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FOREWORD.

THE change in the publication of this *Journal* from monthly to quarterly issue calls for some brief Introduction.

The proposal emanated, more than a year ago, from an officer who may be considered as fairly representative of those junior ranks, who, in the Great War, distinguished themselves, and brought honour on their Corps, by gallantry in action and by marked technical skill. The opinions of such officers are of the greatest weight, not only because they have learned by executive experience what they require, but because it is on them that the future of this branch of the Imperial Army will depend. The views, therefore, of all such were solicited, and the consensus of opinion was undoubtedly in the direction of something better than the existing form.

Progress in all forms of engineering and of military science is continual, and it is necessary for those responsible for policy continually to revise their methods of efficiency. Such a revision was made shortly after the South African War in the change which then (1905) took place in the form and scope of the *R.E. Journal.* That the changes which then took place were an improvement on the preceding issues, is admitted. The time has now come for a further advance.

Certain preparatory steps have, however, been taken, which it is hoped have already tended to improvement, and may be still further developed. One of these steps is the appointment of a small Advisory Committee, consisting of officers of high rank, responsible for actual administration and instruction, and of others who are elected by the Council of the Institution for personal qualifications. On this Advisory Committee devolves the duty of directing the Secretary of the Institution as to the scope and character of the articles to be published, and thus relieving him of a responsibility which it is thought he should not have to bear alone.

Another step is the granting of small pecuniary awards to the writers of selected articles, as a recognition of the trouble they have taken, and of the value of the information given.

In considering the policy of production of a quarterly journal, the members of the Council of the Institution endeavour to keep before them certain fundamental principles. Of these the most vital is that the value of military engineering depends absolutely on its correlation with military science, both in Operations and Administration. Unless, therefore, this science is thoroughly and intimately absorbed by the military engineer, not only will much of his energy be misdirected, but the confidence with which his assistance and opinions are accepted by other arms will be seriously impaired. Articles on purely military subjects which would be out of place in a civil engineering journal are therefore properly suitable for our consideration. On the other hand, among the lessons of the Great War, one of the most valuable is the importance of civil engineering, in its many branches, to an army in the field, not only in works on the Lines of Communications, but in the sphere of actual combat. It is unnecessary to labour this point; the sequel to it must be that, more than ever in the past, the military engineers of our Empire must keep in touch with their civil brethren, whose splendid conquests of natural difficulties go on without ceasing, and who, in their varied researches, and in their published periodicals are affording us continually the insight into new vistas of scientific and practical knowledge. The fact that many officers of the Royal Engineers cannot keep in touch with these various civil technical journals makes it imperative that the Institution should keep them informed of the most important developments in civil life.

While it is recognized that physical science must be at the basis of engineering, it is remembered also that practical experience of actual work is specially valuable. In the past the records (in the *R.E. Journal*) of experience gained, in peace or war, has been comparatively small. It is hoped that an improvement in this respect may be forthcoming. It is hoped that senior officers will encourage those serving under them to write papers on the results of actual experience, and it is to such papers that the Institution would desire most liberally to make pecuniary awards. Officers are sometimes reluctant to write about what they have done, lest it should be thought that they are glorifying themselves. Any idea of this sort may be at once dismissed. They are helping those that follow them, and who may have similar work to do.

As many as possible of the lectures given at the School of Military Engineering by experts will be published, so as to reach a larger audience than can be present at the time of actual delivery.

In geographical and survey work of all kinds, the record of the Royal Engineers in the past has been of the highest. It is believed that in the future it will continue to be in the van of progress in this respect. Papers on the subject will, it is hoped, appear in the pages of the *Journal* from time to time, and any communications in respect of observation and exploration will be very gladly welcomed.

It is hoped, too, that the lighter side of the varied life of the Corps will not be entirely overlooked. It has its importance, and the records of travel, adventure and sport are acceptable in a journal whose readers are in many cases none the worse soldiers and engineers because they ride straight or can manage a yacht in heavy weather.

Such is the programme. It is a big and ambitious one, but with the hearty co-operation which the Council have every reason to anticipate, it is one to which they look forward with confidence.

G. K. SCOTT MONCRIEFF, *Major-General,*
Vice-President, Institution of Royal Engineers.

THE NECESSITY FOR ENGINEER INTELLIGENCE TO ENGINEER COMMANDERS IN WAR, AND HOW IT MAY BE OBTAINED.

Cooper's Hill Memorial Prize Essay, 1922, *by* PRÉVOIR (Capt. C. DE L. GAUSSEN, M.C., R.E.).

IN the history of almost every campaign incidents abound which illustrate the far-reaching effect that Engineer Intelligence, or the lack of it, brings to bear on the result of operations. A study of a few such incidents will assist us in framing a definition of the term, in its widest sense, and in appreciating the importance of good engineer intelligence to Engineer Commanders, and hence to all Commanders of formations.

Taking an example of a situation in which the value of engineer intelligence, as applied to river crossings, was appreciated, we cannot do better than to turn to the battle of Assaye. Wellesley, operating against the Maratha chiefs Holkar and Scindia in 1803, had pursued them from Ahmednagar and found their armies drawn up on the left (north) bank of the Kaitna; he was on the south bank, with no means of crossing the river. All the natives declared there were no fords or crossings in the neighbourhood. Wellesley, however, noticed four miles down the river that on both banks there were two villages opposite one another. At once he realized that here, if anywhere, there must be a crossing: his knowledge of Engineer Intelligence and Reconnaissance served him well and enabled him to inflict a crushing defeat on the Maratha Army.

Another incident involving the problem of a river-crossing illustrates the result of a deficiency of engineer intelligence. In the opening phases of the Great War, the German Ist, IInd and IIIrd Armies first encountered the allied main armies standing on the line of the Meuse, Sambre and Mons Canal. On August 23rd the IInd Army had crossed the Sambre between Namur and Charleroi, and were pressing on to the French Vth Army, established on the heights south of the river, with their right flank resting on the Meuse. The German IIIrd Army, on the left of their IInd Army, was advancing towards the Meuse, almost at right angles to the French line. By a rapid movement across the river they would be able to outflank the French Vth Army, or at all events, very seriously hamper their withdrawal, while the IInd Army engaged them frontally. Accordingly, a special composite division was formed under Colonel von Olnhausen, with orders to cross the Meuse at Fumay and advance on Rocroi. The essence of the operation was rapidity, to cut off the French line of retreat. On August 24th, von Olnhausen beat back the French troops protecting the bridgehead at Fumay, only to find the bridge demolished. He had no bridging equipment with his force, so a crossing there was impossible. He therefore marched eight miles south to the next bridge, at Revin, by forest tracks and bridle-paths, which delayed him considerably and exhausted his men and animals, only to find the bridge there, too, destroyed. Actually the division did not cross until August 27th, when the remainder of the main army came up, with its pontoon equipment. By that time the French had disengaged and the chance of cutting their communications was lost.

The non-provision of bridging equipment can only be attributed to a lack of engineer foresight, or intelligence, as it may be called; the march over bad roads may, or may not, have been due to lack of engineer information, but in any case it was unnecessary, had the value of engineer reconnaissance been appreciated. If the Commander had dispatched a strong reconnoitring party and first ascertained if the bridge at Revin was intact, he need never have undertaken the fruitless and tiring march.

A third incident shows that the importance of careful dissemination of intelligence is just as great as the necessity for collecting it. The engineers of part of the American forces engaged in the operations to cut off the German salient at St. Mihiel, in September, 1918, were ordered to accompany the infantry, and carry bridges for the crossing of the Rupt-de-Madt, a small stream running across the front of attack. The stream ran in territory which had been occupied by the Germans for the last four years and, when reached, was found to be very insignificant and to form no obstacle to infantry. It was discovered later that the General Staff was in possession of intelligence which would have given the engineer commander sufficiently accurate information to have enabled him to avoid this waste of man-power, but, through faulty recording or distribution, it failed to reach him.

From a study of these historical examples, a definition can be framed which will serve as a guide in discussing its value and acquisition:—"any information regarding the theatre of war, the enemy's methods, and their own experiences which will enable military engineers to prepare for and carry out their work in such a way as to render the maximum possible assistance in the attainment of victory."

In the second illustration described, had the responsible engineer commander considered the probable action of the French engineers, he must have realized that the chances of finding the bridges over the Meuse intact were very small. Again, in the third illustration, had the engineer commander been in possession of information regarding the Rupt-de-Madt, he would have been able to allot to his troops more useful work for the furtherance of success of the operations. Under the heading "their own experiences" is included the result of training, study and keeping abreast with developments in engineering science.

It is unnecessary to dwell on the need for the fullest information possible being transmitted to engineer commanders in good time to enable them to draw up their plans for the provision of necessary materials and labour, and to guide them in deciding on the relative urgency of the demands upon their resources. The preliminary investigations and calculations to be made before undertaking any engineer work in peace cannot be too carefully worked out, and if the best use is to be made of engineer troops in war, it is imperative that their commanders be supplied with as ample and accurate information as possible to give them a basis on which to make their preparations for work.

Only an outline of such information required can be given here. New developments in armament and their corresponding effect on the work of engineers must be anticipated. For instance, the extensive use of tanks and mechanical cross-country transport will render the study of terrain and possible obstacles very much more important than formerly; river-beds and crossings, too, must receive special attention. The introduction of aircraft has taught us the necessity for concealment from aerial observation, and we shall need information regarding the vegetation or crops in order to be able to make preparations for camouflage of works or concentrations.

The principal headings under which Engineer Intelligence will be required, then, are :—

Roads.—Class, nature and width; state in winter; sources of material for repair; strength and dimensions of bridges.

Waterways.—Crossings; bridges or fords; strength of current; practicability of floating or pier-bridges; dimensions in summer and winter; floods; possibility of use for transport or communications.

Water Supply.—Reservoirs and pipe systems; wells and springs; geological formations.

Engineer Material and Plant.—Factories, workshops; machinery, tools and engineer stores; timber resources.

Power.—Electric installations and circuits; coal; gas.

Communications.—Railways and rolling stock; telephones and telegraph systems.

Fortifications.

Foreign Armies.—Engineer methods and organization; stores and designs.

Civilian Labour and Transport.

Terrain.—Geological conditions affecting earthwork and mining; possible defensive inundations; whether open or enclosed; nature of vegetation; ravines, nullahs and other obstacles.

SCIENTIFIC AND ENGINEERING PROGRESS IN CIVIL LIFE.

Such detailed information can only be obtained in the leisure and comparative freedom of movement of peace; and, though a great deal can be gathered by the study of technical publications and other books, as will be shown later, for satisfactory results personal visits to the various possible theatres of war are necessary. This is an expensive proposition, and, in deciding upon the most efficient means of acquiring intelligence, the need for economy must not be lost sight of.

The possible sources of information are more numerous than might appear at first sight, if advantage of them all is taken:—

1. *Technical Publications.*—Engineering, commercial or scientific handbooks and periodicals, or even guide-books and photographs, will often provide information and statistics regarding local engineer conditions and resources. For instance, an article in an engineer journal may give all the information required about certain factories or works. Intelligence thus obtained will, of course, often require confirmation or amplification, and, conversely, may be extremely valuable as confirmation of information obtained from other sources.

2. *Agents.*—Of intelligence agents it is unnecessary to say more than that this will be the principal source of information required on particular points. As the size of armies grows and mechanical devices form an increasingly important part of their armament and equipment, so the importance of engineer intelligence becomes greater, and it is very desirable that all agents should have sufficient knowledge or training to enable them to carry out useful engineer reconnaissances.

   Private individuals, too, whether themselves travelling, or by correspondence with others in foreign countries, may be able to render valuable assistance. Germany exploited this method to a great extent before the Great War, and there is little doubt that, as far as the continent was concerned, her activities in this direction stood her in good stead. It is particularly engineer officers who can assist, and, if only for practising themselves in making engineer reconnaissances, they would render their country a great service by always noting—and subsequently reporting—any engineer information that strikes them in the course of their travels.

   The names of individuals who are known to be familiar with certain localities should be noted, in order that reference may be made to them if information is subsequently required on any particular point.

3. Consuls and Attachés are in a position to collect much useful information concerning the country in which they are serving,

and its army. This source, however, should be approached delicately.

4. Foreign army text-books and training manuals are the surest means of ascertaining the methods of troops of foreign countries, and should invariably be studied carefully, if we are to be on guard against the actions of the enemy in war.

In war, the collection of intelligence is simplified in that the areas or armies concerning which we require information are defined, and we are able to concentrate our efforts. On the other hand, the results obtainable from all the above-mentioned sources will be considerably diminished: publications will be difficult to obtain, the activities of agents and communication with them will be very much more difficult, the third source will be non-existent and the fourth limited to documents captured in the course of fighting. In fact, we can hope for little more than to keep up-to-date the information collected in peace, which strengthens the contention that, if we are to be well served with intelligence in war, we must obtain it in peace and base our preparations on information so collected. The principal sources will be:—

1. *Aerial Reconnaissance.*—Though of no great value as regards details, a great deal of information regarding new works, railways and roads, fortifications, bridges, engineer stores and even telephone systems can be obtained from aircraft, and especially from aeroplane photographs.
2. *Refugees and Prisoners.*—A doubtful source, depending upon the knowledge, veracity and communicativeness of the examinee; but, if he is treated in the right way, very valuable up-to-date information can be extracted.
3. *Civil Engineers of Municipalities, Districts.*—If accessible, this source is of first-class value, as probably all engineer conditions of the locality will be known by these officials.
4. *Engineer Reconnaissances before, during and immediately after battle.*—This is a part of the ordinary duties of engineers and will be referred to later.
5. *Captured documents and works* take the place of peace-time training manuals and keep us up to date in development of the enemy's methods.
6. *Our troops' experiences.*—Just as in peace the study of engineering progress enables us to keep our methods, training and equipment up-to-date, so we must make use of the lessons learnt during the campaign. Developments, which cannot possibly be foreseen in peace, are sure to arise and these will cause us to modify our methods as we gain experience.

It has already been shown that equally important as the collection of intelligence is the collation, recording, indexing, revision and distribution of it. If it is to be of any use at all and justify the labour and money expended in its collection, intelligence must be readily available to the man on the spot where and when he requires it. In the final distribution there are three principal dangers to guard against; firstly, to avoid excessive secrecy and thus prevent information from reaching those who should be in possession of it; secondly, to avoid issuing in piecemeal form, badly indexed and therefore difficult of reference on any particular point; and thirdly, that information is not tucked away and lost sight of.

What, then, are the processes through which information transmitted to any responsible headquarters should pass?

1. *Sifting.*—The reports must first be reviewed and the useful portions picked out; that requiring confirmation and amplification must be noted. Technical experts should be referred to, as they only can say what is likely to be of use; the non-technical mind often does not appreciate the small details and clues which may make all the difference to an engineer.
2. *Collation.*—The relevant matter must then be arranged, reports on the same subject from different sources combined in concise form.
3. *Indexing.*—It is at this stage that the danger of losing track of information must be guarded against, by very careful recording and indexing. Only by this means is it possible to extract certain information when required for reference or for revision when corrections are received.
4. *Publication.*—In peace, information will normally be collected systematically and compiled for publication in book form, or on intelligence maps. In war, however, it may be necessary to supplement this by the issue of information as soon as possible after its receipt, in which case the preparation for publication would coincide with the second phase described above. For instance, certain information may come to hand just before battle, the publication of which would give our commanders valuable assistance in finding the enemy's "soft spots," or, as was often the case in the Great War, it was important to issue descriptions of German mine traps as quickly as possible in order that the engineers might be on their guard against similar devices. It will readily be seen that such piecemeal publication complicates records and indexing.

   The form of publication is important. There is little doubt that the most efficient form of issuing intelligence regarding possible theatres of war is on maps. The information stands out clearly and enables a picture of the country to be formed quickly in one's mind's eye, and, above all, hunting through indexes and pages is avoided. For large areas and detailed information, the cost and bulk of such maps would be prohibitive and information must be issued in book form (very well indexed).

Finally, there are pamphlets, circulars and plates issued from time to time. These must be very carefully numbered in series, according to the subject dealt with, for the convenience of the recipients and recorders. The form of publication requires careful consideration, and it should be remembered that large sheets of paper are inconvenient for binding and carrying, and are therefore often tucked away and forgotten. It is the duty of the compilers to reduce to a minimum the possibility of this danger by issuing their publications well numbered, and in form easily bound for reference.

5. *Distribution.*—The factors governing the scale of distribution are :—

(*a*) Everyone to whom the information may be of use must receive it.

(*b*) Too wide a distribution leads to lower formations and units being "snowed under," and consequently much is pigeon-holed and lost sight of when required.

(*c*) Much intelligence is of a highly confidential nature and its wide dissemination is most undesirable.

The weighing of (*a*) against (*b*) and (*c*) and decision as to the final distribution should rest with an officer of considerable experience, and, here again, it is essential that the advice of technical officers be taken regarding matters affecting their branch. A solution of the difficulty of avoiding excessive distribution is to issue lists of Intelligence publications, with brief summaries of their contents, to all who could possibly be concerned. These lists would then be filed with intelligence on connected subjects and the publication (map, book or circular) could be at once demanded when required.

The treatment of Intelligence generally has been discussed up to this point, and the special organization and treatment of Engineer Intelligence must now be considered. The principles on which to base our organization are :—

i. Technical efficiency.
ii. Economy.
iii. Equally applicable to peace and war conditions.

In the definition of intelligence put forward it has already been remarked that there are three main divisions : information concerned with foreign or enemy countries ; engineer practice and progress at home and abroad ; and that concerned with or available in our own territories.

In the case of Intelligence concerning foreign countries (which is the largest and most important division) it is impossible to draw a hard and fast line between Military Intelligence, as required by the General and Administrative Staffs, and Engineer Intelligence as required by the Royal Engineers; full information regarding roads, fortifications, water supply, rivers and other obstacles are equally important to one as to the other, though naturally the R.E. require greater detail in some cases, and it will be economical and efficient if the collection of such information is entrusted to one organization. Further, since the Intelligence branch of the General Staff possesses the machinery (intelligence agents) to do this, it is indisputable that all the groundwork of this portion of the collection be entrusted to them. A special engineer intelligence service could not justify its cost and, moreover, overlapping and the danger of " E " and " I " working in watertight compartments and not sharing the results of their labours would be sure to arise. This does not, however, relieve engineer staffs of the responsibility of informing " I " of any particular information which they require, giving advice as to particular points to be specially investigated, and suggesting sources of information. This necessitates the maintenance of a very close liaison between " E " and " I "; in fact, there should be one engineer officer detailed (either assisted by a staff or as part of other duties, according to the size of the formation and the volume of intelligence work dealt with) whose duty it is to review all information collected by " I " which could conceivably be of use to engineers, and to recommend the scale of its distribution. He will also be able to advise " I " as to points on which confirmation or amplification is required; for instance, it is not sufficient to know that so many wells exist in a certain place—we must know the yield and depth.

In war, too, this officer should be able to examine refugees and prisoners, or, if unable to do so, should give the intelligence officer very definite instructions as to the questions to be put to the examinee. He must have free access to all aeroplane photographs, and be expert in their interpretation, and through " I " inform the R.A.F. of any particular way in which he requires their assistance. Engineer staffs must give " I " very exact details of information they require from agents. For instance, in the case of masonry bridges, they must detail the measurements required: span of bays, number of bays, thickness of arch, width of roadway, dimensions of piers. The value of any technical information supplied in peace by engineer officers regarding foreign countries, to supplement that obtained from " I ", will now be readily recognized.

" I ", however, cannot be expected to judge of the value of technical information contained in books on foreign countries' engineer methods and organization, and it is the duty of engineer staffs to extract such information. This now forms part of the duties of the R.E. Board at the War Office and the machinery so set up could hardly be improved upon. It is for consideration whether the duty of translating foreign technical publications should devolve on "E" or "I"; though not strictly engineer work, it is desirable that an engineer officer should do this, as there is then less danger of misunderstanding technicalities.

Engineer intelligence regarding our own country, or territories occupied by our army in war, and of civil engineering progress falls in the province of engineer staffs. They only are in a position to know how and where such information they require is obtainable, and as it is quite distinct from the military intelligence required by the G.S., "I" is not concerned. In peace, this, too, is fully dealt with by the R.E. Board. In war one of the most reliable sources of information regarding local engineer matters are the civil engineer officials of occupied territories, and it is important that engineer staffs establish close touch with them. Even so, to supplement information from all other sources, engineer reconnaissances will be constantly made, and, particularly on an advance of our armies, one of the most important and primary duties of the R.E. is the execution of rapid and thorough reconnaissances. It is unnecessary to go into details, as the subject is fully dealt with in all engineer training manuals.

To sum up, the collection of engineer information regarding territories up to our own frontiers (or the firing line in war) and technical information extracted from publications is the duty of engineer staffs, and regarding all countries beyond our occupation, it is the duty of the intelligence staff.

In compilation and publication the dangers of duplication and lack of co-operation are even greater, and demand a still closer liaison between "E" and "I." To avoid these dangers, all intelligence including such engineer intelligence as is of use to the army as a whole, should be taken charge of by "I," while purely technical intelligence, as, for instance, geological or electrical information, is dealt with by "E." The "E" liaison officer, therefore, should see all information coming into "I's" hands and, conversely, all information obtained by "E" in their sphere of activities regarding fortifications or roads, and other such matters interesting the General and Administrative staffs, should be passed on to "I." The publication of information thus compiled should be guided by the same principles and it would appear advisable that purely engineer information regarding foreign or enemy countries and their armies, though collected by "I," should be issued by engineer staffs. Both staffs must know exactly what the other has issued and should include the other's publications in their own records and index; otherwise overlapping is bound to occur.

Attention has already been called to the necessity for " I " to consult engineer staffs on the distribution to R.E. commanders and units.

In the British Empire we are confronted with a particularly difficult problem. The defence of our scattered territories may involve us in operations in almost any part of the world; or, at all events, we cannot afford to remain in complete ignorance regarding the greater part of it. The most satisfactory and economical solution appears to be to relieve the Imperial Forces of the collection of as much as possible of the duty of collecting intelligence over this vast area by delegating to the headquarters of the military forces in India and the Dominions the responsibility for dealing with countries adjacent to them. This, too, is consonant with the increasing self-reliance of the constituent parts of the Empire. Uniformity of organization and methods, and a full interchange of intelligence is of paramount importance, and it is suggested that by these very means mutual sympathy in all matters affecting the relations, both civil and military, between the various governments would be strengthened.

A summary of the proposals for the organization put forward will be most clearly shown in tabular form. But, at a risk of calling forth an accusation of repetition, it is again pointed out that the essence of an efficient service of Engineer Intelligence lies in liaison between " E " and " I," and only by maintaining it shall we avoid finding ourselves in the lamentable state of lack of information in which we were placed in the early stages of the Great War.

Subject.	*Collection.*	*Compilation and distribution.*
Foreign Countries (*a*) General, including military engineer matters	" I," advised by " E."	" I "
(*b*) Technical	" "	" E "
Engineering progress and methods at home and abroad, military and civil.	" E," with any assistance possible from " I."	" E "
Engineering information and experiences in our own territories	" E," handing anything of interest on to " I."	" E "

As our standing army is reduced, so we can only ensure efficient action when necessity arises by improvements in organization, equipment and preparations to enable us to meet the most probable dangers. This can only be affected by constant experimental and intelligence work, such as is directed by the R.E. Board, progressing hand in hand, and any undue curtailment of expenditure on these activities would indeed be false economy.

