and other matters of topographical interest.

There is also an extremely valuable collection of photographs of Naval interest dating back to 1860, in which war craft of all types and nationalities, from battleships to coastal motor boats, are shown, as well as views of mercantile vessels, portraits of Naval notabilities, etc.

Copies of the above-mentioned photographs may be secured on application to the Museum, and orders can be dealt with by post where it is not convenient for the person interested to call and inspect the records at the Museum.

This very valuable collection of photographs has already proved of great use for illustrative purposes to authors of official, regimental and Divisional histories, memoirs and other War literature; to lecturers on matters of Naval and Military interest who require to illustrate their lectures with lantern slides; and to individual officers and men who desire to illustrate their own personal diaries of the momentous events which they experienced during the period of the Great War. Upwards of 150,000 prints and lantern slides have been sold to the public, included in this figure being 800 prints and slides actually sold by the Museum in its new quarters at South Kensington, in spite of the fact that the galleries are not yet open to the general public.