MODERN ROAD ENGINEERING.

A Lecture delivered at the S.M.E., Chatham, on 9th November, 1922, by Mr. H. PERCY BOULNOIS, M.INST.C.E., F.R.S.I., *etc., etc.*

THE birth of Modern Road Engineering dates from the advent of self-propelled traffic, about the year 1890.

It was the outcry against dust, flung into the air by the fast-moving vehicles, that initiated the experiments and trials, with coal-gas tar and other compounds, which eventually resulted in a complete revolution in road construction.

It was found that, not only did certain compounds act as dust-palliatives, but that some of them, especially tar and heavy oils, possessed the quality of binding the materials of which a water-bound macadamized road is formed, thus preserving the surface against the wearing effect of traffic, but that it also sealed the surface and prevented the infiltration of water which, in some cases, is almost as damaging as the traffic.

The satisfactory results thus obtained led to the use of tar, or similar bituminous compounds, as binders instead of water and grit, which had been used since the days of Macadam and Telford. I shall speak of these methods later on, but before doing so I must deal with the question of tar-spraying in some detail, as this method of treating our road surfaces must continue for many years to come. Not only are the majority of the roads of the old water-bound type, but this method is also necessary, from time to time, on modern roads in order to keep their surfaces sealed.

In the early trials, to which I have referred, crude gas tar was heated and poured on to the road out of cans and then brushed over the surface with brooms or with squeegees, but now more scientific processes are adopted.

Dry weather is essential, as the least wet, or even damp, will prevent the adhesion, or penetration, of the tar or other compound. The whole object of the treatment would thus be defeated. Before the tar is applied, the surface of the road must be swept and cleansed of all dust, dung, caked mud, etc., any pot-holes, or irregularities of the road should be repaired and made good.

A final sweeping of the surface, with hair brooms, just in front of the tarring operations, is very desirable to ensure adhesion and penetration.

Crude tar contains ammoniacal liquor, light oils, naphthalene, and other impurities which must be removed before tar can be used for this purpose.

Much might be said as to the proper chemical composition of the tar, or other compound, but time will not permit. Suffice it to say that the late Road Board prepared, and issued comprehensive specifications on the matter which are published by Waterlow & Sons, of London Wall, E.C., and if any of you wish to study the question further I must refer you to them.

The application of the tar to the surface requires some skill, for, if too much is applied, it collects in puddles, does not dry off quickly, and so saturates the road that the tar will exude in hot weather and cause trouble. On the other hand, too little tar will not ensure proper penetration.

There are now numerous ingenious machines on the market which spray or spread the tar either by gravity or under air pressure of about 180 lbs. on the square inch. For the latter it is claimed that the tar is atomized and is thus forced into the interstices, thus securing proper penetration and also uniformity of spread. It is also claimed that, as the tar is delivered at a temperature of 250 degrees Fahr., the hot air mingled with the tar, under this pressure drives off any dust that may remain on the surface. Expedition is also necessary on account of the traffic, and some of these machines are capable of covering 1200 square yards of road surface a day, using from 4 to 5 gallons of tar per square yard of surface. Where there is any risk of polluting any stream, or river, with the tar, precautions must be taken to prevent it by stopping up any gullies or outlets with sacks or by other means. At one time it was thought that these bituminous compounds poisoned the fish, but recent investigations revealed the fact that this is not generally the direct cause, but that certain vegetation and animalculæ on which the fish feed, are killed, and thus the fish are starved. One other point, and that is that so long as horses use the roads precautions are necessary to prevent the road becoming slippery. This is generally effected by "dusting" the surface, after tarring, with sand or other suitable material, of about $\frac{1}{8}$ to $\frac{1}{4}$-inch gauge. Some road engineers contend that this practice is detrimental as the particles of sand, or other material, are forced, by the subsequent traffic, through the skin of tar, thus breaking the seal and letting in the water. On the other hand, this "dusting" helps to dry off the tar, forms a thicker skin, and prevents the surface becoming slippery. Some judgment is therefore necessary, though on steep gradients it is advisable to practise this dusting. Having thus far dealt with what may be called the temporary improvement of the surface of roads, I will now turn to some of the problems which confronted the road engineer when the extraordinary revolution in the traffic took place.

The permanent way engineer of a railway knows exactly what is expected of his road, he knows the weights and speeds of the various trains. He is fully cognisant of the behaviour of his rails, their composition, design, and construction, to meet his requirements, and, as a rule, he is not handicapped by want of funds. The road engineer, on the contrary, entered into a hitherto unexplored region of engineering with little to guide him. He found the existing roads incapable of standing up against the altered traffic. How were they to be reconstructed, or strengthened? For what weights and speeds should provision be made? What materials should be selected for their reconstruction or repair? What was to be done about the acknowledged weakness of most of the roads, and what could be done with their bad foundations? Should the roads be widened, and, if so, to what extent? How were awkward corners to be dealt with? And last, but not least, where was the money to come from?

These and other problems confronted the County, Municipal, and Local Surveyors throughout the country and manfully they were tackled, although the Great War sadly hampered their efforts. Dealing shortly with some of these problems, it was found that the dynamic shock of a self-propelled vehicle is greatly increased by the speed at which it travels. In addition to this it was found that there was a brushing, or scouring, action on the surface of the road by the pneumatic tyres of a car travelling at high speed, or in changing speed, and also a side, or lateral push, of the wheels in turning corners. It was discovered that the vibrations set up by a car produced a movement amongst the stones, of which a road is formed, to a considerable depth. This movement caused inter-attrition of the stones, thus rounding them off, and preventing the interlocking, or binding, of the materials of which the road is formed. This showed that even the submerged materials required some thicker, and more resiliant, binding material than water and grit. This quality was found in the bituminous compounds of which modern roads are now constructed. It was soon observed also that fast motor traffic tended to produce ruts, as the drivers preferred the centre of the road for purposes of safety against vehicles emerging suddenly from side roads, etc.

Other questions arose affecting the wear of roads, such as the proportion of the width of tyres to diameter of wheels, the damage caused by metal tyres, especially those fitted with diagonal bars, and also the squeezing effect of twin rubber tyres. The "wabbling" motion of heavily loaded trailers was also found to cause some damage.

All these questions, and others, were carefully studied and investigated, with beneficial results.

With regard to width of roads, as affected by the altered traffic, in the horse-drawn vehicle days the best width of the carriage-way was found to be a multiple of 8 ft., as in that width vehicles could safely pass each other. The Bye-Laws regulating the width of new streets fixed the minimum width at 36 ft., of which 24 ft. was carriage-way with a 6 ft. footpath on each side. Modern traffic, however, requires greater width, not only on account of greater speeds, but also because the width of some vehicles has increased to 7 ft. 6 in. over the axles, and consequently the multiple should be raised to at least 10 ft. The new arterial and trunk roads, now in course of construction, are, some of them, being given a width, between the properties on each side, of 100 ft. divided as follows: two carriage-ways of 30 ft. divided by a strip 20 ft. in width (to be ultimately utilized for a tramway or planted out with trees and shrubs) and a foot-path 10 ft. in width on each side of the whole road.

Intersections of roads and corners require special treatment with the object of securing liberal space and a clear view for the drivers. In order to minimize the effect of the lateral thrust of motor-cars at corners, it is now the practice to give a super-elevation of the road on the outside edge, the same formula being used as that on railways, the speed being assumed at 50 miles per hour.

Gradient is not of so much importance as formerly, as most self-propelled vehicles make light of hills. In the case of impervious surfaces, however, the gradient should not exceed 1 in 18, on account of slipperiness.

The question of camber is important. As a rule the camber is excessive on our roads, and in some cases even dangerous. The object of camber is merely to secure a proper "run off" of the water, so that with modern impervious surfaces the camber may be considerably reduced from that which was necessary with comparatively rough surfaces. My own opinion is that the following gradients for camber would be now sufficient:—

Natural Rock Compressed Asphalt ...	1 in 60
Wood Pavement	1 in 50
Granite Setts	1 in 45
Tar Macadam, etc.	1 in 40
Tar-sprayed Macadam	1 in 40
Ordinary Water-bound ditto	1 in 36

A good deal might be said about the importance of the foundation of roads and the necessity of thorough drainage of the base, etc. Also as to the need of supporting the haunches with kerbs, submerged concrete walls, large stones, or other means to prevent the lateral spreading of the road, but time will not permit.

I will now pass on to deal with some of the modern methods of road construction which have been introduced to meet the requirements of which I have spoken.

These may be enumerated as follows :—

1. Pitch Grouting.
2. Tar Macadam.
3. Tar Slag.
4. Asphalt or Bituminous Carpets.
5. Unsurfaced or Bare Concrete.

1.—Pitch Grouting.

This method may shortly be described as follows :—

Ordinary broken macadam, of suitable gauge, is laid on a consolidated road after hacking, or on a newly constructed hand-pitched foundation, and rolled to a consolidated thickness of 2½ in. to 3 in. A hot tar or pitch mixture is then poured over the surface and brushed into the interstices. Care must be exercised to see that the stones, to a depth of at least 1½ in., are absolutely dry. This used to be done by hand buckets, or cans, pouring the tar on to the road, but is now effected in a more certain and expeditious manner by a tar-boiler on wheels delivering the hot mixture direct on to the road. There are a number of "recipes" for the pitch mixture, but generally it consists of carefully prepared tar, pitch, and creosote oil, heated to about 300 degrees Fahr., to which is added heated dry sand in such proportion as will allow the mixture to flow readily into the stones so as to come up to within ½ in. of the surface. The road is then sprinkled with small stone chippings whilst light rolling proceeds. Care is necessary with this method of construction or failure will follow, due to faulty mixture, faulty "cooking," dampness of the surface or stones, insufficient penetration, too rapid cooling and setting of the "mixture," or the unsuitability of the stones for proper adherence.

2.—Tar Macadam.

This may be taken as the earliest form of modern road construction. Broken stones were heated on thin iron plates supported on low sleeper walls with a fire underneath, the stones being turned over with hand forks until thoroughly dry and hot. Then hot tar was added and the mass was turned over and over, until each stone was coated with tar. This was then carted to the road, spread on it, and rolled to the required thickness. Modern machinery effects this process in a much more satisfactory and expeditious manner, ensuring proper proportions, thorough coating of the stones, and proper temperatures.

The late Road Board prepared some General Directions for Surfacing with Tar Macadam which I don't think were published, the main points of which are as follows :—

The road should have a proper foundation, or sub-crust.

The consolidated thickness of the tar macadam should be not less than three inches, according to traffic requirements. For a greater thickness it should be laid in two coats.

The aggregate should be composed of broken stone of approved quality and consist of 60 per cent. of 2-in. standard gauge, 30 per cent. of 1½-in. standard gauge, and 10 per cent. of ¾-in. to ½-in. chippings should be used for filling the voids during rolling operations. In the case of two-coat work the sub-crust should consist of 2-in. standard gauge stone, the wearing surface of 1½-in. ditto with 10 per cent. of chippings as before. The stone to be absolutely dry. The tar to be in compliance with the Board's Specification Tar No. 2 and be heated in a boiler specially designed to prevent frothing, which inevitably occurs if the tar contains even a small percentage of water. The desired temperature is generally found to be between 260 degrees and 280 degrees Fahr. in the boiler or heater. The quantity of tar used to coat one ton of stone varies from 9 to 12 gallons, according to the gauge of the stone and method of mixing. Less rolling is required than for a water-bound macadam road; a 10-ton roller is ample for the purpose. After the road has been subject to the traffic for some weeks it is advisable to apply a coating of about one gallon of tar to every 6 super yards of road surface, sprayed on at a temperature of about 270 degrees Fahr. For gritting it is recommended that stone chippings, crushed gravel, coarse sand, or other suitable material, free from dust, not larger than will pass through a ¼-in. square mesh, should be used. It is further recommended that the tar should be tested by a qualified Analytical Chemist before being used.

3.—TAR SLAG.

Selected Furnace Slag is an excellent substitute for the manufacture of Tar Macadam. It must, however, be carefully selected; the most suitable is said to be that which contains about 40 per cent. lime, 40 per cent. silica and 20 per cent. alumina. It should weigh not less than 25 cwt. per cubic yard and have as little honeycombed appearance as possible. There is an excellent material of this description on the market known under the trade name of "Tarmac." In this case the slag is taken direct from the furnace, allowed to cool to a certain temperature, then broken to suitable sizes, and whilst at this temperature is plunged in hot tar.

It is claimed that as the slag is taken direct from the furnace it is perfectly clean, that the intense heat has reached the very centre of it without damaging the structure, that every drop of moisture has been driven out of it and that the tar has entered all the crevices and voids.

Mr. Purnell Hooley, the late County Surveyor of Nottinghamshire, is the discoverer of this method which he patented. It proved so successful that there are now many miles of this method of construction all over the country.

4.—Bituminous Carpets.

I believe I ought to call these *Asphaltic* Carpets, as modern nomenclature has reversed these names; what I have always known as Bitumen is now called Asphalt, and *vice versa*. However that may be, this description of road surfacing is the most modern of any system that has yet been introduced. It may shortly be described as a fairly thin coat of a very carefully-graded mixture of sand, pulverized stone, or powdered mineral matter, and specially prepared bitumen, carefully mixed together in pre-arranged proportions at certain temperatures. When finished it appears to approach the composition of natural rock asphalt. The grading of the sand, or other materials, and the proportions, require great care, and they must be absolutely clean, dried and heated to a certain temperature, generally about 330 degrees Fahr.

Time will not permit me to give you the numerous "recipes" that exist for the manufacture of these carpets, but the following will give you some idea of the care necessary in proportioning the various sizes of the materials:—

In this case the material was sand.

10·7	per cent.	passing	100	mesh	sieve.
15·7	,,	,,	76	,,	,,
45·7	,,	,,	50	,,	,,
10·0	,,	,,	40	,,	,,
10·6	,,	,,	30	,,	,,
4·6	,,	,,	20	,,	,,
1·5	,,	,,	10	,,	,,
1·2	,,	,,	10	,,	,,

A "filler" of either Portland Cement, or fine dust of a mineral nature, was added to the extent of 9 per cent., and to this was added 13 per cent. of bitumen to 78 per cent. of the mixture.

This description of road surfacing is generally laid in two coats, the lower one being made of rather coarser material than the upper, but the total thickness of the two coats, when consolidated by rolling, rarely exceeds three inches.

The selection of the bituminous, or asphaltic composition, requires great care, and consequently a number of tests are made before selection. These are carried out with special instruments designed for the purpose. It would take too long to describe the process of these tests and the interpretations to be gained therefrom, but you may judge of the amount of laboratory work involved by the following list of some of the tests that have to be made :—Specific gravity; solubility in carbon disulphide; viscosity; determination of the fixed carbon; evaporation; the melting point; the flash and burning points; ductility; and toughness. If any of you require further information as to the instruments to be employed I must refer you to "*The Testing of Tars and Pitches for Roads*, by John Hutchinson, to be obtained at the offices of *The Surveyor*, 34, Bride Lane, E.C.4.

It is not everyone who has the time or knowledge to make these tests or the necessary machinery for the manufacture of these carpets, but fortunately various materials or compounds can be obtained under trade names which are thoroughly reliable and meet all the requirements for the construction of good roads.

Before passing on to concrete roads, a few words are necessary with regard to waves and corrugations which so frequently appear on the surface of bituminous roads after a short spell of traffic. These deformations are sometimes attributed to the action of the rollers, especially if too heavy; others contend that variations in temperature are the cause, or that the fault lies with the material or method of laying; others, that it is caused by the rhythmic action of the motor traffic, in the same manner that the wind produces waves on the sea. No doubt there are many contributory causes and that, as observations are made, these will be discovered and a remedy found. My personal view is that the initial rolling is the primary cause, and that careful cross-rolling with lighter rollers will go far to prevent this blemish.

5.—Unsurfaced, or Bare Concrete.

Although this description of road has been made in America and Canada for many years it has not found much favour here for various reasons.

Objections were raised as follows :—

The necessary diversion of the traffic for three or four weeks whilst the concrete is setting; the hard character of the surface causing noise from metal tyres and jarring of horses' hoofs; its liability to crack when laid in monolith; the difficulty of opening up for the laying of gas, water, or other pipes, especially if the concrete is reinforced; the liability to become dusty; the careful and constant supervision necessary during construction to secure satisfactory results; doubts as to its length of life, as this method of construction is too recent to form an opinion.

As I have been a rather persistent advocate of concrete roads, I will deal with these objections.

Undoubtedly, concrete must be allowed three or four weeks to set before traffic is allowed on it, but arrangements can often be made to divert the traffic, and judgment is necessary in selecting the neighbourhood for this description of construction. Concrete is not intended to supersede other systems, but only as a substitute where found desirable. As to noise, I think that metal tyres will gradually disappear and no doubt horses will become scarcer on our roads. With regard to cracks, these can be absolutely abolished if the concrete is made, and laid, by machinery to a rigid specification. As to the difficulty of breaking it up, it is exactly the same with all paved streets with concrete foundations, the recent introduction of pneumatic drills has considerably reduced the labour and cost of this operation. As to dust, if this is feared, it is easy to tar the surface and thus prevent it. With regard to the care and supervision necessary, it is perfectly true that unless this is exercised failure will follow · I am, however, often struck with admiration at the wonderful manner in which concrete behaves after the careless manner in which it has been made and laid. A rough banker of boards, on which it is mixed with inferior cement, recklessly proportioned; the aggregate of gravel, or broken stones, probably not very clean, the water slopped on in too abundant quantity, as the wetter the concrete is the more easily does it slide off the shovel. If concrete can stand such treatment and yet behave as it does, it is evident that with skilful treatment much more may be expected of it.

Time will not permit me to give you a specification of the right manufacture of concrete for road construction, but if you desire further information on the subject I must refer you to my recent book entitled *Modern Roads*, published by Edward Arnold. There are now concrete-mixing machines on the market by which the proper proportions of the ingredients, aggregate, cement, and water are absolutely secured, as well as thorough blending. Concrete should be placed *in situ* as speedily as possible after mixing. A bed of dry ashes, or similar material from 3 in. to 4 in. in depth should be placed on the surface of the excavated ground on which the concrete road is formed; this prevents the adhesion of the concrete to the soil and minimizes one of the chief causes of cracking. After the concrete is laid, finished off and screeded, it should be protected for some weeks by a covering of canvas sheets, or 3 in. or 4 in. of earth, saturated with water, in order to prevent too quick evaporation. Reinforcement is desirable where heavy traffic is anticipated or the ground is treacherous. It distributes the unequal pressures of the weights and consequent shocks and stresses due to the moving loads. It also assists in preventing cracks and so strengthens the concrete that less thickness is required, thus saving material and excavation. (Here the lecturer showed a model of the Walker Weston method of reinforcement and explained it.)

As to the last question, that of probable length of life, we have not at present much to guide us, but I know a road in Kent, constructed about eight years ago, in a rather perfunctory manner, during bad weather, and adverse traffic conditions, which has received no repairs and yet appears to be in practically the same condition as when constructed, though subjected to very heavy traffic. Look also at some of the, so-called, artificial concrete flags laid on foot-paths which last as long, or longer, than York or other natural stone flags. I have walked on a promenade paved with Purbeck marble where the foot traffic had so worn this hard stone that the cement joints stood up like knife-edges, at all events, showing that cement had worn better than this stone.

With regard to other forms of road construction: improvements have been made in granite setts so that they can be laid closer together owing to more careful dressing, thus reducing noise, the bugbear of this class of pavement.

Durax, or small stone cubes, have been laid with varying success, but do not appear to stand against heavy traffic unless laid on concrete, which considerably adds to the cost, so that ordinary setts might just as well be used. Soft wood creosoted blocks still hold their own as a good street pavement, when laid on a sufficiently strong concrete foundation, and it is difficult to see where a substitute is to be found. There is some talk of rubber, but the excessive cost is against it and also the difficulty of getting it to adhere to any foundation. (Here the Lecturer showed samples of the "Gould Rubber Block," but said the cost was at present too great for practical road-making.)

I have said but little, in my lecture, about the numerous and varied machinery and plant now required in modern road construction, but such a subject would require a lecture in itself to do it justice.

I have endeavoured, however, to show you how Modern Road engineering has altered in the last few years. Much has been done in the past, but much remains to be done in the future. Engineering knows no finality and advances in science and practical application go hand in hand. It has been wisely said that "When an Engineer ceases to learn, he ceases to be an Engineer." This is perfectly true, for after a long and strenuous life of engineering I begin at last to realize my ignorance.

I will now show you a few slides to illustrate some of the points of my lecture and then, through the great courtesy of the Limmer & Trinidad Lake Asphalt Company, you will be shown a cinematograph illustrating the digging of the bitumen out of the celebrated Trinidad Lake, and following up the various processes of refining and preparation of the bitumen, its final spreading, rolling and completion, and the traffic such roads have to bear.

The following is a list of the slides shown on the Screen and explained by the Lecturer :—

1. Type of pressure tar-spraying machine.
2. Type of gravity tar-spreading machine.
3. Spreading tar with hand-pressure machine.
4. The same machine showing horse quickly liberated in case of fire.
5. Detail of hand-spraying pump.
6. Type of trailer gritting machine.
7. Tar boiler grouting machine.
8. Midget patching outfit.
9. Double drum drying plant for tar macadam.
10. A quick reversing steam roller (6 tons).
11. A 7-ton petrol roller.
12. Pneumatic drill picking up bituminous road surface.
13. Ingersoll drill breaking up concrete.
14. The same, showing work in Ludgate Circus.
15. Type of handy air compressor for above drills.
16. " Aero " concrete mixer fitted with " caterpillar " wheels.
17. Type of complete plant, mixing concrete, and laying it on the road, with moving template and screeds.
18. Detail of the above template.
19. A complete concrete road in America.

A METHOD OF SETTING LOCOMOTIVE SLIDE VALVES.

By Lieut. H. G. POTTLE, M.C., R.E.

THE writer of this article, having completed a railway course, mainly on the mechanical side, with one of the leading railway companies in the country, had many opportunities of studying the method adopted by this company for setting locomotive slide valves. Many readers will probably know the method about to be described, but it is hoped that there will be others who do not know it, or at any rate, some of its features. To the latter the following description may prove interesting and perhaps useful, especially as the method can easily be adapted for setting slide valves of stationary steam-engines.

For the sake of clearness and simplicity, the method of setting the valves of that very common type of locomotive—the twin inside cylindered, fitted with the ordinary "D" slide valves and Stephenson's link motion—will be described.

The method can be divided into five distinct operations:—

1. Finding the points of "cut-off" of the valves.
2. Finding the maximum port openings.
3. Recording the port openings.
4. Calculating and making the adjustments to equalize the port openings.
5. Trying over the valves to see if they are set correctly.

1.—FINDING THE POINTS OF "CUT-OFF" OF THE VALVES.

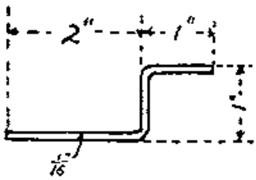


FIG. 1.

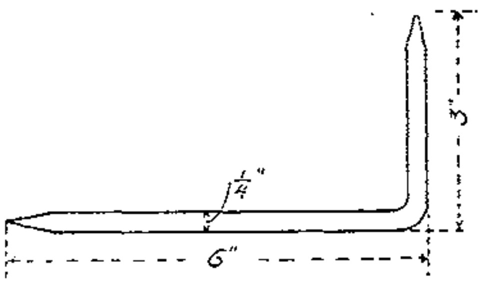


FIG. 2.

The "cut-off" points are found for each of the two valves separately, and to do this a piece of mild steel, about 3 in. long, 1 in. wide and $\frac{1}{16}$ in. thick, is shaped as in *Fig.* 1. This is called a valve stop. A one-legged mild steel trammel, about 6 in. by 3 in., with sharp points, case-hardened for preference, is also made (see *Fig.* 2).

Taking each valve separately, the valve spindle is disconnected from the intermediate spindle, and the front steam chest cover is removed. The valve stop is inserted in the front steam port, and the front edge of the valve is rammed hard up against it as in *Fig.* 3. A centre pop mark is made in a convenient position on the back of the cylinder casting, and one point of the trammel inserted in it, while with the other point a mark is scratched on the spindle at A (see *Fig.* 3). A centre pop is then made on this mark. This gives the " cut-off " point for the front port.

The valve stop is released and inserted in the back steam port, and the back edge of the valve rammed hard up against it as in *Fig.* 4. The trammel is used as before, and the " cut-off " point for the back port is obtained at B (see *Fig.* 4). The distance between A and B ought to be twice the outside lap of the valve plus twice the thickness of the valve stop.

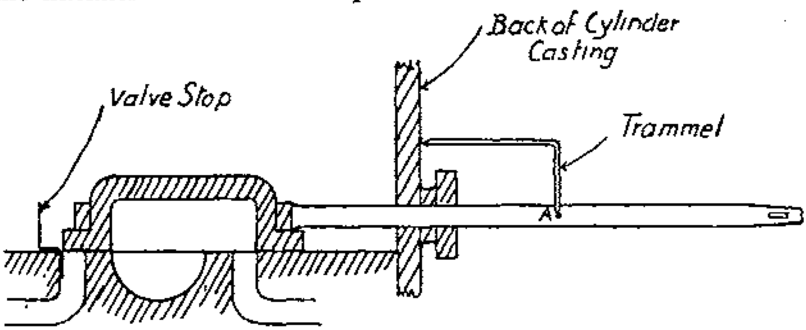


FIG. 3.

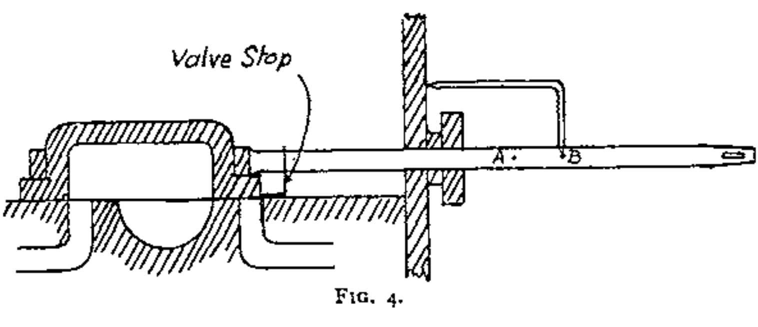


FIG. 4.

2.—FINDING THE MAXIMUM PORT OPENINGS.

Taking each valve in turn, the valve spindle is connected up to the intermediate spindle. The front steam chest cover can be replaced as no further work needs to be done inside the steam chest.

The reversing lever is placed in the usual running position in fore-gear, say in the notch corresponding to a 50 per cent. cut-off. The engine is then slowly moved forward with the aid of pinch-bars used between the wheels and the rails. It is very desirable to do this over an ashpit, so that more room is available in which to work. A suitable position having been taken up inside the motion of the engine, the trammel is held in position as in *Figs.* 3 and 4, and as the pop mark at A on the valve spindle passes the point of the trammel on its *outward* journey, *i.e.*, *away* from the cylinder casting, scratches are made with the point of the trammel from side to side on the valve spindle, stopping when the spindle commences its return journey (see *Fig.* 5). A moment's thought will show that the distance from A to the last scratch at C (*Fig.* 5) gives the maximum opening of the front port.

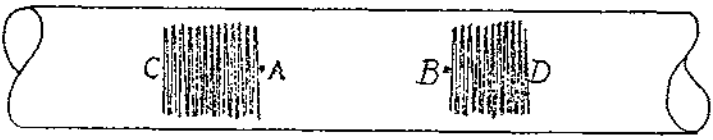


FIG. 5.

Attention is now transferred to the pop mark at B. As this point passes the point of the trammel on its *inward* journey, *i.e.*, towards the cylinder casting, scratches are made on the spindle as before, stopping when the spindle commences its return journey. The distance from B to the last scratch at D (*Fig.* 5) gives the maximum opening of the back port.

Actually the thickness of the valve stop should be added to get the correct port opening in each case, but as it is the *difference* between the front and back port openings that is required, the thickness of the valve stop need not be taken into consideration.

With practice, instead of finding the port openings for one valve and then repeating the operation for the other valve, the port openings for both valves can be found in one operation, thereby saving time and lessening the distance the engine has to be moved with the pinch-bars. From the position of the eccentrics, and from the fact that the engine has its right crank or left crank leading, it can be found which port will open first, and the order in which the other three ports will open. By transferring the trammel quickly from one valve spindle to the other, and back again, as the ports begin to open, the whole operation can be completed in just over one revolution of the driving wheel.

The reason why the reversing lever is placed in the usual running position—in this case it has been taken as the notch corresponding to a 50 per cent. cut-off—is that, in Stephenson's link motion, owing to the angularity of the eccentric rods, the front port opening becomes smaller than the back port opening as the lever approaches mid-gear and *vice versa*. Therefore it is advisable to make certain that the port openings are equal when the lever is in the position in which the engine does most of its work.

The maximum port openings of the four ports in fore-gear have now been obtained, and with a pair of fitter's spring dividers these are transferred to the plate shown in *Fig.* 6. This plate will be described in detail later.

The reversing lever is now placed in its running position in back gear, and the engine moved backwards. The scratches on the valve spindle are erased with emery paper, and the process of finding the maximum port openings is repeated. These four port openings in back gear are likewise transferred to the plate (*Fig.* 6).

3.—Recording the Port Openings.

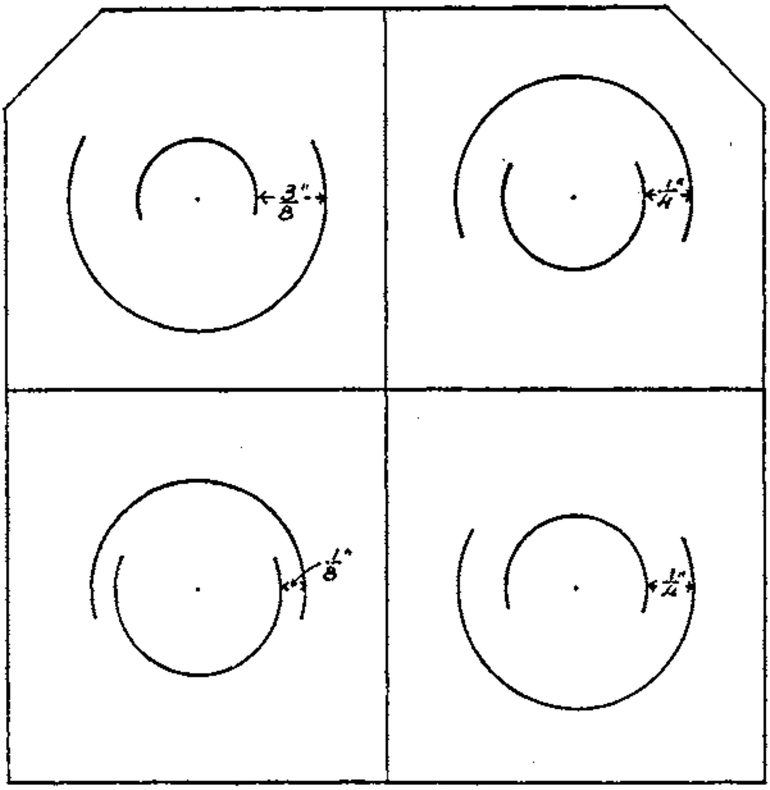


Fig. 6.

Fig. 6 shows a piece of tin plate, 4 in. × 4 in., with two of its corners cut off. The plate is divided into four parts, and a small centre pop mark made in the centre of each quarter. The port openings obtained on the valve spindle are transferred to this plate with a pair of dividers, by describing incomplete circles, the radii of which are equal to the port openings. In each quarter of the plate, the upper incomplete circle denotes the front port opening, and the lower incomplete circle the back port opening.

Now the top right hand quarter represents the port openings of the right valve in fore gear, the top left hand quarter the openings of the left valve in fore gear, and the two bottom quarters represent the port openings of their respective valves in back gear. Remembering this, it is quite an easy matter to transfer the respective port openings from the valve spindle to their correct positions on the plate. The corners of the top edge of the plate are cut off to denote that this edge represents the front end of the engine. The plate thus gives a complete representation of the maximum port openings of the two valves in both gears, and the difference between the openings can be measured from the plate itself.

4.—CALCULATING AND MAKING THE ADJUSTMENTS TO EQUALIZE THE PORT OPENINGS.

The plate in *Fig.* 6 is a representation of an actual plate obtained in practice. For the sake of clearness it will be as well to take each set of port openings separately to show how the adjustments are calculated and made.

The top right hand quarter, *i.e.*, the port openings of the right valve in fore gear shows the front part *larger* than the back by $\frac{1}{4}$ in. Therefore the right foregear eccentric rod must be *lengthened* by half this amount, *i.e.*, by $\frac{1}{8}$ in. This will have the effect of closing the front port by $\frac{1}{8}$ in. and opening the back port by the same amount, giving the two ports an equal opening of $\frac{1}{2}$ in., since the original measurements are $\frac{5}{8}$ in. and $\frac{3}{8}$ in. respectively (see *Figure*).

The bottom right hand quarter, *i.e.*, the port openings of the right valve in back gear, shows the front port *smaller* than the back by $\frac{1}{4}$ in. Therefore the right back gear eccentric rod must be *shortened* by $\frac{1}{8}$ in. This will have the effect of opening the front port by $\frac{1}{8}$ in. and closing the back port by the same amount.

The top left hand quarter, *i.e.*, the port openings of the left valve in fore gear, shows the front port smaller than the back by $\frac{3}{8}$ in. Therefore the left fore gear eccentric rod must be shortened by $\frac{3}{16}$ in.

The bottom left hand quarter, *i.e.*, the port openings of the left valve in back gear, shows the front port larger than the back by $\frac{1}{8}$ in. Therefore the left back gear eccentric rod must be lengthened by $\frac{1}{16}$ in.

The length of the eccentric rods are altered by handing them over to the blacksmith, who " draws them out " or " jumps them up " as the case may be, or metal liners of the requisite thickness are inserted or removed from the joint between the eccentric rod and strap. A point against the latter practice is that there is a possibility of the liners falling out when the engine is in service.

It must be mentioned here that with a new engine, which is having its valves set for the first time, an allowance is made, in calculating the adjustments, for the fact that the engine settles on its springs after a while. In an engine with inclined cylinders this settlement causes the valve to move forward in the steam-chest. To compensate for this the maximum front port opening is made $\frac{1}{16}$ in. larger than the back, so that when settlement has taken place the port openings are approximately equal. In an engine with horizontal cylinders the movement of the valve is in the opposite direction, so the front port is made $\frac{1}{16}$ in. smaller than the back.

5.—Trying over the Valves to See if They Are Correctly Set.

After the eccentric rods have been altered they are put up, and the process of finding and recording the maximum port openings is repeated. If the adjustments have been made correctly, it is found that the second plate shows the circles in each quarter practically coinciding. In the case of *Fig.* 6 they would all have a radius of $\frac{1}{2}$ in. showing that the maximum port openings have been equalized. A difference of $\frac{1}{32}$ in. or less is negligible. If the valves were very much out in the first instance, however, it is often found necessary to make a second series of adjustments, because a large alteration in the length of one eccentric rod would to a certain extent affect the other rod controlling the same valve. This series of adjustments is made in exactly the same manner, except, of course, that the "cut-off" points are already found, and it is therefore not necessary to remove the front steam-chest cover.

Setting Valves to Give Equal Lead.

To use the above method to set valves to give equal lead, the four dead centres are found in the usual manner by trammelling from engine frame to wheel rim and marking the slide-bar and crosshead. The engine is then placed on each dead centre in turn and the port opening in this position is marked on the valve spindle with the trammel as before. These port openings are, of course, the required leads. They are transferred to the plate and equalized in exactly the same manner as already described for equalizing the maximum port openings.

Opinions differ as to whether it is better to set valves to give equal maximum port openings or equal leads. The former method, which has been described in detail, and which was generally adopted by the railway company the writer was with, has the advantage that both ports give the maximum opening when the piston is moving at its maximum speed, and the admission of steam does not tend to be strangled at one end. Also the method is much quicker, as the dead centres have not to be found, and in a locomotive running shed, where time is a valuable factor, this is an important consideration. On the other hand, if it is found that there is very unequal compression at each end of the piston stroke, the valves have to be set to give equal lead, and the equality of the port openings has often to be sacrificed to enable this to be done.

In conclusion, the writer considers that the method described above is better than the method of finding the port openings by direct measurement or by the insertion of wedges. Owing to the restricted space in the average steam-chest, the back port is not very accessible. While there is usually enough room to get a hand in and insert the valve stop shown in *Fig.* 1, there is not enough room to hammer in a wedge or to take a direct measurement, and in consequence the port openings cannot be measured so accurately. Also by the use of a plate, as in *Fig.* 6, the state of the valves can be seen at a glance, and much more easily than they could be if the readings were tabulated on paper. The method necessitates a somewhat long and detailed description, but in actual practice it proves to be quite simple and gives very satisfactory results.

THE NEW MAP OF EUROPE.

A lecture delivered at the S.M.E., Chatham, on 16th November, 1922, by FRANK J. ADKINS, M.A. *Camb.*

SINCE frontiers enter so largely into this subject, a few words about frontiers in the abstract are, perhaps, worth while by way of introduction.

Good frontiers provide actual barriers, or No Man's Lands, between states, *e.g.*, the sea, a mountain water-shed, marshes. Bad frontiers, on the other hand, are those purely arbitrary and ever-shifting lines traced by successive peace treaties (the straight-lined frontiers one sees so often in the New World have as their original an old line drawn by the Pope between Spanish and Portuguese Brazil). A river-line is not a good frontier. Bridgeheads are required beyond it ; and, moreover, it divides an area which has been united by Nature : namely, the basin drained by the river. The redrawing of frontiers always intensifies the difficulties of irredentism of the minority left on the wrong side of the frontier, and trying to rejoin the majority. No frontier can be so drawn as to make clear divisions. If a process of exchange of holdings and sorting out on both sides of a given frontier can be organized, greater stability is likely to result. Lastly, frontiers which cut up economic units and separate mutually dependent and complementary areas are obviously sources of future trouble.

Turning from the unsatisfactory fringes of States, let us now consider the nature of the growing principle by which States have been formed from their original nuclei. The habitable land of a temperate area like Europe is of two kinds : either the low-lying and originally tree-covered valley of a river, or else the grass-covered uplands of the watersheds and plateaux. These two sorts of land attract two types of man. The valley forests are gradually cleared by the settlers ; the upland grass-lands are the grazing grounds of the nomads. The settlers, in the course of generations, clear the forests to the watershed and, following the river course, reach the sea at its mouth—as the Poles did along the course of the Vistula long before the Brandenburgers conquered Prussia. The settlers are the builders-up of Nationality based on agriculture and held together by a common language and customary law. We might imagine, therefore, that national areas, undisturbed and developing under ideal conditions, would coincide with river basins, and national boundaries follow watersheds. But such undisturbed development is never found. The lowland settlers are frequently raided by the more vigorous of the nomadic peoples, whose incursions, though destructive for the moment, are also, in the long run, stimulative to the slowermoving settler type. Where fusion of the two has taken place, a more energetic race has, as a rule, resulted. But frequently such fusion has not occurred and thus we find, in most parts of Central and Eastern Europe, two distinct types intermingled: the settler agricultural peasant, and the ruling class descended from the original nomads; and in particular from those blue-eyed, light-haired Nordic nomads of Scandinavian type who play so large a part in the history of Europe. Lastly, in so far as a middle class of traders and professional men exists in these parts of Europe, such a class is supplied from a third source: the alien or Jew. The fusion of these contrasted types is a difficult business; and nationality, as we know it in Western Europe where definitely French, English, Dutch, Swiss, Belgian, Spanish nations are to be found—even in spite of mixture of languages as, *e.g.*, in Belgium and Switzerland—becomes progressively more hard to determine as we move eastwards across Europe

I propose, therefore, to leave out of account the whole of West Europe. Such changes as the French recovery of Alsace-Lorraine belong to another category from the changes in Central and Eastern Europe and I do not propose to plunge into the Empire of Charlemagne and the Partition of Verdun to trace the varying fortunes of that No Man's land between France and Germany—Lothar's Kingdom, Lothringen or Lorraine—which becomes one of the chief battle lines of the Continent.

On the East my subject is also limited. Europe is really one of the peninsulas of the great mass of Asia; and Europe of the Sea may justly be regarded as springing from the Continental mass along the line which now forms the Western boundary of Russia. Russia is now geographically Asiatic: perhaps, also, its outlook tends to become increasingly Asiatic. At any rate, I exclude Russia from this lecture.

In studying the remainder we have first to note the influence of the two great inland seas, the Baltic and the Mediterranean, on the land mass. The Finnish movement southward gives us that fringe of non-Slav peoples along the Eastern Baltic which has crystallized into the new states of Esthonia, Latvia, Lithuania; while the earliest rule in Russia was that of the Swedish house of Rurik which at one time extended as far south as Kieff: a notable example of Nordic domination of the Slav.

The Mediterranean influence has been more profound. Rome and Constantinople, capitals of the Western and Eastern Empires, became the civilizing centres whose influence, chiefly religious, spreads throughout the Continent. Even Protestant Europe is only Reformed Roman: while the Russian Church is but a branch of the Orthodox Church which still centres in the Patriarch of Constantinople. In between the two Churches, occupying the Ukraine (Ruthenia) and Transylvania, we find the Uniate Church, Orthodox in form but acknowledging the Pope. Further, to Rome we owe those conceptions of Law and Union which express themselves later as the Holy Roman Empire, International Law, etc. The Pax Romana may be compared with the League of Nations; and W. T. Stead used to advocate the re-establishment of the arbitration powers of the Pope. Lastly, Roumania is in a sense Roman: ancient Dacia, with a language moulded on Latin lines.

We can now turn to that portion of Europe which lies between Russia and the Rhine, and across this area I wish to draw yet another line: a line running due North from Venice. I wish, for the purposes of this lecture, to regard this line as marking the Westward limit of the Slavs, for it is about the Slavs that I am chiefly concerned this evening. Whether the words Slav and Slave are connected or not, the Great War may be regarded essentially in its results as the freeing of the Slav and the re-establishment of those ancient States which existed in Europe before the empires based on Teutonic or Turkish domination were built up out of them. If, then, we can imagine the Slav as spreading originally over the whole of Europe east of this line, we have the basis we need. But, as I have said already, this basic mass of peasants is subject to penetrations, and it is these penetrations that we now have to trace.

The first is the Teutonic penetration which, in the guise of a Crusade, led the Teutonic knights of Brandenburg under their Hohenzollern leaders along the Baltic. From the younger sons of these Baltic barons, essentially German although Russian subjects, the pre-war Russian bureaucracy was largely recruited. Russia was thus largely a Slav body with a German head. The other Teutonic penetration took the form of an advance along the Danube to the point where it enters the Great Plain of its basin, *i.e.*, to Vienna, which becomes the bulwark of Christendom against the Turk after he had overwhelmed the ancient bulwark of Constantinople in 1453. As the Turk was pushed back Austria grew by the absorption of the reclaimed lands until it became the great composite Empire we knew before the War. With its Magyar extension and the Latinized Roumanians to continue the line to the Black Sea we have a non-Slav band stretching right across the centre of the Slav area and dividing Slavdom into two portions: the Northern (Russians, Poles, Czechs, etc.), and the Southern (the Serbs, Bulgars and others of the Balkans). Perhaps the most striking point to note about the New Map is to see what has happened to this dividing band of non-Slav states (the Magyars are more of the Turanian or Mongol type than white). It is still there, but so thin and shrunken that (with the exception of Roumania, which has, of course, swollen out enormously at the Eastern end of the band by absorbing Transylvania from Hungary and Bessarabia from Russia) at one time Hungary, at any rate, seemed to be in danger of being pinched out altogether. The new states of Poland and Czecho-Slovakia on the North and of Yugo-Slavia on the South have been constituted by the break-up of the Empire which originally represented the reward and result of the Austrian championship of the Cross against the Crescent.

The second penetration is from the South-East and has already been referred to more than once: it is the Turkish penetration from Asia which began in the middle of the 14th century but made its greatest headway after the fall of Constantinople in 1453. (It should be noted, of course, that Constantinople had been Christian for a thousand years before it became Mohammedan; and that to-day it is still a great Greek Christian centre.) The Turkish advance into Europe continued until it was checked before Vienna by John Sobieski, King of Poland, about 250 years ago; but from that high-water mark the Turks have been receding ever since, as a study of any historical atlas will show. We cannot, however, pursue the consequences of this penetration for the moment. We must leave it until we have dealt with the Northern Slav States, Poland and Czecho-Slovakia.

There was a great Moravian Empire stretching indefinitely into Russia in the ninth century. Bohemia was a Duchy before Vienna appeared on the map. The University of Prague is the oldest north of the Alps. The Prince of Wales' Feathers were originally the crest of the King of Bohemia killed at Creçy, 1347. John Huss is the connecting link between our Reformer Wyclif and the German Reformer Luther. The Winter Queen, whose expulsion from Bohemia led to the Thirty Years' War which reduced Germany to savagery, was a sister of Charles I. The Bohemians should have had a position within the Austrian Empire at least equal to that of Hungary, but the old Emperor Francis Joseph always refused to go to Prague to be crowned. The new President Masaryk was a Professor of London University in the days of his exile. The new State has great resources, but is landlocked. The internationalization of the Elbe, the Oder and the Danube give her some sort of access to the sea, at any rate in peace time; and Pressburg is becoming an important Czech Danube port. Moreover, at Hamburg and Trieste the Czechs have customs-free areas. Nevertheless, the tradition of Vienna is still strong enough to draw and retain much of the business and banking of the new State—and still more of South-East Europe. (If anything could be done to save Vienna from sinking to the size of a capital of a few million Austrian-Germans, Europe would be the gainer. Its central position has suggested to some that it might make a good seat for the League of Nations.)

The New Poland is in a less assured position. Three hundred and fifty years ago Poland reached almost to Moscow and Odessa. We have seen what Europe owed to the Poles under Sobieski. But Poland, although able to save Europe, could not save herself. As a result of three partitions she was absorbed by her neighbours, Prussia, Austria and Russia. Napoleon, however, reconstituted her for a moment in connection with his Moscow campaign as the Grand Duchy of Warsaw. French support of the new state is thus on historical lines. Nevertheless, if Poland is to play the part assigned her of a State to keep apart those two complementary States, Germany and Russia, she will need very exceptional political qualities; and the story of her past hardly suggests that she possesses them. Moreover, in pre-war days the ally of France was not Poland, but Russia; and if ever the unofficial feelers between France and Russia now to be observed should become more definite, possibly French interest in Poland would take a somewhat different form.

We turn now to the Southern Slavs of the Balkans, who had been overrun by the Turks and kept marking time for centuries. The Turk, unprogressive himself, had no use for progress among his subject peoples, who, nevertheless, managed to retain their Faith and their sense of Nationality. The primitiveness of Turkish political ideas may be judged from the fact that only in this year (1922) have they ventured to separate the Temporal and Spiritual powers of the Caliph. Their rule is a militant theocracy and therefore unlikely to meet the needs of other races and creeds and the complexities of modern conditions. The rate at which they lost their huge Empire, stretching, as it did originally, from Vienna to the Persian Gulf and from the Caspian to the Red Sea, is an indication of their political and administrative limitations.

The Greeks, helped by Lord Byron, were the first to shake themselves free about a century ago. But the Slav peoples did not agitate effectively till after the Crimean War. In the twenty years, however, which separate that war from the "Jingo" war between Russia and Turkey, Russia was encouraging her younger sisters of the Balkans against the common enemy; and the Treaty of Berlin in 1878 redrew the Map of the Balkans so as to leave Turkey merely the strip from the Adriatic through Albania to the Bosphorus with which we were all familiar in our school days. But the shrinkage of Turkey continued in the twentieth century also. The Revolution of 1908 lost her not only the Suzerainty of Bulgaria (Prince Ferdinand becoming a King and "Czar of the Balkans"), but also the provinces of Bosnia and Herzegovina which had been handed to Austria to administer, but not to possess, by the Treaty of Berlin in 1878. In 1908, however, 30 years afterwards, Austria seized them and thus took a step which, as we shall see directly, led to the Great War.

But the troubles of Turkey did not end with these losses. A year or two later she found herself at war with Italy over Tripoli, and this war so exhausted her that she had no strength left for the new danger which threatened in 1912. Venizelos had managed to bring all the neighbours of Turkey together into the Balkan League; and these Allies smote Turkey on every front with such effect that she crumpled up and retired to the Chatalja lines. But the unity which had secured this triumph broke down under the strain of dividing the spoil. Bulgaria, who had done most of the fighting and secured an Ægean outlet as a reward, wished for a Westward extension towards the Adriatic also; and thus came into conflict with Serbia over the Monastir area; while, as regards Greece, Bulgaria wanted Kavalla. Thus arose the second Balkan war of 1913, in which Bulgaria suffered defeat in the West. The Turks, moreover, seized the opportunity of Bulgarian weakness to push their frontier back again to Adrianople, while even Roumania seized the same opportunity for pushing her Dobrudja frontier further South. Thus was the backwardness of the Balkan States, due as it was to centuries of stagnation and arrested development under Turkish rule, emphasized.

I have already spoken of the seizure of Bosnia and Herzegovina by Austria in 1908 as important: as leading, indeed, to the Great War. In the eighth century Serbia extended along the whole of the Adriatic shores westward to a line which took her west of Istria and back northward to the Drave. Thus originally the two provinces which had gone in 1908 to Austria were part of Serbia and remained so at any rate till the middle of the twelfth century. The Serbs had always expected to recover possession of these provinces on the break-up of Turkey, and when they found them seized by Austria they determined to prevent them from settling down as Austrian provinces. To deal with the Irredentist Movement thus started Austrian Army manœuvres were organized, and in connection with these the Austrian heir, the Archduke Ferdinand, paid that visit to Sarajevo which ended in his assassination on June 28th, 1914.

The establishment of Yugo-Slavia as the greatest of the Balkan States with a long coastline on the Adriatic has caused some anxiety in Italy, who has, of course, inherited the Adriatic traditions and position of Venice. The Doge was Duke of Dalmatia. Venetian factories and trading stations like "Zara Italianissima" dotted the whole of the Balkan coast as European stations to-day dot the coast of Africa. When, therefore, the Slavs of the hinterland awoke to national consciousness they found all their ports and openings in Venetian hands. The story of D'Annnunzio and Fiume is thus, in a sense, a throw-back to a picturesquely medieval period. But Italy is wiser than her warrior poet and has agreed to arrangements on the opposite coast which give to the new State all the openings she needs. Zara alone remains under Italian protection; also the island of Lagosta, while one of the two Channels between the islands to Fiume is mainly Italian. Nevertheless, the contrast between the two coasts of the Adriatic is still striking and we can understand Italian anxieties as to the possibility of developments among peoples so newly freed and in consequence so relatively undeveloped as the new States which face her across the Adriatic.

For a handy geographical study of the peace terms, readers are referred to "Aftermath," by Marian I. Newbigen, D.Sc. Macmillan (3/6).—EDITOR, *R.E.J.*

NOTES ON RAILWAY WORK IN EAST AFRICA, 1914–1918.

By Captain H. L. Woodhouse, M.C., R.E.

The provision of railway troops for the Indian Army was taken in hand as a result of the experience gained during the China War of 1900. Two companies of Railway Sappers and Miners were raised in 1903 and 1906, and the East African Expedition of 1914 was the first time that these companies were used in the field. In comparison with the other campaigns of the Great War this was a small side-show; however, at one time there were 80,000 British troops in the country, 40,000 of whom were white, and about 400,000 native carriers; and in 1917 the bloodiest battle ever fought by British troops in Africa, not excluding the actions of the South African War, took place. In one respect the campaign was of especial interest, as its conditions bore considerable resemblance to those of the small wars which have been so frequent during the last hundred years. The opposing forces were moderate in number, distances were great, means of communication bad, and climate most trying. Except for the Uganda Railway, and the two railways of German East Africa, tansportation in pre-war days was usually by porter. Animal transport was unreliable owing to the ravages of tsetse fly over large areas, and the prevalence of East Coast fever; navigable inland waters were few; and roads hardly existed, thus much increasing the difficulties of motor transport; so that railways and tramways took a large part in the transportation arrangements.

The Railway Detachment which formed part of I.E.F.B. was built up on the two companies of Railway Sappers and Miners, and the Loco and Traffic reserve attached to them. It also included a Labour Corps raised from the relatives of the Sappers, from whom the most promising men were afterwards enlisted into the companies, and a number of artisans drawn from the Indian State Railways, who formed the workshop staff. In addition to the eight R.E. officers with the companies, six Indian State Railway officers formed part of the original force, and as the campaign progressed, additional railway officers from India and South Africa arrived, while the care of the large bodies of African labour employed was entrusted to East African residents.

I.E.F.B. landed at Mombasa in November, 1914. The 25th and 26th Companies were almost immediately distributed over the

Uganda Railway as bridge guards, but six weeks later they concentrated, and after being fitted out with ox transport were employed on the road from Kajiado to Longido, and on the posts on Longido mountain. Early in March, 1915, they rejoined the rest of the Railway detachment at Voi, a station on the U.R. about 100 miles from the coast, and started railway work.

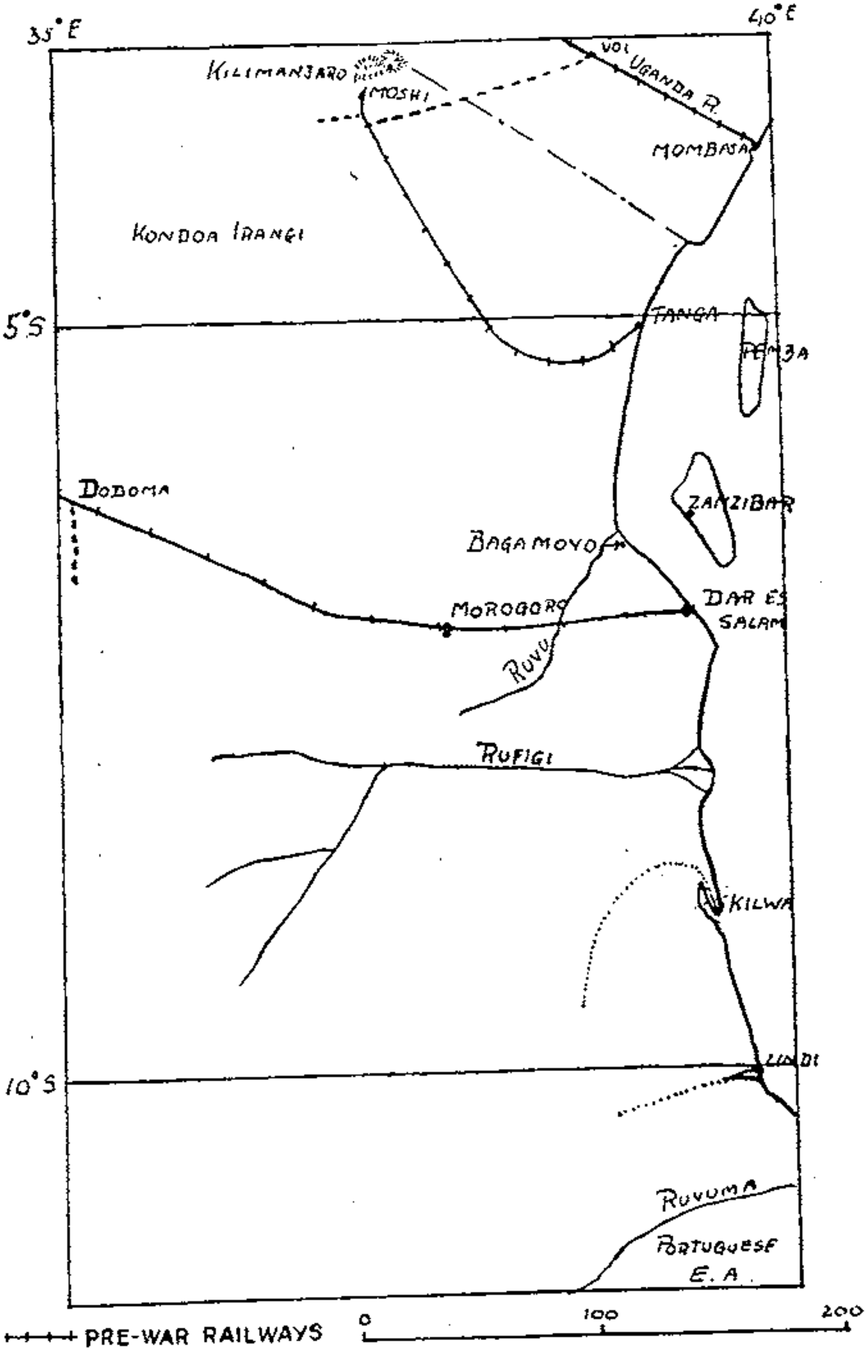
This work fell into three parts. The first, which took from March 1915, to April, 1916, was the construction of a line from Voi to Moshi, the terminus of the German line from the port of Tanga to Kilimanjaro, and the improvement of the U.R. by the addition of a number of crossing stations. The second comprised the repair of the damaged German railways and the construction of two short branch lines. This took from May, 1916, to June, 1917, during which time the whole of the Northern Railway and some 500 miles of the Central Railway were made fit for traffic, and a good deal of work done on the harbour wharves at Dar-es-Salam. The third period, from June, 1917, till the German forces were driven out of German East Africa, was spent on laying 60-centimetre lines from the southern ports of Kilwa and Lindi inland, and in wharf building at Lindi.

Owing to military considerations the Voi-Moshi line was laid in three parts. The first 38 miles to Maktau was constructed in March–June, 1915, the next 20 miles to Njoro in January and February, 1916, and the final 37 miles in March and April, 1916. The main engineering difficulties were the lack of water and the shortage of plant. The standard metre gauge common to both British and German lines in East Africa was naturally adopted. It turned out to be very suitable, as it struck the happy mean of reasonable capacity without unduly ponderous material, the latter of no small importance when it is remembered that all material, with few exceptions, had to be brought from overseas. The ruling grade was 3 per cent. as compared to the U.R. 2 per cent. In one instance this was departed from, as a choice between very sharp curves on the maximum grade, or very heavy earthwork, was settled by laying a straight line on a 4 per cent. grade. This was of less importance as the heavy traffic ran down the grade, and only lightly-loaded trains had to pull up the slope. A 4 per cent. grade was also adopted for a velocity dip in which the momentum gained by running down one side helped the train up the other. At first this was rather a stumbling-block to the drivers, but after a train which had tried to take it too slowly had stuck at the bottom, they learnt to rush it.

Earthwork was done by African labour, after the survey had been made by a special survey gang from India. For the first 30 miles the bush was very thick, which added enormously to the difficulties of choosing a good location. A surface line was aimed at, and heavy banks or cuttings were few.

Platelaying, bridge erection, station buildings and water supply

SKETCH MAP OF EAST AFRICA.



PRE-WAR RAILWAYS

METRE GUAGE LINES BUILT DURING THE WAR

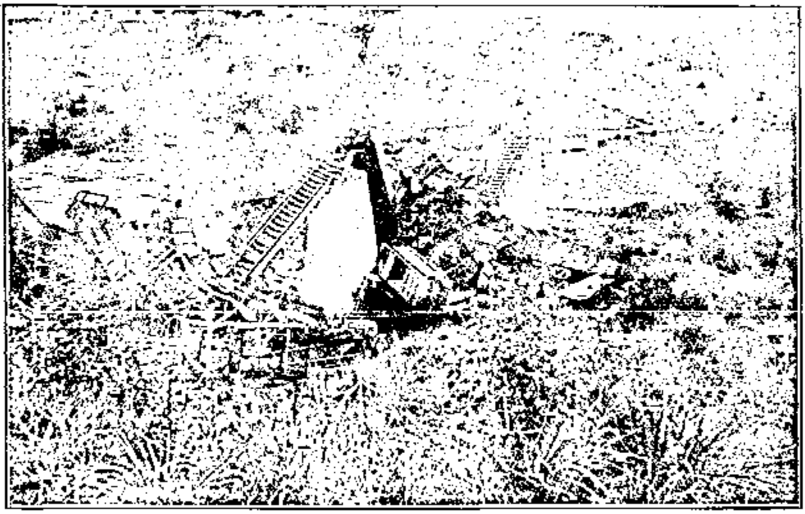
60 cm TRAMWAYS DO

were undertaken by the Sappers with some attached African labour. The chief difficulty in the platelaying was the great variety of material used. Not only had the detail of work to be altered frequently, but a careful watch was necessary to ensure that train-loads were made up of the same pattern of material. Four types of sleeper and as many types of rail were used in the first 38 miles. Progress was limited by the supply of material. The old engines in use, at first, found half a mile of track quite as much as they could manage over the steep grades. Later, when better loco power was available it was found that for continuous work a mile a day for a company of about 165 working strength and with 150 Africans to carry sleepers, was most economical. If this rate were exceeded the output of energy per man per day exceeded his recuperative powers by night, and the sick list went up considerably. If speed were of great importance two shifts were worked, each company taking one shift, but the normal procedure was for the companies to platelay on alternate days and spend the other day packing the work just done. All wooden sleepers were bored before reaching railhead, and in view of the difference in breadth across the foot of the various patterns of rail, the spacing of the holes had to be altered to suit the rails for which they were intended. A gang of coolies 50 strong was kept continuously employed on this job, and the consumption of augers was considerable. Both dog-spikes and coach screws were used with the wooden sleepers. The latter made a rather better job provided that a watch was kept that they were not hammered home instead of being screwed in, but they were a little more trouble to fix. If there were sufficient men available to double the number of spikers, the falling off in speed of linking due to the use of screws instead of spikes was not great.

In the 95 miles there were only eight bridges with spans of 40 ft. or more. This gives some idea of the dryness of the country. Spans of plate girders of 20-ft. or 40-ft. clear span were brought up by rail, already cross-braced. The piers were 12 in. × 12 in. piles or trestles. Pile-driving was done by hand. The girders were launched on well-greased rails, which were removed after the girders had been lifted clear of them on jacks. Some 85-lb. rails were found very useful for this job. In two instances the bridges exceeded 100 ft. in length, but there was nothing unusual about any of them. The streams over which they were thrown were in ordinary times insignificant, but were liable to sudden floods which severely tested the work done.

Culverts were made of corrugated iron pipes. These were easily carried forward by the earthwork parties, and put into position by the officers in charge of the earthwork party before starting work. The first lot of pipes were bought, but later a set of wooden rollers was put together in the base workshop which made quite good pipes,

NOTES ON RAILWAY WORK IN EAST AFRICA.



Bridge on Central Railway G.E.A. Demolished by the Enemy.

Voi—Moshi Railway in course of construction.

The photographs were taken by Lieut.-Colonel L. N. Malan, O.B.E., R.E.

and by their use a considerable saving was effected. A plentiful supply of culverts was found to be the truest economy, as, in several doubtful cases where they had not been installed, the result was a wash-out sooner or later.

Where there were streams, water was supplied for the engines by A-frame hand pumps, pumping into 4 ft.×4 ft.×4 ft. or 8 ft.×8 ft.×4 ft. tanks on Sullivan staging. This is a portable form of scaffolding made of piping and rods which can be erected easily to any reasonable height. The hand pumps were replaced by steam pumps later on. From miles 20 to 74 there was no natural supply, and recourse was had to a pipe-line laid to miles 32 and 38 for the supply of the troops. All engines had an extra water-tank behind the tender, which reduced the useful load they could pull.

Station buildings were the grass huts of the country. Tarpaulins were added to make them water-tight during the rains. In some cases they were within the perimeter of fortified camps, in other cases small blockhouses were built round them.

Train working was by telephone, under the direction of a central control station.

The repair shops at Voi gradually increased in size as more engines and tools arrived. The chief difficulty confronting the loco officers was, however, the fuel supply. Wood was used at first, as was the U.R. practice, but time had to be allowed for the newly-cut wood to dry, so requirements had to be foreseen some time ahead. As traffic increased, it became more and more difficult to allow time for the fuel trains to pick up loads from the stacks along the line. The difficulty became so great that in the end coal replaced wood as the fuel.

Up to the time of the main advance in 1916 the enemy made constant attacks on the line. His usual method was to lay contact mines, which rendered it necessary to run bomb-crushing sand trucks in front of all engines. Night running was prohibited and the line patrolled daily before the first train ran. Between sleepers the earth ballast was kept 2 in. or more below the bottom of the rails, and on several occasions bombs were discovered and removed owing to the disturbance of this arrangement. By day sentries were posted to watch each straight, and a patrol arranged to inspect the whole line at intervals so short that enough time was not allowed for laying a bomb in position. No serious attempt was ever made to interfere with the working parties, though at one time the line was being built five miles in front of the outpost line.

The time of greatest pressure on the Traffic department was during the concentration of the South Africans around Maktau in January, 1916, but the most critical time was in April of that year. General Smuts had driven the enemy out of the Kilimanjaro area just before the rains began, and it became imperative to get the railway through, as the roads became practically impassable during the rains. The line was open to Moshi four days only before supplies would have run out. In one place the line went through a flat which the rains turned into a swamp. The sleepers floated and had to be held in place till the rails were laid on them. After the first train had passed, the whole line disappeared beneath the mud, and soon the rails were as much as 6 in. out of level. The sight of a train creeping through what appeared to be a sea of mud, with every vehicle tilted to a different angle was one not easily forgotten. The construction train was naturally frequently derailed; usually, after safely passing apparently impossible places, waggons would come off for a trifling cause. The task could not have been accomplished in time had it not been for the whole-hearted efforts of the sappers.

During the intervals of railway construction extra stations were laid on the U.R. and some road-making and fortification work was carried out at Maktau, which led to several skirmishes.

The second phase began in May, 1916. The enemy had destroyed stretches of line amounting to about 20 miles in all, and had blown up all the bridges on the line from Kilimanjaro to Tanga. This line was found to be about three-eighths of an inch narrower gauge than the U.R. metre gauge, but beyond some squeaking on curves which wore out wheels rather quickly, there was no trouble in running our own rolling stock on the line. The first train had some difficulty in getting up the steep slope from the outposts on the day the advance began, owing to an unusual cause. The line was intact, but had not been used for some weeks, and the grass had sprouted to a height of about six inches. As the leading wheels crushed it down the juices spread on the rails, which became so slippery that the engine could get no grip and slipped furiously. It was not until an advance party had cleared the grass away that the train could cover the first mile or two. Where the track had been destroyed the rails had been left lying in the side ditch, but the sleepers had been removed in places and used for bridge cribs, dug-out roofs and other purposes. They were easily recovered, but the smaller stores, such as fish-plates, fish-bolts, and sleeper-clips, were not so easily found. After some progress had been made it was found to be simpler to relay with new material. The various expedients tried, such as clipping every third sleeper, resting the ends of the rails on wooden blocks and fastening them there with coach-screws, were very slow and did not give a good enough track. Various methods of bridge repair were adopted. Rail girders on cribs built of German sleepers and filled with ballast were common, but had to be replaced after a time as the steel sleepers gradually flattened out. The first of the three 50-metre spans met with was repaired in a morning, as the demolition had been poorly executed; the two others, which were over the Pangani river, were replaced by temporary trestle bridges with girders of 85-lb. rails.

While occupied on this work the 25th and 26th Companies, with some details (the whole under the command of Lieut.-Colonel Wilkinson, then Commandant of the Railway Sappers), had to drive off a party of enemy some 600 strong, who were attempting to interfere with the line of communications.

The enemy rolling stock was found on the last 30 miles of the line. In some places trains were found wrecked on the running line, but the positions for these obstacles had not been well chosen and diversions were quickly made, pending their removal. The telegraph instruments had all been removed or destroyed and the engine watering arrangements damaged, but repairs were carried out as fast as the line was put into running order. The country was much better watered than was the stretch across which the Voi-Moshi line had been built. The points and crossings had, in most cases, been destroyed or removed. In some cases the missing parts were recovered, in others British material was installed. The amount of smith's work required in the manufacture of junction fish-plates to join British and German rails was very considerable. A strong party of coolies with civilian bridge erectors followed the companies down the line and strengthened the hasty repairs where necessary.

The 27th and 28th Companies had joined the force in April and May. The latter assisted in repairing the Tanga line, the former built a short branch from near Moshi to improve communications with the detachment at Kondoa Irangi. This line required several fair-sized bridges to be built, but was never much used.

After a short halt at Tanga the companies moved by sea to begin work on the Central Railway. The main army had cut this line at Morogoro, 100 miles, and Dodoma, 250 miles from the coast, and temporary repairs had been made by the South African Pioneers between, and for some distance on either side of, these places. These repairs were enough to allow of 30-cwt. lorries mounted on railway wheels carrying supplies to the columns on the flanks. Two companies landed at Dar-es-Salam, and the other two at Bagamoyo, whence they marched across country to start work at once on the repair of the large bridge over the Ruvu river, which had been completely destroyed. The efforts of the whole battalion resulted in the line being repaired as far as Tabora (500 miles inland) in two months, or one-third of the time which the enemy had allowed for the work. Fortunately, no damage had been done to the track, so the companies advanced in leapfrog fashion from one bridge to another, carrying their baggage first on trollies hand-propelled, later by motor lorry. This could hardly have been done if the enemy had destroyed the track as he had done on the Tanga line.

From the coast to Morogoro the line ran through rough country entailing a large number of bridges, and it was here that the principal damage had been done. However, an oversight on the part of the enemy assisted the work considerably. Just before the war some five or six miles had been reconstructed. The rails and bridges on the old line were practically intact, so a little work enabled this stretch to be taken into use again in place of the new line, on which a number of fair-sized bridges had been thoroughly destroyed. A very useful find was a number of 20-ton differential blocks. With these and a derrick quite a number of 10-metre plate girders which had been blown off their abutments, but were otherwise little damaged, were rapidly replaced either on the repaired abutments or on trestles.

When the temporary repairs had been finished more substantial work was put in hand, including rebuilding damaged abutments in masonry, re-erecting German water-tanks, and combining the undamaged parts of bridges to form new spans. In March, 1917, three companies began work on a new branch southwards from Dodoma, but by the time this was ready changes in the situation had made it unnecessary. The fourth company was meantime employed on the construction of wharves at Dar-es-Salam, and the installation of steam cranes.

It was at about the end of the time spent on the Central Railway that the effects of the climate began to grow serious. During the work on the Voi-Moshi line the sick rate had been very low, lower, in fact, than that of the infantry, a result which was probably due to the steady work during the long period during which the Army was stationary, awaiting the arrival of the South African reinforcements. The climate was not at all bad for the tropics, and the physical standard of the men good.

The expansion of the companies and the drain on India for recruits of all sorts had lowered the physical standard considerably by the middle of 1916, and the prolonged work in the very unhealthy coastal region of the Central Railway sapped the health of all ranks. The companies employed on the Dodoma branch, which was several thousand feet above the sea, recovered, to some extent, but the company employed at Dar-es-Salam during that time had become decidedly the worse for wear by June, 1917.

The third phase opened in June, 1917. The enemy had retreated southwards from the positions he had held for some time on the Rufiji river, about 50 miles south of the Central Railway; and the line of supply for the main body of our troops was changed to the Port of Kilwa, on which part of the Army had been based for some time. A 60-cm. tramway to supply this force had been started by a party of coolies, and two companies were sent to take over and hasten its advance. Another company was sent to Lindi, a port near the Portuguese frontier, which had been occupied by a detachment some time previously. A pre-war 60-cm. line ran inland for 13 miles to some large plantations, but the inland terminus was, in June, still in the hands of the enemy. A few months later the main base was transferred from Kilwa to Lindi, and this line and its extension became the line of supply for the greater part of the Army. The two companies on the Kilwa line were brought round by sea to help on the Lindi tramway, and half of the company which had been left on the Central Railway was set to work to build more wharves at Lindi.

The track for the lines from Kilwa and Lindi was obtained from the plantation lines which had been built on many of the large estates. Ford cars were mounted on tramway wheels and used both to carry loads and to drag trailers. The latter were made up from the bogie waggons found on the plantations, altered by the substitution of much lighter wooden bodies for their heavy iron bodies. These were quite satisfactory and had the advantage that in case of a serious breakdown they could be lifted clear of the track by a few men. The drivers were from South Africa and India and were very short of training. In most cases they had no idea of putting right the smallest fault in the engines, so the tractors were run in convoys of about a dozen at a time and a mechanic travelled on the rearmost vehicle. Every time a stoppage occurred the whole convoy behind the lame duck stopped till the mechanic came up to put matters right. His job was no bed of roses. In addition to mechanical breakdowns one set of tractors reached the force with a bad fault in design, which resulted in every one of the lot being out of action with a broken back axle in a few days. The junction between the axle and the stub of reduced diameter on which the wheel was carried had been made square and not rounded off. It seems a trifle, yet the results were most serious. Shops were built at the sea terminus to execute repairs, but there was a shortage of mechanics and cars failed much faster than they could be repaired. Two small steam engines were tried, but they shook the light track about to such an extent that their use had to be stopped almost at once.

The extension of this line when the advance began was a difficult problem. The capacity of the line was already being taxed by the forwarding of supplies, and the provision of tractors to take forward track was very difficult. Matters became critical during the time which elapsed between the arrival of the main body on the Lindi line, and the arrival of the Kilwa companies and tractors. The unhealthy climate, too, was having serious effects. On men already below par, its results were disastrous. One company which landed at Lindi in June, 1917, with a working strength of about 150, could with difficulty muster more than 35 men for work in January, 1918.

Of the three Indian officers and 40 other ranks who had formed part of the original company and were still with it in June, 1917, two Indian Officers and ten other ranks died during the following six months.

By this time, however, the railway work of the campaign had been almost finished. The enemy retreated into Portuguese territory at the end of November, 1917, and from then onwards was pursued hither and thither in such a way that there was never time to do much towards improving any particular line of communication before it had become of minor importance. In these circumstances one company returned to India in February, 1918, two more in April, and the last, weeded of its weakest men and strengthened by those from the other companies who were the latest arrivals, remained till September before following the other three.

THE ENGINEERS OF AN ARMY CORPS IN FRANCE.

By MAJOR W. HYDE KELLY, D.S.O., R.E.

IN the original Expeditionary Force of 1914, the only Engineer establishment laid down for an Army Corps (or Army, as it was then called) was one Chief Engineer (a colonel) and one clerk. No particular units were told off as Corps Engineers, although one or more Fortress Companies might be available as Army Troops. The Chief Engineer was, as War Establishments expressly stated, a " technical adviser in Engineer matters " without any executive powers. This anomalous situation, of course, was rapidly altered at the outset of the campaign.

At first, the Chief Engineer had to detail what R.E. labour he could borrow from divisional engineers. Two fortress companies, the 20th and 42nd, were early on the scene, and the two bridging trains acted to some extent as Army Troops, and furnished officers for supervision of working parties.

Up to the time when the Armies came to a halt on the Aisne (September 12th, 1914), practically all the engineer work had been confined to the divisional engineers, but with the consolidation of the positions on the Aisne, it became necessary to start work on Corps defence lines. The only labour available for this work was that of battalions in reserve, and with the continual attacks and alarms these battalions got very little rest and were continually changing. There were no civilians in the neighbourhood, all had fled on the first invasion, and although the villages had not yet been much damaged, they were empty. The farmhouses were searched for tools, and a large number of the long-handled French shovels were collected for the working parties. Fire trenches were dug more or less extensively on the high ground south of the Aisne, and mostly among the sugar-beet fields. Not much could be done, however, owing to the heavy calls on the troops in the front line.

When the Army moved northward into the Ypres-Armentières region, a large number of Belgian and French refugees were still pouring westward, and from these fairly large working parties were formed under R.E. officers.

The 20th and 42nd Fortress Companies (later called Army Troops Companies) became virtually Field Companies, and were distributed as far as possible, with civilian digging parties. Behind these few units, the Siege Companies of the Royal Monmouth and the Royal Anglesey R.E. were coming oversea, and by December, 1914, a number of Territorial Fortress Companies had been mobilized and equipped for service. Some had already landed in France.

From these small beginnings, there gradually developed a Corps R.E. organization under the hand of the Chief Engineer, but always in those first two years there was a shortage of R.E. labour. As new Army Corps were formed (the Vth Corps was formed in April, 1915, and the VIth in early June), the Chief Engineer's staff was increased by three field engineers and a second clerk, or draughtsman. One of the field engineers was to act as Staff Officer to the Chief Engineer, but a regular R.E. officer was detailed for this appointment, if possible. The other two field engineers were given some special task, such as the road-repairing work, or the water supply.

The Staff Officer also acted as Stores Officer until resources expanded, and had much the same duties as those of the Adjutant to a divisional C.R.E.

By the spring of 1915 Corps had become more or less permanently fixed in their areas, and engineering problems could be organized and tackled on systematic lines. The areas included large " hinterlands " which gradually filled up with new R.F.C. squadrons, casualty clearing stations, rest camps, etc.

At this period, road work was perhaps the most important of of the C.E.'s duties. The rapid increase of motor transport knocked the bottom out of the French roads, fine as they were to begin with, and, until railway transport was developed, new sidings built, and the labour organizations at the base increased, the efforts of the Corps engineers to save the roads seemed to have but small effect. A few truck-loads of stone arriving in the area daily were swallowed up at once, and 1915 was well advanced before even the first road roller made its appearance on the Poperinghe–Ypres road, which was the main artery of two Army Corps.

In the northern sector of the British Army, companies of Belgian " Travailleurs " were available and were allotted to the two northern Corps. These units were composed of men too old or too infirm for service in the Belgian Field Army, and were administered in groups under their own Commandants. They were the first labour units met with, and as each of the two Corps referred to had from four to five of these companies attached, the resources of the C.E.'s were very much improved.

Usually these companies were employed in the woods and plantations around Proven, cutting pickets and pit-props, making hurdles and fascines, at which work they were admirable. One company, whose O.C. was an engineer by profession, was employed on the defences of the " Kaaie Salient "—the north-west corner of Ypres—working with a section of the 1st Royal Monmouth Siege Company. Another company did very good work around Elverdinghe and Brielen, constructing breastworks. Their brushwood revetments were their "forte." Another company was employed in road repairs. The fact that these companies were self-supporting and only came to the C.E. for work, was of great advantage, as the C.E.'s office is not the place for administrative details connected with units' billeting troubles, etc. Our later organization under Labour Commandants proved the value of the separation of these functions.

About June, 1915, the first of the Labour Battalions arrived. These were R.E. units at first, definitely allotted to the Corps. They were composed of elderly men hastily enlisted, and required "sorting," but they showed a remarkable adaptability. Some of them had grievously understated their ages, but this proved their keenness to serve, and every man found his place.

The Labour Battalions were employed on road work, formation of large dumps of engineer stores, concrete dug-outs in the "Corps Line," and hutting.

The defence works of the Corps Line were largely constructed by siege companies of the Special Reserve, with companies of Belgian "Travailleurs" and Labour Battalions; also by working parties furnished by the cavalry divisions. The greater part of the defences of Elverdinghe in 1915 were built by cavalry working parties, under the Chief Engineer of the Corps.

At this time a Corps would have two divisions, both in the line. There were divisions in reserve in certain sectors, but these were preparing for the Loos operations. There was no clear line dividing the areas for which the divisional C.R.E.'s and the Chief Engineer of the Corps were responsible, but roughly the Corps Engineers worked up to the limits of horsed transport by day.

Divisional workshops began to grow, employing refugee labour, and even Field Companies collected old stationary engines from nowhere, and set up little factories, all intent on trying to meet the ever-increasing demand for trench boards, revetting frames, dug-out frames, etc. But over and above these, the Corps started workshops and dumps on a bigger scale. These were usually situated on a normal-gauge railway, but in some cases a special yard had to be constructed, with sidings laid down, and a large area levelled and metalled.

The Corps workshops gradually superseded the divisional shops for the manufacture of standard articles, as divisions changed more frequently, but the latter always had a considerable field for their own exploitation. At first, the Corps Workshops were manned by a handful of sawyers and tradesmen collected from a variety of units, but as Army Troops Companies arrived, one of these units would be told off to run the whole yard. A varied assortment of articles would be manufactured at these dumps:—trench boards, revetting frames, artillery bridges, Bangalore torpedoes, concrete slabs, hutting sections, etc. Almost every Corps had its own design for sectional hutting, until the Nissen hut was evolved and superseded all other types of the smaller sizes. The manufacture and painting of notice boards was in itself a very busy side-line, as any square mile of country would testify.

The Corps dump was kept closely under the hands of the Chief Engineer. His Staff Officer kept daily stock lists, and supervised the flow of receipts and issues. Monthly estimates of requirements were sent in to Army Headquarters, and the unnecessary accumulation or cornering of stores was watched by the C.E. As divisions increased in number, so did the Corps dump in size, and in most cases a separate stores officer was introduced into C.E.'s offices.

Corps workshops are an inseparable part of the Corps anatomy and it would seem desirable that they should be allowed for in War Establishments. Like the company cooks, they have got to be there.

With the increasing number of units, R.E. and others, working under the Chief Engineers, it became necessary to relieve the C.E. of the administrative work, and of a portion of the executive work of the units. In the spring of 1917, C.R.E.'s of Corps Troops were appointed, even with an adjutant, one clerk, and one draughtsman. The C.R.E. also had to deal with the demands for engineer services from the large number of units forming Corps Troops. The C.R.E., who was a Lieut.-Colonel, theoretically commanded all the R.E. units attached to the Corps, but in some cases, one or two units were kept directly under the C.E.

The work of the Corps Engineers may be roughly divided into the following classes, in order of priority :—

i. Defence Works.
ii. Roads and Communications, from the points where the Army or Road Directorates' functions cease, to the divisional sphere.
iii. Water Supply.
iv. Camps and other rearward services.

i. Defence Works.

These began with a few isolated works with one or two open machine-gun emplacements apiece, and strongly wired. Considerable attention was paid to getting a good wire obstacle completed, as a definite stage. "Defended localities" were popular in 1915, and several works reached an advanced stage, with good revetments and trench-boarded floors ; but the trench boards were usually removed for fuel, and "resident" caretakers became necessary. Defence works deteriorated somewhat rapidly ; horses out for grazing were frequently seen damaging parapets, and two-legged trespassers were also to be reckoned with ; therefore it is not extravagant to spare a few elderly or non-robust men to look after these works and keep them in repair. The amount of work which can be put into the "Corps Line" varies very much. Labour is never forthcoming as plentifully as a C.E. could wish for, but in the case of some of the Corps which occupied their sectors continuously for a year or more, as they did in 1915 and 1916, the lines were in a very advanced state, and were provided with concealed machine-gun emplacements, deep dug-outs and other shelters. Before machine-guns became plentiful, the leading principle was to obtain cover from which rifle-fire could be developed to its maximum; then came an era of carefully sited machine-gun posts in the parapets; later, the machine-gun posts became more cunningly disposed in unlooked-for places, and later still came the principle of siting machine-gun posts and wire entanglements designed to shepherd the enemy towards the machine-guns, leaving the earthworks to be developed as a somewhat secondary stage. Pill-boxes were introduced into defence lines in 1918, and the camouflaging of these became a source of great interest.

In the strenuous days of 1918, when defence lines grew up, one behind another, with astonishing rapidity, the C.R.E.'s chief work was the supervision of the Corps line; large scale plans were made of the works in progress, and were revised every week to show the state of completion. Army Troops Companies were employed on the machine-gun emplacements, screens, look-out posts, revetting, draining, etc., while labour companies furnished the bulk of the working parties. Officers of the Tunnelling Companies, temporarily out of their own job, were lent to supervise sectors of the line.

ii. Roads and Communications.

Until the formation of the Roads Directorate, Chief Engineers were responsible for very large areas, and were dependent on their own resources for labour. Material was distributed by the Army, and was delivered at certain railheads selected for the purpose, and formed into "road dumps." The road work was at all times very heavy, and there were always urgent demands for more and more material. Not infrequently the sites for camps would be selected at considerable distances from any roadway, and after a week or two of occupation, piteous appeals for road-making would come from the occupants who saw themselves getting cut off in a sea of mud. The only remedy for these cases was to give them fascines and a little help, with which their own labour could do something until their plight could be properly attended to.

On the subject of the roads, practically the first lesson learnt, at any rate on the Flanders side, was the necessity of shoring-up the sides before adding fresh metal. Most of the roads consisted of a pavé centre with unmetalled strips of varying widths at each side—"trottoirs cyclables" was the local name for them. These sides naturally took a lot of traffic at the outset, motor cars and lorries monopolizing the pavé. The side tracks, of course, soon became quagmires; their outer edges fell away into the ditches, and their inner edges sank and let down the edges of the pavé in its turn. The sides having been shored up, it became possible to fill in the soling, and then the metal.

On communications, the Corps had a variety of work. There was an early demand for trench tramway. One of the divisions in the Ypres sector utilized wooden rails, made in their own and the Corps workshops, until the 60-cm. decauville track became a normal supply. The wooden rails were supposed to deaden the sound of the trolleys, but they were so frequently damaged that they were discarded as soon as they could be replaced. The "points" were armoured with biscuit-tin sheets. Still, there was a great advantage in any sort of tramway which would help to reduce carrying parties, and therefore reduce casualties.

In some sectors, Corps tramways developed extensively, notably in the XVII Corps sector north of Arras. In this part, a 60-cm. decauville system was laid down, with its base close to the main dump, and its railheads in the support line. Trains were made up of two or more bogey trucks and drawn by two mules. The track ran on the open ground. The carrying parties saved thereby meant economy of life and better rest for the tired battalions out of the line. The maintenance of the system was light; traffic went up by night, and the organization was the object of visits from all parts. Curiously enough, in the sector immediately to the south, an entirely different set of conditions was met with. There the town of Arras enabled horsed transport to go up by night to Brigade dumps within 600 or 700 yards of the front line. A tramway was laid in this sector in a specially widened trench, but it was not popular and was little used; a tramway in a trench very quickly gets blocked.

As a rule Corps tramways were limited to supplying the heavy artillery positions. Special tramway companies were formed in 1917, and these worked under Corps tramway officers. By 1918, the tramways were intimately connected with the light railways, which were part of the whole system of Transportation.

In position warfare, tramways have many uses, and although in the forward area their maintenance may require a permanent repair gang, it was often the case that their use over shell-pitted areas of mud saved carrying parties, while during a battle the wounded could be brought back at any rate a few degrees more comfortably than they would be carried by hand over the terrible ground which formed the Ypres Salient in the winter of 1917. Such tramways as these will usually fall within the province of the divisional C.R.E., but the Corps may have the base-end of the system to look after.

On the formation of the Roads Directorate, the responsibilities of Corps Engineers for roads became reduced, and the forward limit up to which the Director of Roads was responsible, or what was called the D.G.T. line, was advanced to within two or three miles of the front line. This left the Corps Engineers with the task of making the planked or corduroy roadways, a form of road surface which had the great advantage that the planks could be taken up and used again as the more permanent road metalling advanced. In the Ypres Salient in 1917 several miles of beech-planked roads were built by Corps Engineers.

Bridges.—During the days of stationary warfare, very little bridging work fell to the Corps Engineers, but in 1917, when the Germans retreated, the demand for bridges became very prominent. Most of the work was deliberate, *e.g.*, replacing the bridge over the railway at Arras station, carried out by an A.T. Company in April and May, 1917. In August, 1917, there were fresh bridges required over the Ypres canal, and at various other places. But it was not until the great days of August, 1918, and onwards that the arrangements for heavy bridging really became put to the test. Then the work of the Corps Engineers became chiefly road-repairing and bridge-building. There were many more bridges than units to build them, and Tunnelling companies were lent to Corps to help in the work. In some Corps, a specially selected A.T. Company was told off as the Corps Bridging unit, but in most cases bridge-building was allotted to whichever R.E. unit was next available. Corps Bridging officers were appointed to look after the issue of available materials, and to advise generally.

iii. Water Supply.

As with the other services, this began in a small way. One of the Field Engineers would be told off to develop the local resources —clearing wells, digging new ones, fixing up pumps—either hand or motor-driven—on the more prolific wells, borrowing labour from Army Troops Companies. Then came a demand for better organized horse-watering places, with long troughs and metalled standings; schemes for providing for the accommodation of the cavalry divisions in view of big operations; and special filling points for water-carts and water-lorries. In the Somme operations, the task of carrying water supplies forward with the advance entailed a vast amount of work which was usually carried out by the Army Troops Companies of the various Corps. Water-columns formed of lorries carrying 300 and 400 gallon tanks and pumps were organized as G.H.Q. units for emergencies, and arrangements for filling these columns were made by the Corps.

The multiplication of pumping stations—every village would have one, if not more—which had to be manned by sappers, put a strain on the Army Troops Companies, and later on personnel from the Electrical and Mechanical Companies took charge of a large number.

iv. CAMPS AND OTHER REARWARD SERVICES.

Under this heading came many varied calls for engineer work. The erection of huts was largely done by unskilled labour, with sappers distributed as far as they would go. Units were naturally very keen on getting themselves housed, and would apply to C.E.'s for immense quantities of materials. Some units did remarkably good work in erecting their own huts and devising horse-shelters, and recognizing that there were not enough sappers to go round, they set to without delay. Heavy batteries were handicapped in this respect, as their men were continually at work and had few opportunities of tackling such things as horse-shelters. Batteries multiplied so rapidly, and moved about so frequently, that it was really worth while to tell off an R.E. officer to cater for them entirely, both for work at the battery positions and at their wagon lines. In 1917 and 1918 there was more of everything, and it became possible for more or less permanent hutting parties to be told off, and regular hutted camps could be built methodically. But the number of units to be provided for in the Corps area became legion, and demands could not all be met. There was a good deal of waste of material, owing to the quantities demanded being several times more than were necessary.

It was a safe rule to divide all demands of this class by fairly large factors, yet any camp would show reasons why supplies wouldn't meet demands. There is no clear remedy for this state of things: thrift is not a national characteristic, and the average Corps dump looks a perfect gold mine of materials to the unit newly arrived in the area and thinking out its housing schemes.

Something might be done in the way of standardizing such things as small accessories, cook-houses, ablution sheds, etc., etc. Huts, of course, were standardized, but the odds and ends were not, and handy reference lists of materials required for, say, a battery cook-house, would tend to check exorbitant demands. No S.O.R.E., working thirteen or fourteen hours a day, can look closely into all the demands which come in for stores.

"Bunking barns" became a very active item in 1916 and 1917, and when operations on a large scale were imminent, every barn that could stand it was fitted up with two, three, or even four tiers of bunks. These wire-netted tiers were of various types according to the materials available, and large parties were at work on them

Some healthy rivalry grew up between "resting" Field Companies and A.T. Companies as to the number of bunks completed in a day, and in one Corps area on the Arras sector in the winter of 1916 as many as 1,100 bunks per diem for several days were completed.

Aerodromes, situated some distance in rear of Corps Headquarters, called for a good deal of engineer work, although the squadrons did an immense amount for themselves. Usually, the R.F.C. units asked for a few sappers to be attached to them on loan; but the practice of parcelling out A.T. Companies among various other units, schools, etc., is unsound, and leads to a great reduction in the available engineer personnel at disposal. It also leads to the detachment being used for other purposes than those for which it was detailed; it takes sappers away from their own officers, and leads to waste of time and material. Whatever the job that has to be done, the sappers must work under their own officers.

Casualty clearing stations are on the C.E.'s list. These require many services; good entrances and exits for ambulances; plentiful water supply; clean duckboard paths; good lighting in the operating ward or tent; concrete floors at the cook-houses; destructors; comfortable quarters for the nursing sisters; baths; racking for stores and equipment, etc., etc.; all of which need R.E. assistance.

It was astonishing how readily a C.C.S. unit would achieve things for itself; the personnel always included someone with the necessary skill, but no units were more grateful for any assistance that could be given.

Cinemas must not be omitted. A Corps Cinema was a recognized adjunct to Corps Headquarters. They were usually of modest dimensions, and did not appear on the scene until all divisions had been well supplied.

Prisoner of War compounds were also Corps matters. These grew to be very elaborate, and of necessity had to be self-contained. Similar compounds were required for native labour companies to keep them apart.

Ammunition dumps were built for Corps purposes, usually on a roadside, but several were large affairs requiring metalled roadways and shedding. Light sheds of poles and curved corrugated sheets for the roofing were put up with unskilled labour. A standard pattern was evolved towards the close of the war which was capable of very rapid erection.

Corps Reception Camps were necessary for the reception of drafts and partially-trained reinforcements. Corps Rest Camps, Corps Schools of all kinds, Corps Railheads, Mobile Veterinary Sections, etc., were all items of importance.

Town Majors, too, had calls on the Corps Engineers; houses damaged by shell fire or bombs required pulling down or shoring up; cellars needed stiffening or opening out.

In 1918, when the great advance began, a new form of engineer work arose; villages which had not been wholly wrecked had a few houses which could be patched up, re-tiled, and made habitable for troops. Tiles were collected from the less promising houses; holes in the walls were patched over with any handy material, and debris cleared out. A company working at this in small groups could in a few days increase the billeting possibilities very considerably.

The catalogue of work which falls, or may fall, to the Engineers of an Army Corps is practically without end. In such a theatre of War as France, the very existence of civilized conditions involved a wide range of additional works, in order to cater for the enormous numbers of troops quartered in the restricted areas. The result was that there was more than ever a need for engineers' work, and every variety of it.

CAPTAIN LIDDELL HART AND LIEUT.-COLONEL BOND

A Summary and a Judgment.

By COLONEL J. F. C. FULLER, D.S.O.

INTRODUCTORY NOTE.

THE Editor of *The Royal Engineers Journal* has asked me to sum up and attempt to give a decision as to the value of the theories propounded by Captain Liddell Hart and Lieut.-Colonel Bond, in this *Journal* during the last two years.

The articles for my consideration are as follows :—

(i) " A Science of Infantry Tactics." Captain Liddell Hart. Vol. XXXIII. No. 4. April, 1921, and Vol. XXXIII. No. 5. May, 1921.

(ii) " A Study of the New French Infantry Regulations." Captain Liddell Hart. Vol. XXXV. No. 5. May, 1922.

(iii) " The Tactical Theories of Captain Liddell Hart (A Criticism)." Bt. Lieut.-Colonel Bond. Vol. XXXVI. No. 3. September, 1922.

(iv) " Colonel Bond's Criticisms. (A Reply)." Captain Liddell Hart. Vol. XXXVI. No. 5. November, 1922.

(v) " The Tactical Theories of Captain Liddell Hart (continued)." Lieut.-Colonel Bond. (Unpublished).

It is with some diffidence that I have agreed to carry out this task: first, because my time is very limited; second, because during the recent war my work was on the staff; thirdly, because I know Captain Liddell Hart, but have not the pleasure of knowing Colonel Bond; and fourthly, because Colonel Bond's final criticism has not been published. I hope, however, that, if I do an injustice to either side, it will not be considered wilful and that, to defend myself, I shall not be forced to assume the attitude of a contracting funnel.

In order that the reader may logically follow me through this paper, I intend to divide it as follows :—

Part (i) The tactical theories of Captain Liddell Hart.
Part (ii) Certain tactical views of Colonel Bond.
Part (iii) A criticism of the theories of Captain Liddell Hart.
Part (iv) A criticism of the tactical views of Colonel Bond.
Part (v) Judgment.

Such quotations as I may make from Colonel Bond's unpublished paper I will place in square brackets.

PART I.—THE TACTICAL THEORIES OF CAPTAIN LIDDELL HART.

The tactical theories of Captain Liddell Hart, so far as this *Journal* is concerned, are contained in Nos. 4 and 5, of Vol. XXXIII, and they are elaborated from two analogies—two men fighting in the dark, and an expanding torrent of water.

(i) *The Man Fighting in the Dark.*—In order to establish a science of infantry tactics, Captain Liddell Hart postulates as the simplest and most realistic form of war two men fighting in the dark. From this postulate he elaborates five battle principles:—

(*a*) The principle of protective formation.—Each man extends one arm in front of him.

(*b*) The principle of reconnaissance.—Each man attempts to grip his opponent's throat.

(*c*) The principle of fixing.—Once the throat is gripped it is held firm.

(*d*) The principle of decisive manœuvre.—Whilst the "fixed" man is trying to free himself, his adversary knocks him out.

(*e*) The principle of exploitation.—Before the knocked-out man can recover his opponent renders him powerless.

Captain Liddell Hart next attempts to simplify the whole process by dividing the above actions into two categories—guarding and hitting, to which he attributes two governing principles, those of Security and Economy of Force.

So far his premises; all that now remains to be done is to apply them.

Security.—Security is of two kinds—material and tactical. The first is security against physical loss and the second against the loss of tactical energy. Security is gained by an application of the first three battle principles.

Economy of Force.—Economy depends on expending only the very necessary force on the application of the first three battle principles and the bulk of it on the remaining two.

From these considerations it follows that every front line unit in battle must be divided into two parts—a forward unit to reconnoitre and fix, and a manœuvre unit to punch and pursue, the strength of the punch depending on the perfection of the fixing.

Having settled on his protective formation, the commander must attempt to accentuate his strength by surprising his enemy, by speed of movement, by momentum, by searching for a "soft spot" to hit at, by husbanding his men and by arranging for mutual support and for exploitation.

As Captain Liddell Hart finds that the pre-war system of infantry attack not only does not maintain these principles, but violates them, in place of a battle line reinforced at those places where the greatest losses are experienced, he suggests a battle front of infantry groups, based on the platoon, which, on account of the extensions between them, will be in a position to manœuvre and discover the lines of least resistance to their advance. These groups he calls human tanks, because they possess power of movement, offensive power and their formation protects them like armour. He then lays down a series of maxims for the platoon in the attack which, in the main, are based on searching for a "soft spot," and when it is discovered, of pushing ahead irrespective of most other circumstances.

(ii) *The Expanding Torrent System of Attack.*—The "soft spot" must be found, consequently, "we must feel and test the position everywhere, and endeavour to push in the weight of our reserves where a weak spot is found or made. . . . Hence we must create a scientific system of attack which will reconcile and combine *speed with security*. The breach must be widened in proportion as the penetration is deepened by automatically progressive steps, beginning with the platoon and working up to the brigade." The writer then deduces from the analogy of a torrent breaking against a dam four principles of attack :—

(*a*) The forward sub-unit makes or finds a breach and, followed by the manœuvre body, pushes straight ahead.

(*b*) The forward units on its flanks, if held up, send their manœuvre bodies through the breach and widen the gap.

(*c*) The rear units press through the gap and deploy—expand.

(*d*) The held-up units, directly resistance is broken, follow through the gap as manœuvre units.

By means of these principles the whole process of attack becomes automatic, once the soft spot is found, and confusion is reduced to a minimum.

"The defence is simply the attack halted," consequently protection against the expanding torrent is to enclose it in a "contracting funnel" of fire.

PART II.—CERTAIN TACTICAL VIEWS OF COLONEL BOND.

The line to be adopted in searching for a solution to future tactics is laid down as follows, by Colonel Bond :—

["A certain experience since the war of the training of troops, of being instructed and of instructing, has led me to think that the watchword of our training for war ought to be 'reality,' that the test of everything which we teach and practise must be : Can the troops really do this? with the weapons and munitions, etc., with which mobilization will actually provide us, with the men we have, against the actual enemy we are training to fight, in view of the methods and weapons which he may be expected to use, is it probable that this method will succeed? . . . If this is true, then the great enemy to our training will be found in 'formalism.'"]

Here I think is presented to us the key to the secrets of Colonel Bond's tactical theories of war, which apparently are based on the lessons of the recent war, for he writes :—

"What, then, are the true tactical lessons of the Great War? I say, unhesitatingly, that they are the same as for every war in which we have been engaged. We should have learnt three things: The psychology of our soldiers, the material and moral effect of existing weapons in various circumstances, the necessity at all times of thinking objectively, that is to say, of basing action not on theories—on what we should *like* to do—but on the hard facts of the particular case—on what we *can* do . . . Armed with this knowledge, with this habit of thought, with the true spirit of the basic principles of war, and with the will to win, our leaders ought to be certain of victory, wherever their duty calls them."

We must, therefore, cultivate an "objective outlook" and think the thoughts of the front line soldier before we can theorize. The reason why we do not do so is that "The true lessons are avoided because they are of their nature spiritual, difficult to express, difficult to teach, impossible to draw." Formalism can only lead to mental inertia, [" to the retention of obsolete methods beyond their time, to our entering in a new war with the methods of the old, to preparation for the wars of the past rather than for the wars of the future."]

What is required in the place of formalism, which aims at establishing a method, is tactical judgment, [" because in war there is none but the particular case"]. In the past judgment has on the whole been disappointing. [" How to combat this tendency, how to create this judgment: that is the problem."]

From the above condensed ideas on tactics and training I will next turn to Colonel Bond's criticism of Captain Liddell Hart's methods.

Briefly, the charges he brings against this writer are :—

[(i) "That, at the close of a great war, he" has "chosen to base his doctrines not on the experiences of that war, but on unsound arguments drawn from analogies."

(ii) "That he" has "ignored the human factor."

(iii) "That he" has "proposed a tactical system, to be imposed on all commanders up to Brigadiers, involving the use of set and invariable forms.

(iv) "That he" has "intended that system to be universal, regardless of very varying conditions of the Empire."]

The Expanding Torrent system is cast aside: "can there be anything more unlike than inanimate water bursting through a passively resisting dam, and a trickle of tired men, torn and bewildered by the psychological impact of battle, passing through a gap in an actively resisting hostile front to meet fresh, unknown and unlocated dangers ahead? The two things are totally dissimilar."

With the drying up of the expanding torrent we are left with no solution to the infantry attack against a highly-trained and well-equipped antagonist save that of ["tanks or the support of very strong artillery."]

To accentuate these views Colonel Bond quotes the opinion of an infantry officer of much experience. This officer says :—["Not only were great depth and the dispersion of defensive posts forced on us by the great power of the artillery and mortars of the attack, but the possibility of penetrating such a system is absolutely dependent on the possession of tanks or of very powerful artillery support. People seem to forget our experiences in the early days of the war. To attack a regular enemy without using tanks or without the support of plenty of artillery would be to repeat our experiences of 1914–15 with the chances five times as heavily against us. Penetration such as Liddell Hart appears to consider normally possible is, I consider, only feasible under two conditions, *i.e.*, either the posts must be very badly sited or they must be prevented from functioning by very heavy artillery covering fire."]

Part III.—A Criticism of the Theories of Captain Liddell Hart.

The main premises of my criticism on the above two parts of this paper will be the problem Captain Liddell Hart set out to solve, namely, can a science of infantry tactics be established? It may be possible to establish such a science, personally I do not consider it feasible, for though I believe in a science of war, I consider that tactics are the application of this science to the ever-changing conditions of active operations. As Captain Liddell Hart will probably disagree with me, I will first of all examine his scientific method as outlined in "The Man Fighting in the Dark."

He starts by assuming that the fundamental principles of war may be deduced from a fight between two men. With this I agree. Then he adds, "under similar conditions, such as in the dark," and so spoils his premises by selecting a special case. From these spoilt premises he declares his five battle principles.

I will take two cases of two men in the dark which I believe will show that his conditions are special and not general.

(i) It is dark and two men are placed on Hampstead Heath, one at the eastern extremity and one at the western ; they are told to find each other and fight Does warfare resemble such an operation? No, because, not being cats, they might wander about for months and never be near each other. Arm these men with knives, would they seize each other by the throat and then deliver the decisive blow? No, they would immediately deliver a blow, decisive or otherwise, on contact.

(ii) Two men are placed in a room and the lights are turned out It is dark and I am one of the men, what would I do? I would take my shoes off and feel my way to a corner, so that I may gain flank protection. I would place one shoe two yards to my right and the other two yards to my left, and my coat I would take off and place two yards in front of me. Then I would crouch low in my corner and listen. Sooner or later my adversary, following Captain Liddell Hart's method, with left hand outstretched will approach me, strike against my entanglement and in an instant I would launch my attack, aiming a blow at where I calculated his solar plexus was. What have I done? My object is to knock him out; first, I secure myself by selecting a corner and by covering my flanks and front by means of my shoes and coat; secondly, I economize my strength and opportunity by not wandering about in the dark; thirdly, I concentrate my strength by crouching low, and fourthly, when he is near me, I move with lightning speed, surprise him and deliver my offensive. All the means at my disposal I have used—walls, clothing, ears and muscles, and I beat him by better co-operation. I have, in fact, carried out the principles of war, all of them, as laid down in the Field Service Regulations, but I have not reconnoitred, I have not fixed and I have not exploited. I have assumed a "protective formation," and have carried out a "decisive manœuvre"—I have guarded myself and I have knocked out my adversary.

From guarding Captain Liddell Hart deduces the principle of security, with this I agree; and from hitting he deduces the principle of economy of force, with this I disagree; for from hitting I deduce the principle of the offensive.

Now as to his battle principles. The first two—protective formation and reconnaissance, in my opinion, fall under Security, and the last three—fixing, decisive manœuvre and exploitation are special applications of the Offensive. Then, as to the attack principles. Surprise comes under Surprise; speed and momentum under Movement; the soft spot under the Objective; husbanding under Economy of Force; mutual support under Co-operation and exploitation under the Offensive.

All the F.S.R. principles of war are, therefore, included, not as general truths, but (and certainly in several instances) as special cases. Here, in my opinion, is Captain Liddell Hart's initial mistake, and to me it appears to confuse the whole issue of his argument, for several of his principles are not principles, that is general truths, but rules which admit of exceptions. On these faulty premises he bases the theory of his infantry tactics. These tactics I will now examine.

Very rightly, in my opinion, Captain Liddell Hart criticizes adversely our pre-war infantry tactics, which were based on the idea of maintaining a continuous firing line which though it started weak ended strong, so that fire supremacy might be obtained. These tactics were, in fact, but those of an advancing line of pikemen, they were antiquated and the war proved them most costly and totally unsuited to modern weapons. Nothing daunted, Captain Liddell Hart sets out to solve the difficulty, and he finds his answer in reducing the size of the human target by endowing the unit with power of manœuvre—power to make use of ground for cover (guarding) and for fire (hitting) and the result of combining these two is protected mobility.

So far I consider his ideas excellent, but now he jumps the rails of reason. So carried away is he by his discovery that movement, weapons and protection are the elements of war, that he not only calls his attacking infantry groups human tanks, but treats them as if they actually were tanks. Bullets and the fear of bullets are now lost sight of and his groups manœuvre and search for the "soft spot" as if they were encased in half-inch armour plate. The "soft spot" found, and it may only be a few hundred yards wide (and be it well remembered that a machine gun can bring effective fire to bear at a range of 2,000 yards) the human spate advances, it expands outwards, widening the breach, and reinforcements flow through the gap. What do we see here, not the outline of an infantry attack, but that of a tank attack, for one of the commonest uses of tanks, once they have penetrated an enemy's front, is to move them outwards, in order to widen the breach in the enemy's line. The tank can do this, because it is impervious to bullets; the infantry soldier cannot, because every bullet which goes home puts a man out of action. The man in the tank does not care a damn for bullets, the man outside this machine does not care a damn for anything except bullets. I am here taking the simplest case, but even if we add artillery fire, though the movements of tanks become more difficult, so also do those of the attacking infantry.

Setting out to bless the infantry, I cannot help feeling that Captain Liddell Hart has ended by cursing them, and by cursing them he has revealed to us all a system of tactics admirably suited for bullet-proof men and only such as these can rightly be called human tanks. He is, in fact, if not in word, a tank enthusiast.

Part iv.—A Criticism of the Tactical Views of Colonel Bond.

I will now turn to Colonel Bond. In attempting to criticize his views I am at once faced by a real difficulty, namely, a total lack of tangible pegs whereon to hang my criticism. Captain Liddell Hart offered me many "soft spots," Colonel Bond offers me none, for I am unable to differentiate between what is hard and what is soft in his argument. I am enveloped in a thin mist of platitudes and when I snatch a handful of it and open my hand there is nothing there.

It is no good telling me, or any soldier possessing a normal intelligence, that the true tactical lessons of the Great War are the same as for every war in which we have been engaged. This is really too easy, and though philosophically it may be true, to the working soldier it is utterly false. It is no good saying to a watchmaker's apprentice that the art of watch-making consists in constructing a machine which records time, for what he wants to know is *how* to construct a watch. On the shelf behind me, as I write, stands a tall foolscap volume of notes on tanks. In it are recorded over one thousand lessons as regards the use of tanks. I agree that all these lessons could be boiled down into one lesson—the conservation of tank energy in war. Suppose, I tore out the present pages of this book and substituted one page with the above seven words in it, what use would the book be? To myself, who possess some knowledge of tanks, I can frankly say it would be absolutely useless, how much more so to a tank section commander struggling to learn his trade.

I know perfectly well that *a* lesson of every war is the understanding of military psychology and I know also that Shakespeare is a noted poet. Further I know that it is perfectly useless to give Shakespeare to a child who cannot spell out the alphabet, and how many soldiers can spell out the alphabet of military psychology or even can define the words?

But enough, for having now belaboured the philosophic formalism of Colonel Bond, I can turn and shake him by the hand when he says that, if we are armed with "the true basic principles of war," and the will to win, we need never dread defeat.

"We must, therefore, cultivate an objective outlook," and I cannot understand why Colonel Bond has not done so. The object aimed at by Captain Liddell Hart is the establishment of a science of infantry tactics. Colonel Bond tears this science into waste paper, but replaces it by nothing tangible. Had I been Colonel Bond and believing as he does in the basic principles of war, I should have tackled Captain Liddell Hart's argument somewhat as follows:

The object is to defeat the enemy and the means are infantry. What must the infantry do? They must be able to move (principle of movement), hit (principle of the offensive) and guard themselves (principle of security). Then I would in detail examine Captain Liddell Hart's tactics and would discover that the "soft spot" in it was guarding, and that, on account of the extreme difficulty of moving men forward in face of determined machine gunners, movement would cease and, with the cessation of movement, the remaining four principles of war—surprise, concentration, economy of force and co-operation—would be rendered inoperative.

I would then tackle the "soft spot." How can I make this spot a hard spot. Smoke clouds—no, these won't stop bullets and will adversely affect movement; scattered formations—no, these won't stop bullets and will detrimentally affect leadership and consequently the gaining of the objective; artillery covering fire—yes, but this may violate the principle of surprise; armour—yes, but won't this reduce movement?—By Jove! I've got it—the tank. One moment . . . a man in a tank is very much a man in the dark . . . and the expanding torrent . . . of course, of course . . . why it is as clear as a pike-staff. I would now step forward and shake Captain Liddell Hart by the hand.

And this, I am glad to say, is exactly what Colonel Bond does, for after waltzing round his opponent through many pages in which he sticks pins into the "soft spots" of Liddell Hart's tactics, he also, in the words of a friend, proclaims himself a tank enthusiast.

Judgment.

Having now said so many unkind things about both writers, and still fearful of the "contracting funnel," which I feel will soon close on me like the iron maiden of Nuremberg, I wish to make amends and to vanish like a man in the dark, but without having my throat pinched.

I admire Captain Liddell Hart's pluck. He has set out to champion the P.B.I.; he has liberally sweated blood to do them a good turn, and in doing so he has shown a fine spirit. We still have infantry, and the bulk of our army is infantry, and we have very few tanks. It follows, therefore, that, if we go to war in the near future, we shall have to employ infantry; the question consequently to be answered is how are we going to employ them? In my own opinion there can be little doubt that Captain Liddell Hart's method of tactics is a great advance on the method of 1914, for, even if it fail, it will not fail at so great a cost. A method it is, and a method we must have, for it is method which cements a mob into an army.

I admire Colonel Bond's offensive spirit, I am one with him as regards the danger of slavishly following rules and formalities and I shake him by the hand every time he reminds us that when we set out to think of war we must begin by thinking in terms of men. The value of judgment he accentuates and there can be no doubt as regards its value. By judgment we discover truth and then when we have discovered it we inculcate it by method.

Here ends my criticism and my applause. It has been an interesting study, this struggle of two men in the dark. Round the room they creep with their left arms thrust forward . . . there is a throttling grip on each other's throat . . . I can stand the strain no longer . . . I turn up the lights . . . and what do I see? Two men wringing each other's coat tails (loud laughter). Case dismissed!

NOTES ON INSTRUMENT TRANSFORMERS.

By LIEUT. E. A. BARCLAY-SMITH, R.E., B.A. *Cantab.*

ALTHOUGH they play an important rôle on every alternating current switchboard, instrument transformers receive but scant attention in most text-books.

The following notes may prove of some service for a fuller comprehension of the subject.

In addition to their recognized function of transforming high voltages and large currents into smaller and more easily measurable values, instrument transformers play another important part in high-tension transmission, namely, that of insulating the instruments from the high-tension circuit.

Current transformers may have to "take" large currents without much drop in potential. On the other hand, potential or voltage transformers may have to "take" high voltages, but at the same time pass little current.

A bar of conducting metal will "take" a large current with very little voltage drop, but in order that a piece of apparatus may "take" a high voltage and yet pass little current, a large number of alternating flux turns must in some way or another be built up to oppose the high voltage, otherwise it will be necessary to use a large number of resistance coils.

Hence a potential transformer designed to contend with high voltages is of necessity a larger, heavier and more costly piece of apparatus than a current transformer designed to accommodate large currents, provided the output required is small, such, for instance, as would be necessary to work a voltmeter or an ammeter.

It is, therefore, a distinct advantage that under most circumstances more of the latter than of the former are required.

For example, in the case of a three-phase system sub-station where a number of feeders are taken off the mains, three potential transformers only will be required to give the voltages between lines, since these are identical for each feeder. On the other hand, three current transformers would be needed for each feeder in order to ascertain the load taken by each feeder and, more important still, to discover if any feeder is taking an unbalanced load.

In discussing instrument transformers it is necessary, in the first place, briefly to set out the ordinary characteristics of a transformer.

If to the primary terminals of any transformer an alternating

P.D. of value V_1 is applied there is induced a back E.M.F. E_1 in the primary windings, an E.M.F. E_2 in the secondary windings, and a P.D. value V_2 at the secondary terminals. Furthermore, if the secondary circuit is such as to permit a current I_2 to flow in it there will be induced a balancing current I_b in the primary in addition to the magnetizing current I_o which is independent of secondary conditions.

The relations between the foregoing quantities (all R.M.S. values) are as follows* :—

$$\overline{E}_2=\overline{V}_2+\overline{I_2Z_2} \qquad \overline{V}_1=\overline{E}_1+\overline{(I_b+I_o)}\,\overline{Z}_1$$

$$\frac{E_1}{E_2}=k=\frac{I_2}{I_b}$$

where k is the ratio of the primary to the secondary turns, and Z_1, Z_2 are the internal impedances of the primary and secondary windings. The internal impedance of a winding is considered to be the resultant of the resistance of the coils and the reactance due to leakage flux.

For primary pressures over 4000 volts, potential transformers having, of necessity, a large core and many turns in the primary winding with some of them at a high potential difference, are usually of the core type and oil insulated and cooled. For three-phase work three-phase potential transformers are made with star-star windings, the neutral point on the secondary side being brought out to a terminal. (*Vide Plate* I.)

For pressures below 4000 volts they may be of the shell type and air cooled. (*Vide Plate* II.)

Potential transformers generally transform down to a maximum pressure of about 100 volts. For primary potential differences of over 4000 volts the secondary turns usually number about 70, but for lower primary pressures may be as many as 120. The number of primary turns is, in each case, as many as will give the correct pressure ratio.

Current transformers for values of k below 1/40 are frequently found to consist of a magnetic circuit surrounding a single primary conductor; the secondary turns, of course, being wound round the limbs of the magnetic circuit. Examples of this type can often be seen on the bars at the back of a switchboard, the bar itself being the primary turn encircled by the magnetic circuit.

In high-tension systems the primary turn sometimes consists of a rod cemented inside a porcelain sleeve which, in addition to supporting the rod, is surrounded by a ring of iron about which the secondary is wound.

* In this and subsequent discussions the effect of harmonics other than the fundamental are neglected; with the flux wave sinoidal the magnetizing current wave is taken to be the "equivalent sine" wave.

The secondary is well insulated from the primary by such an arrangement.

For values of *k* of 1/40 (*e.g.* 200/5 amps) and above, the primary may consist of two or three turns wound on a hollow cylinder of insulating material inside which are the secondary windings wound round a limb of the magnetic circuit. In similar transformers made for ratios down to 20/5 amps, the primary consists of a much larger number of turns wound on the hollow cylinder. (*Vide Plate* III.)

A current transformer with two or more primary turns used on an H.T. system of over 6,600 volts is generally immersed in a small oil tank to prevent the primary winding breaking down to earth. The two primary terminals are brought out of the tank through the same porcelain. (*Vide Plate* IV.)

The main purpose of an instrument transformer is to produce a secondary pressure or current having a definite ratio to the primary pressure or current.

When the primary of a current transformer is carrying the line current of a power system, the secondary may be open or short circuited, but the drop in the primary or power circuit caused by the transformer will in neither case affect the main primary current to any appreciable extent. Hence there will be a constant primary current and the primary drop will adjust itself to secondary loading conditions. Thus the amount of primary drop is unimportant and no attention need be paid to primary leakage flux.

The primary current has two functions :—

(1) To provide ampere-turns to balance the secondary ampere-turns.

(2) To provide magnetizing current I_o.

Hence, if the current ratio is to be inversely as the turns, the magnetizing current should be as small as possible.

The magnetizing current depends on the flux which, in its turn, depends on the secondary P.D. Thus, for accuracy, the P.D. required to force the desired current through the secondary circuit should be as small as possible, and for ordinary working conditions the saturation of the iron should be well below the "knee" on the B–H curve.

If an ammeter be placed across the secondary terminals the secondary P.D. will be small and the currents, to all intents and purposes, inversely as the turns. Frequently a few turns of the secondary winding are omitted, thereby compensating for the magnetizing current effect under ordinary working conditions.

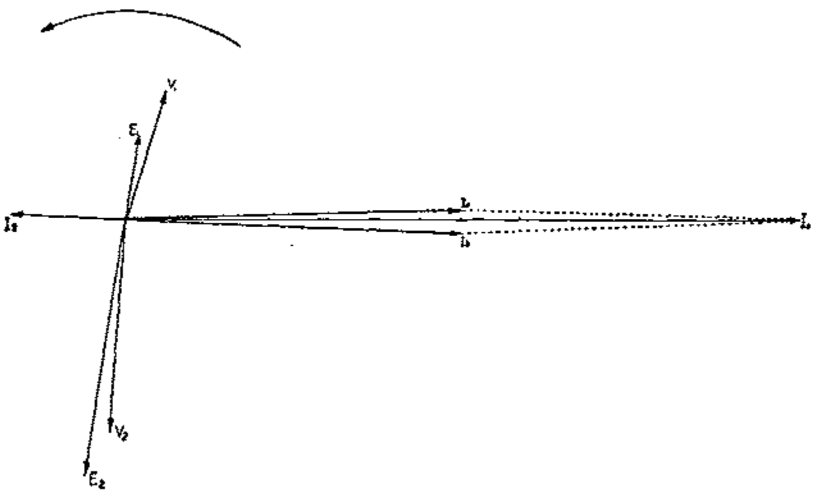
When the primary winding of a potential transformer is connected across the lines of a power system, the current in the primary will not affect the main pressure between lines as long as the secondary is not short circuited (in which case the coils would be rapidly burnt out). Hence there will be a constant primary pressure and the primary current will adjust itself to secondary loading conditions.

From the ordinary transformer equations it is obvious that, if the pressure ratio is to be proportional to the turns, the internal drops in the two windings must be as small as possible. Hence the secondary current should be minimal and the leakage flux very small in proportion to the core flux. To attain these conditions, the core should be saturated at working pressures, and there should be little leakage space between the two windings; at the same time the secondary windings must be well insulated from the primary.

A few turns of the primary winding are often omitted in order that under ordinary conditions the effect of the two drops may be neutralized.

As the name implies, instrument transformers are not intended to transmit much power. Potential transformers, however, as has been previously pointed out, are of necessity fairly large pieces of apparatus, and as their windings must have a certain cross-section for mechanical reasons they can carry an appreciable secondary current, the sole result being that the pressure ratio is altered to some extent.

Sometimes the arrangement is such that the current from the secondary of a current transformer shall work a tripping device in addition to passing through an ammeter. In this case the tripping coils offer a fairly large reactance, and in order that the secondary current may pass, a secondary P.D. leading the current by nearly 90° will be required to overcome this reactance.



Vector diagram for a current transformer, the secondary current of which passes through the coils of a tripping device.

V_1 = Primary P.D. E_1 = Primary E.M.F. I_1 = Primary current.
V_2 = Secondary P.D. E_2 = Secondary E.M.F. I_2 = Secondary current.
I_b = Balancing current. I_0 = Magnetizing current.

Hence there will have to be a proportional drop in the primary circuit leading the balancing current by nearly 90°. To obtain this drop, a magnetizing current lagging behind the drop by nearly 90° will be required. The balancing current and the magnetizing current will thus be nearly in phase. As the constant primary current is equal to the vectorial sum of the balancing and the magnetizing currents, the secondary current will be very nearly minimal for that particular value of the magnetizing current concerned, and the transformer will be in a condition of minimal advantage.

A case has been known where a current transformer intended to work an ammeter and to trip a switch at full load current was found to produce, on full load, a secondary current of only half the value it would have been had the turn ratio been maintained, and it could not be made to trip the switch by any increase in the primary current, however large.

When a current transformer is to be used for working tripping gear, it should contain several primary turns and be capable of giving a much greater K.V.A. output than the current transformers previously described; as a consequence a larger and heavier piece of apparatus is necessary.

It has been stated that removing an ammeter from the secondary circuit of a current transformer without first shunting the ammeter is a highly dangerous proceeding, since, the secondary being on open circuit, the transformer will form a choking coil in the primary circuit. This, it is considered, would cause a considerable reactance drop across the primary terminals and a correspondingly increased pressure difference across the secondary terminals, with the result that, as soon as the secondary circuit is broken by the removal of one of the leads from the ammeter, a dangerous difference of potential will arise between the lead removed and the ammeter terminal.

This is true in the case of a current transformer capable of a certain K.V.A. output, but the following typical example will show that it is untrue for a current transformer designed for the purpose of working an ammeter only.

In the case of a 2000/5 amp. bus-bar type current transformer carrying full load current at a frequency of 50 cycles, the secondary potential difference when the secondary circuit is broken can be calculated as follows :—

On the primary side there are 2000 amperes and 1 turn.

$$\text{Max. M.M.F.} = 0{\cdot}4 \times \pi \times 2000 \times \sqrt{2} = 3550.$$

Length of magnetic path of flux $= 24$ in.

$$\text{Max. Magnetic Force} = \frac{3550}{24 \times 2{\cdot}54} = 58{\cdot}3 \text{ gausses.}$$

For Transformer steel B(max.) would equal about 16500 lines per square centimetre.

Note that the core is saturated.

Cross-section of magnetic path $=0 \cdot 9$ sq. in.

$\phi=$Flux (max.) $=16500\times 0\cdot 9\times (2\cdot 54)^2=95800$ lines.

Effectual secondary E.M.F. $=4\times f\times \phi\times n\times F\times 10^{-8}$ volts.

where $f=$ form factor of E.M.F. curve, $F=$ frequency, $n=$ number of secondary turns.

In this case $E=4\times f\times 95800\times 400\times 50\times 10^{-8}$ volts, and, the wave being assumed sinoidal, $E=84$ volts.

The result cannot be considered a very dangerous voltage.

If the primary current were 100 per cent. overload the secondary potential difference would be less than 100 volts, owing to the saturation of the core.

In the case of a 200/5 amp. current transformer with 5 primary turns, the secondary potential difference on open circuit would be less than 84 volts.

Under many circumstances the secondary circuit of a current transformer is always closed through an ammeter. As the secondary E.M.F. is required to force the secondary current through the secondary winding and the ammeter only, it is never large. As a result, the flux flowing round the magnetic circuit is always small, and in certain designs the necessity for lamination of the core would disappear, since with very low flux densities eddy currents need not be considered.

If the current transformers previously described were made with solid cores, there would be a saving in the cost of manufacture of 25 per cent. However, there is always a danger that some part of the secondary circuit may be broken or by accident be left disconnected. Should such occur to a transformer with a solid core, the latter would speedily heat up and burn the insulation on the coils.

Summary.

1. When the output required is small, potential transformers are more bulky, heavier, and more costly than current transformers.
2. Under ordinary circumstances current transformers are required in larger numbers than potential transformers.
3. Two types of potential transformers are:—
   (a) The core type, oil cooled and insulated, used for pressures over 4000 volts.
   (b) The shell type, air cooled, used for pressures below 4000 volts.
4. Current transformers have one primary turn for large ratios and several primary turns for small ratios.
5. The magnetizing current should be minimal in a current

transformer, while the internal drops should be as small as possible in a potential transformer.

6. Low-power current transformers should not be used for working tripping-gear.
7. The statement that it is dangerous to break the secondary circuit of a current transformer is untrue in the case of a transformer designed for the purpose of working an ammeter only.
8. If the secondary circuit is kept closed through an ammeter, it is unnecessary in certain cases for the core of a current transformer to be laminated.

I have to express my grateful thanks to Messrs. Johnson and Phillips for the loan of photographs of transformers which they manufacture, and to Professor E. Wilson of King's College for most useful criticism. There are certain statements in this paper with which Professor Wilson will not agree and for which he cannot be held responsible.

NOTES ON INSTRUMENT TRANSFORMERS.

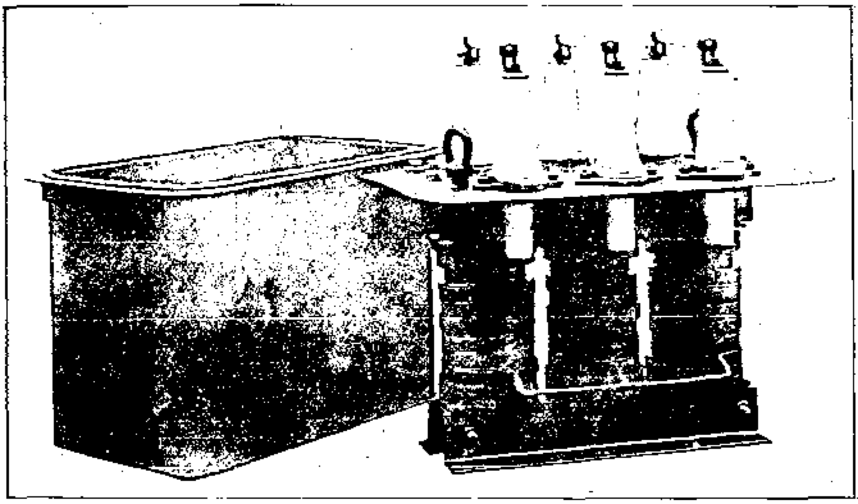


Plate 1.—A 6,600/110 volt, 50 cycle oil cooled and insulated, three-phase potential transformer, with fuses mounted in position, removed from its oil-containing tank shown on left.

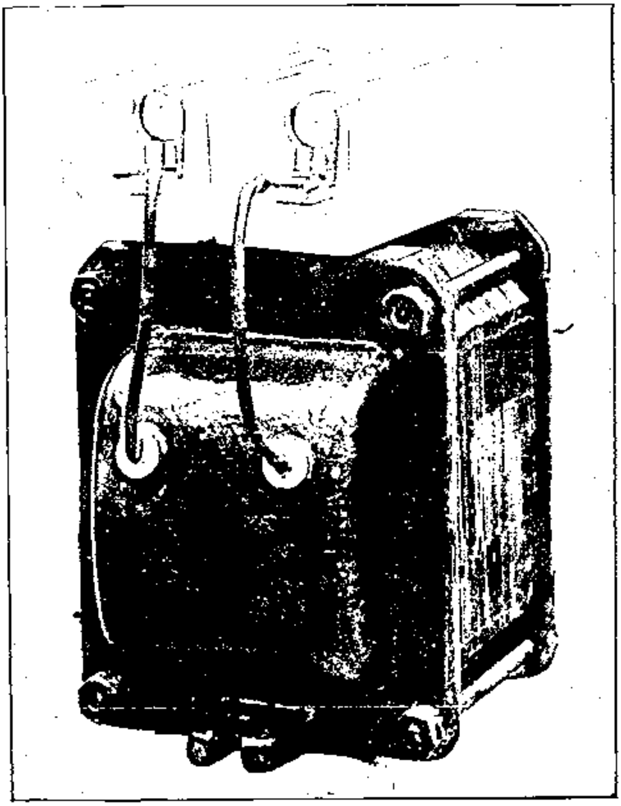


Plate 2.—A 3,300/110 volt, 50 cycle shell type potential transformer, with fuses mounted in position.

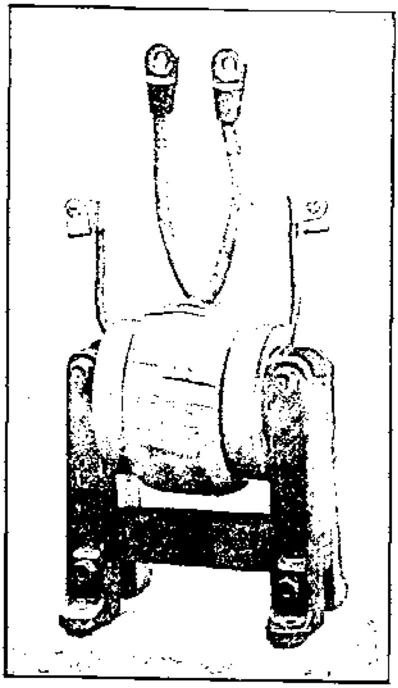


PLATE 3.—A 25/5 ampere current transformer.

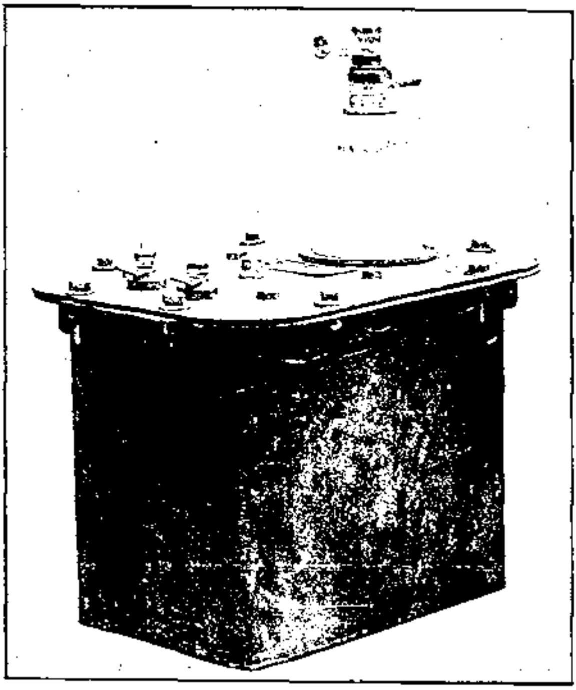


PLATE 4.—A 40/5 ampere current transformer enclosed in an oil tank for use on high-tension circuits.

THE WAY OF AN EAGLE.

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

To anyone who had served in the front line during the last war, it would be a commonplace to say that " it takes a ton of lead to wound a man." And I suppose the average is well maintained in sea fighting, though the unit of success in destruction there is the ship and not the man.

Shooting by Field Artillery at single men was very rarely indulged in, owing to the infinitesimal chances of success and the certain waste of ammunition. I was sniped by a German field-gun at about 3,500 yards while reconnoitring, and it was not till the third round that I was even sure of the nature of the target. What chances of success would an optimistic Gunner maintain for a direct hit from a field-gun on a single man advancing diagonally across his field of fire at 5000?

And the target would only be moving at the rate of from four to six miles an hour, according to his state of mind. Consider a target for a similar gun, but moving thirty times as fast, though five times as large. The chances of a direct hit have decreased six-fold.

These objects are moving in two dimensions, but air fighting has added another, and Gunners who are keen on their art must thank the gods that human beings know so little about a fourth. With an aeroplane moving in three dimensions at anything up to a couple of hundred miles an hour, or from fifty to a hundred yards a second, the barometer of hope in the mind of the most sanguine Gunner must be at something like " forty below." To add to the difficulty of the problem, the target can suddenly arrive by day or night; in fact, the terrors of darkness are greater for the attacked than for the attacker. The chances are, that in the next great war the first notification will not be the cartel of defiance or ultimatum, but a sudden bombing raid of gigantic proportions which will continue throughout the hours of darkness till either the attackers have been scared away or the nerve centres of the country attacked have been so paralysed that the initiative rests with the attackers. Such a raid, if carefully prepared and executed, would be a knockout blow for any but the stoutest heart.

It was with a mind perplexed by this riddle that I attended a

Senior Officers' Course at the Anti-Aircraft School at Perham Down.

After a fortnight's most interesting instruction, but one slender thread of hope remained in my mind for the defenders during a night raid. It consists of the fact that it has so far been found impossible to eliminate the sound of the hum of the propeller and the roar of the exhaust. Means will, no doubt, be found in the future by science to deaden the latter, but every revolving blade has an inherent vibration which it is impossible to quench, and on this propeller note hangs the whole of our salvation at present.

In daylight fighting the target is certainly visible and can be followed, provided that there is no convenient cloud or mist behind which it can dive for safety. The ultimate range of the 3-in., 30-cwt. A.A. gun and fuze is 21,000 ft.; the gun cannot fire very effectively at a greater angle of elevation than 75° and authorities prefer it at less than 70°. So that the total period during which the gun might be able to bring effective fire on the passing target is limited to a couple of minutes while advancing and another couple of minutes while retiring; this was referred to by "Experto Crede" in the May 1922 number of the R.E. Journal. And, conversely, it would seem that the best chance of safety for the aeroplane passing within easy range of a single gun is to steer a course directly overhead, so that for 30 degrees it is within the safety zone, where it cannot be effectively fired at. If the weather is fine enough the spotters can pick up the target while still beyond range, and there will be time for the heightfinders and deflection predictors to give valuable information to the gun, but otherwise the want of time must preclude the efficient use of the numerous instruments of precision which are necessary to measure movement in three dimensions at such a speed.

The problem for the Gunner is to predict the future position, in space, of the target at the instant when the shell which he has previously sped upon its way to the rendezvous will have arrived at that identical spot and burst. If visibility is good and there is time enough, all the necessary readings can be obtained in a fraction of a minute and applied to both gun and shell; the different manipulations are made as automatic as possible by means of the most ingenious mechanical and electrical devices.

The chances of success, then, depend upon the high degree of training, firstly, of the gun commander and instrument numbers in estimating height and deflections, and secondly, of the gun crew in the rapidity and accuracy with which they can carry out their orders.

By night the problem would seem to be made impossible were it not for the slender thread previously referred to. Sound waves are independent of light or darkness, rain or fine. But without some very sensitive detectors, a searchlight beam could only be thrown upon the place where the operator thought he heard the noise. Sound waves move at approximately 1,100 ft. per second, so that, if the enemy is flying at 11,000 ft., and a speed of 150 miles an hour, he has moved approximately 750 yards, or nearly half a mile, from the spot at which were originated the sound waves heard at the gun or searchlight. Each searchlight is supplied with a sound locator, with which a well-trained crew can pick up the target wonderfully quickly on a clear night, and once picked up, three converging searchlights can hold it while within their range and pass it on to the next three in the cordon. And it must be remembered that the aeroplane requires a fairly clear night to bring its mission of destruction to a successful issue.

If our scientific investigations proceed as successfully as heretofore, there does not seem to be any reason why warning of a hostile air raid should not be recorded while the raider is still some fifty miles, or a quarter of an hour's flight, from our coasts. In addition, every class of aeroplane engine makes a different note in vibration. Some are quite easily distinguished by the unassisted human ear, so that there should be no inherent difficulty in recording, on suitable instruments, the difference between all classes of machines.

One night, like Pharaoh, I dreamed a dream; but in my dream the lean years had been followed by the fat years, and there was plenty in the Treasury to enable politicians to act up to the good old Roman proverb which begins, "*Si vis pacem*——," without thought of axes and other hindrances.

In a quiet underground Control Room sat an officer among the shaded electric lights. His country is in the midst of war, and he sits in the centre of the air-intelligence web. Round him, on tables or hanging on the walls, are numerous transparent maps, telephones and electrical instruments, including self-developing cinema films, a tape machine and a master clock.

A telephone tinkles and a spot of purple light appears on one of the maps. He dons a head receiver and a breast transmitter, to leave his hands free, and receives a message of warning from one of the very distant light-ships, which is indicated by the purple glow-lamp; the report is soon corroborated by wireless from one of those Policemen of the Seas, a Naval patrol. Certain land areas are at once warned by the officer on duty, to be ready for air-raid action. He also rouses an assistant by pressing a button at the edge of the table. Five minutes later two of the High Water Mark Sound Locator Stations report a "B" raid (*i.e.*, of two to five machines), probably Gothas or Aviatiks, flying in a S.W. direction. The initial warnings are flashed to their destinations and one of the maps of the Kingdom, divided into large areas by broad black lines, becomes suffused with the dull glow of small electric lamps. Some of the areas become red, others green. The first are those over which the raid will progress if it holds on its present course; the latter, surrounding the red, form a band of green areas which have received the first warning message for preparation. Naval Air Headquarters are busy obtaining all the information available to enable their fighters to sweep up the residue of the raiders when on their return home.

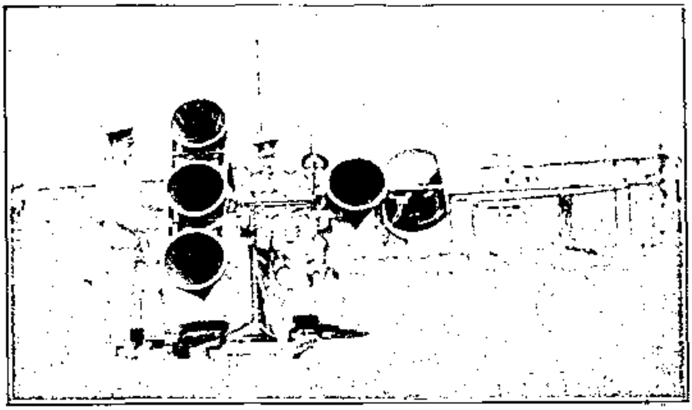
Soon a soft hum in the Control Room indicates that the films and tape machine have come automatically into operation, and are busy with their remorseless indications of the raiders' movements. His leading machine has arrived over the outer sensitive indicator line which follows the shore. A tiny white light has appeared at the coast of another map, and is soon followed by four others, which all move slowly inland. There are five machines in all. The uncoiling films and tape give the details necessary for the military defences, such as the exact height and speed at which each is flying, which, together with the make and size of the machine ascertained from the notes of their propellers, enable the probable object and tactics of the raid to be divined. Three heavy bombers protected by two fighters. Double how they may, the tell-tale spots of light, originated in sound vibration, follow with relentless certainty. The greens on the area map give place to reds, to be surrounded in turn by other greens further afield. The tape machine, meanwhile, has been recording every message sent to the Spider in the centre of his web, as he waits to pounce. These messages are from countless sources, observation cordon posts, county police stations, naval or military garrisons; but the gist of them all, when sifted and weighed, forms an ever-certain clue to the exact position and objects of the "flies," and as such is being transmitted to other offices.

At last they approach an active gun area. In certain battery and searchlight control rooms, five tiny dots of light on a similar squared map are approaching the defended circle: a tape machine gives the corroborated and digested details required to enable all concerned to take action, which is synchronized by the electric sub-clocks.

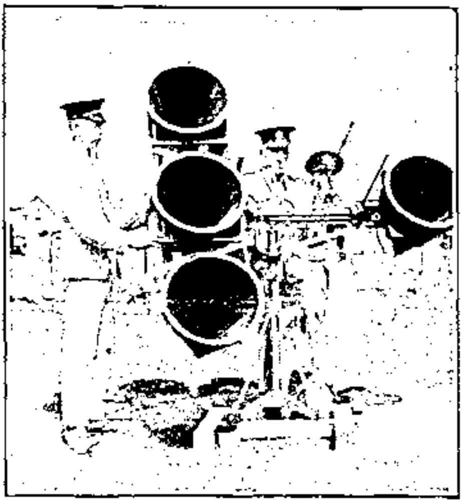
Space above the country-side is divided into great columns of invisible bricks, one and a half miles by one and three-quarters on the ground, while each of the bricks composing the column is a thousand feet high.

Suddenly one of the bricks, the tenth from the earth, becomes alive with bursting shell, while eighteen dazzling pencils of light pierce the heart of the column. A haze makes observation difficult at present, but provides the information that the objective of the raiders has not been reached, for visibility is as necessary to the fly as for the spider. Every defending searchlight is provided with a sound locator, which begins to indicate the direction of the target before it is within range. So that when the expectant beam is eventually uncovered it is already near the required line, and a few

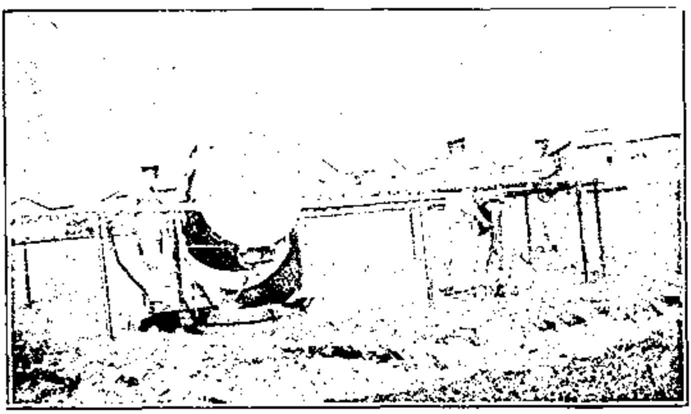
THE WAY OF AN EAGLE.



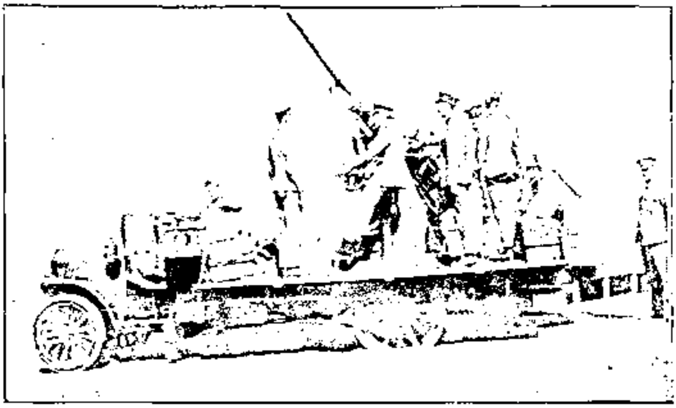
Installation showing Sound Locator on left and Searchlight with Long-arm director behind.



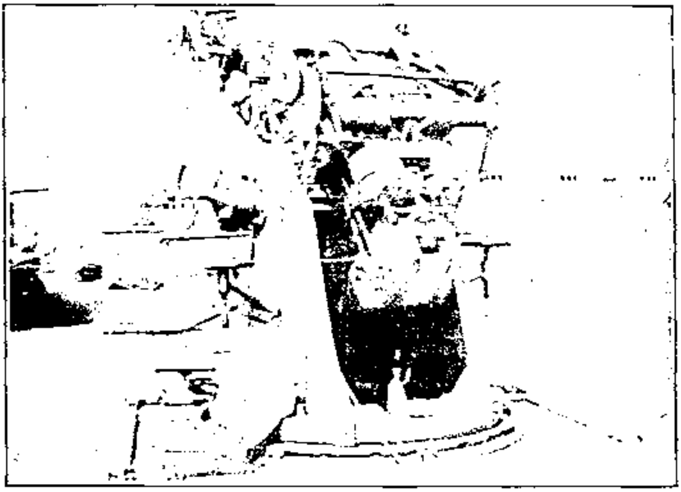
Sound Locator with crew at their stations. The man on the right directs by telephone the man on Long-arm of Light.



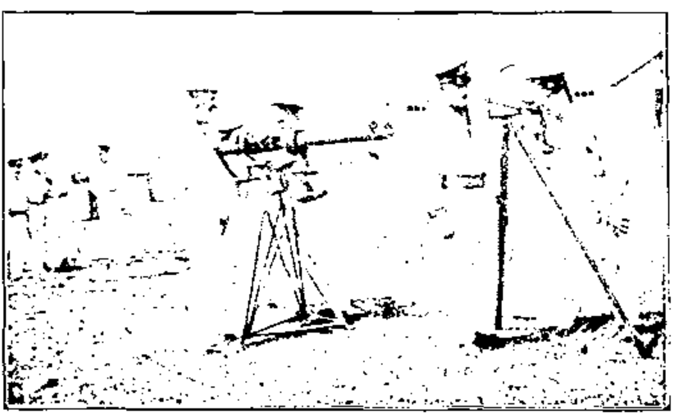
Searchlight emplacement without earthwork defence, showing man on Long-arm with telescope, who directs the beam.



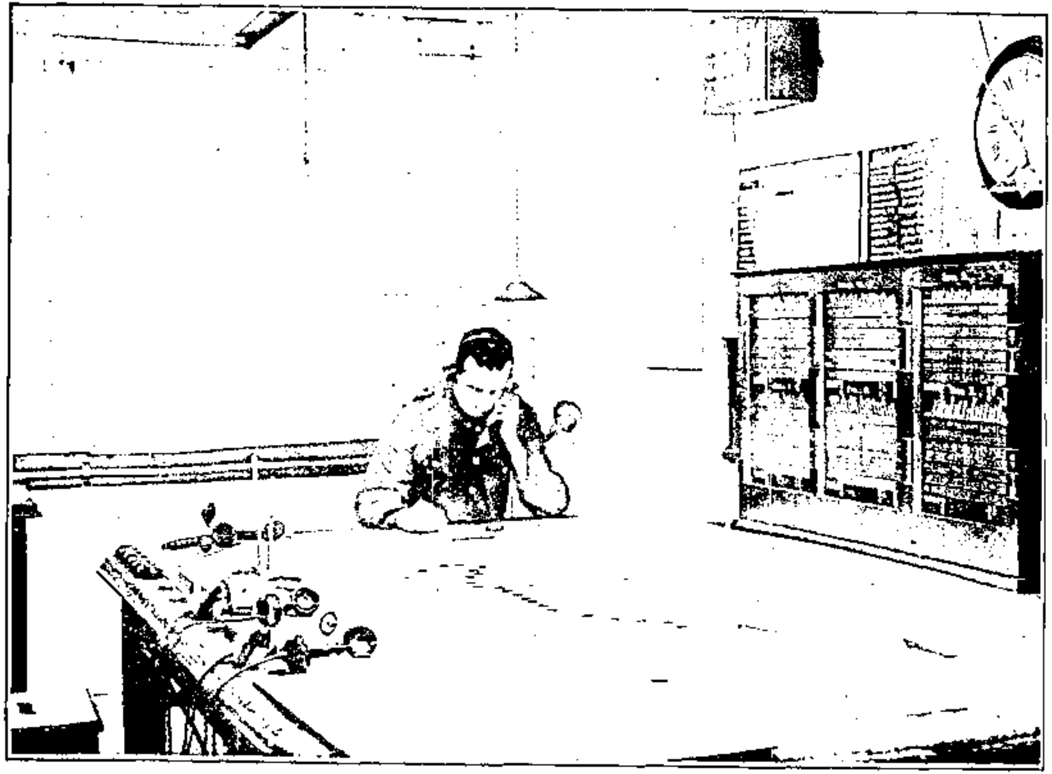
3" A.A. Gun on Mobile Mounting.



3" A.A. Gun on Semi-Fixed Mounting.



Left—Height Finder. Right—Height Fuze Indicator.



CONTROL ROOM LONDON A.A. DEFENCES, DURING THE WAR.

seconds' manœuvring suffices to correct it and make the target visible if atmospheric conditions permit.

At last, in a patch of clearer sky, the underside of an aeroplane is lighted up by a searchlight; instantly two other beams fasten on to the victim, and in the deadly triangle he is held while all the guns in the neighbourhood reach up and finally pull him down. He is one of the escort.

Now the raiders pass out of the turmoil of gun-fire into an area of peace and quiet, where their minds are vexed only by the waving pencils of light which seem always to work in threes. No gunfire! Now is the time to sink to bombing height so that they can see to make sure of the artery in the neck of the enemy which they have come to sever. They pay the penalty of descent by feeling the intangible lights fasten upon them from below. As each beam touches its target, two others immediately join it and all three cease their wavings and remain fixed with a nerve-shaking steadiness. Suddenly a crackle of machine-gun fire from below his tail, and one of the bombers goes nose-diving to earth; he has been attacked without chance of escape, by a Bristol fighter swooping out of the darkness. It is like firing at an illuminated ball in the booth of a country fair. The defending machines can remain in the darkness till they spot an illuminated enemy, when they know that the beams will keep steadily on it and not be a danger to themselves.

Soon the defending zone is crossed and the invaders are met with a second burst of gunfire. No. 2 bomber loses his nerve and feels that he has had enough of it, so he turns round, unloads his eggs and makes a bee-line for his happy home, climbing fast as he goes. But as he clears the outer gun zone and comes over the sensitive sound locators again, his direction, height and speed, indicated by the spot of light on the map, when read in conjunction with the record of the cinema film, tell their unmistakable story to the Spider in his control den, before even the tape-machine begins to corroborate. He makes a terse remark to his subordinate, who passes on the information to the waiting sea-planes which are now cruising at their "ceilings" far above the mist and clouds.

The third bomber gallantly dives for his objective, to be caught by the searching white beams and "archied" in mid career. There is nothing left for the survivor but to climb out of the inferno at top-speed and seek his way back by a devious route at his maximum height till he is clear of all entanglements.

I woke with a fresh problem in my mind. Can the hum of a propeller and the whine of the wind in the rigging be absorbed or covered up effectually by the scientific application of another purposely produced sound vibration, just as one muffles a loudly-ticking clock in a blanket? During the later phases of the last war our precious transports were escorted by destroyers through the dangerous waters. When a submarine attack was thought to be imminent, one destroyer often surrounded the transports with a smoke-ring, through which the assailant was unable to sight its weapon on the target. It should not be too difficult to produce a suitable mist in the atmosphere from kites or captive balloons, even over a large area, so as to cause the enemy to descend to dangerous heights before he can obtain reliable enough information by which to unload his bombs with any degree of accuracy. Gas-shell might produce a larger lethal space than explosives, but greater effect still would follow the discovery of a directional device for the projection of a ray of heat as one now projects light.

EVERY-DAY MATHEMATICS FOR ENGINEERS.

A Lecture delivered at the S.M.E., Chatham, on February 15th, 1923,
by LIEUT.-COLONEL G. H. ADDISON, C.M.G., D.S.O., R.E.

"Divine Mathematics, which alone can purge the intellect and fit the student for the acquirement of all knowledge."—*Roger Bacon*: 1250 A.D.

IT is customary for a lecturer to open with an apology for his unworthiness, followed by an explanation that he is actually much worthier than anyone else. In the present case both apology and explanation are precisely the same, and are simply that I am not a mathematician.

The peculiar psychology of the pure mathematician leads him to surround his trade with a fog of awe and mystery, by means of which he successfully disguises the fact that much of it is a very simple and ordinary business.

All through History one finds this atmosphere of black magic.

The earliest mathematical work, of which any copy exists, is a treatise by one Ahmes, an Egyptian, dating from, roughly, 2,000 B.C., and this bears the illuminating title "Directions for obtaining the knowledge of all Dark Things."

Pythagoras, the first of the great Greek mathematicians, some 1,500 years later founded a school, the members of which were sworn to the utmost secrecy in regard to their knowledge and discoveries.

There is no time for a history of mathematics, but few romances are more engrossing than the story of how the works of those wonderful old Greeks were preserved through the ages by the Arabs, and were brought by them to Spain in the X. and XI. centuries. There they were sedulously guarded by the Moslems from the eyes of Christians and other infidels; and it is recorded* that English men of learning underwent incredible dangers in the endeavour to get copies of these writings. One Adelhard of Bath is stated to have secured the first copy of Euclid after adventures that must have far surpassed those of any modern Bull-dog Drummond.

Later on, again, we find that all through the XVIII. century, English and Continental mathematicians were working apart, and jealously guarding their discoveries from each other on account of a petty quarrel as to whether Newton or Leibnitz was the true author of the Calculus.

* For this and other historical facts, see *A Short History of Mathematics*, by W. W. Rouse Ball. Macmillan & Co.

Now the engineer has no use for black magic or mystery; he wants something that will help him to solve practical problems. I can imagine no better analogy than that which is always used by Professor Inglis; that of the "tin-opener." Doubtless, a tin may be opened without the use of an efficient tin-opener, but the result is generally to damage the fingers and to spoil the contents of the tin. So also an engineering problem may possibly be solved without the use of mathematics; but it is apt to be a laborious and ugly business, and very likely to end in a mess.

It is further true that nearly every branch of common mathematics has its origin in the need for some kind of "tin-opener." Geometry (γῆ—the earth, μετρέω—I measure) was first evolved by the Egyptians in the service of Land Surveying.

Aristotle was led to the study of the lever by noticing how much easier it was to have a tooth extracted by means of a pair of pincers than by the bare fingers.

Arithmetic grew up with the requirements of commerce and trade; this explains at once why a gentleman was never expected to have a mathematical education; a tradition which some of the great public schools and universities have scarcely yet succeeded in stamping out.

Tables, weights and measures are all derived from parts of the body, or from things in common use; *e.g.*, foot, digit, furlong (=furrow-long). The decimal system comes from the fact that there are five digits on the human hand; if we had been born with six, no doubt, the duo-decimal system would be universal. (It seems a pity that we were not !)

The primary unit of weight and measure has almost everywhere been the grain of barley. Such examples might be multiplied indefinitely.

Trigonometry arose from early efforts to study Astronomy.

The Integral Calculus has an interesting origin.* In 1612, there was a mammoth wine harvest in Germany, and no one could say whether the supply of casks would suffice to carry it. The question was referred to a great mathematician, Kepler, who had made a special study of areas contained by closed curves. He solved the problem for the wine-merchants, and subsequently produced a book, the title of which (in Latin) was "A New method of measuring Wine-Casks." This seems to contain the first mention of the Infinitesimal Calculus.

John Napier,† to whom mathematics were mainly a pastime, invented logarithms out of sheer horror at the waste of time involved in long and useless calculations. One of his contemporaries spent the whole of a 70 years' long life in working out the value of π correct to 35 places of decimals; as recently as 1873, one, William Shanks, worked it out to 70 places of decimals !

* See *Applied Calculus*, by F. F. P. Bisacre. Blackie.

† Napier was born about the middle of the XVI. century.

Fortunately for the engineer, two places are generally ample for practical purposes, and these may be read off at once from a slide-rule, which is the natural offspring of Napier's invention.

I suppose that every modern engineer gets accustomed to use a slide-rule at a very early stage. Those who do not are merely choosing to remain in the XVI. century—a not exactly intelligent choice.

This question of degree of accuracy is a very important one, and one on which the engineer and the mathematician wholly part company. Time does not permit me to do more than draw attention to its importance, and to the fact that common-sense is chiefly required in dealing with it.

This virtue—common-sense—is also highly necessary in approaching the subjects of limiting values and infinite series, through which we are led to the Calculus. In the V. century, B.C., the philosopher Zeno suggested the problem of Achilles and the Tortoise, which so disturbed the mathematicians of that day, that for centuries the Greeks avoided any idea of an infinite series; in the XX. century, A.D., infinite series and limits are mere commonplaces; but what is to be said of a system that introduces new ideas to a youthful student in words such as these?—

3. *Definition of a Differential Coefficient.*
If fx denotes any function of a variable quantity x, and if $f(x+h)$ denotes the *same* function of $x+h$ when x receives a small *increment h*, then the *limiting value* of

$$\frac{f(x+h)-fx}{h}$$

when h is indefinitely diminished, is called the *differential coefficient* of fx with respect to x, and is denoted by

$$\frac{dfx}{dx} \text{ or } f'x.$$

This definition may be conveniently expressed as

$$\frac{dfx}{dx}=lt\,\frac{f(x+h)-fx}{h}$$

(lt) being the abbreviation employed to denote the limiting value, as h is indefinitely diminished and ultimately becomes zero.

Since $f(x+h)-fx$ is the increment of fx corresponding to the increment h of x, therefore

$$lt\,\frac{f(x+h)-fx}{h}$$

is the *ultimate ratio* of the corresponding increments of fx and x, denoted by dfx and dx, and called the *differentials* of fx and x; and thus $\frac{dfx}{dx}$ measures the *rate of increase* or *growth* of fx; while $\frac{f(x+h)-fx}{h}$ represents the *average* rate of increase of fx from x to $x+h$.

The chief object at the outset of our subject is the determination of the differential coefficients of functions, and the application of them to the discussion of the geometrical and analytical properties of the functions.

The algebraical difficulty in the determination of the differential coefficient lies in the reduction of its original *indeterminate form* $\frac{0}{0}$ to a determinate limit.

(Hall and Knight, *Higher Algebra*, chap. xx.)

The name *derivative* or *derived function* is sometimes used instead of *differential coefficient*.

The differential coefficient $f'x$ of a function of fx may be supposed to derive its name from being the coefficient which turns the differential of x into the differential of fx.

(Wicksteed, *The Alphabet of Economic Science*, p. 32.)

This extract is taken from the opening pages of a work that was for years the standard text-book at many universities and public schools, and also at the R.M. Academy. The last paragraph is peculiarly inspiring, and the oftener I read it the easier I find it to realize why it took me thirty years to understand that there could be any possible use in a differential coefficient.

And yet, of all branches of mathematics, the Calculus is surely the most essential in the fashioning of our tin-opener.

In physical problems we are continually dealing with quantities that are varying in such a way that any change in one of them produces a corresponding change in the other or others. Many simple cases may be—and very frequently are—solved by graphical methods; but these are usually slow, and the accuracy of a solution depends upon the very variable personal equation of the draughtsman. One may take a mean, or average, value; this is aptly described by the French as being the certain method of getting an inaccurate answer. The only perfectly general method of attacking such problems is by means of the Calculus, and it was invented by Newton for that purpose.

Let me take a very simple case: the statement of Newton's 2nd Law of Motion, which may be analysed in either of the two ways following:—

$$P = M\,a$$

$$P = M\frac{dv}{dt} \ldots\ldots (i) \qquad \Bigg| \qquad P = M\frac{ds}{dt}\cdot\frac{dv}{ds} = Mv\,.\,\frac{dv}{ds} \ldots\ldots (ii)$$

whence, integrating between values $v = v_1$ and $v = v_2$,

$$P \times t = Mv_2 - Mv_1 \qquad \Big| \qquad P \times s = \tfrac{1}{2}\,Mv_2^2 - \tfrac{1}{2}\,Mv_1^2,$$

or, put into words:—The time effect of a force is to produce change of momentum, while the space effect is to produce change of kinetic energy.

Equations (*i*) and (*ii*) are termed "differential equations," and many will be met with in engineering problems that are little, if any, more alarming than these two. Certain standard tricks have to be learnt, and by their means the solutions of all ordinary equations that arise out of practical work can be written down.

I choose this particular example because it has a tale attached to it.* Rather more than two hundred years ago, a bitter quarrel began as to whether the "force of a body in motion," as it used to be expressed, should be measured by the product Mass × Velocity, or Mass × (Velocity)^2. England asserted the former; Germany, supported by Holland and Italy, the latter; France was divided. The whole of Europe was shaken by the struggle for 40 years, during which rival mathematicians set each other an endless series of problems, but always with the result that both sides got the same answer. Finally a Frenchman proved that they were, in fact, both right. One party had measured the effect over an interval of time, the other over a distance, and the whole trouble was one of phraseology.

This question of phraseology has a very important bearing on our subject; witness the extract given earlier. A good example of the devastating influence of bad phraseology is the following:—It is stated† that the Ancos, a race on the River Amazon, cannot count beyond three, since the simplest word they can find for three is "Poettarrarorincoaroac."

An illustration of a similiar kind to my first may be met with in the study of Thermo-dynamics.

In any reversible change, when the working substance does work, we have the simple relation:

$$\delta Q = \delta E + p\,\delta v,$$

which is merely a statement of the general principle of the Conservation of Energy. A little easy algebra and heat theory combined lead to:—

$$\delta Q = C_v\,\delta\tau + p\,\delta v \qquad C_v = \text{specific heat (constant volume)}$$

$$\frac{\delta Q}{\tau} = C_v\frac{\delta\tau}{\tau} + \frac{p\,\delta v}{\tau} \qquad p v = R\tau \quad \therefore \frac{p}{\tau} = \frac{R}{v}$$

$$= C_v\frac{\delta\tau}{\tau} + R\,\frac{\delta v}{v}$$

$$= C_v\,\delta\,(\log_e \tau) + R\,\delta\,(\log_e v)$$

$$= \delta\,(C_v \log_e \tau + R \log_e v)$$

$$= \delta\,\phi.$$

* See *Elementary Rigid Dynamics*, by E. J. Routh. Macmillan & Co. (*Note.*—This book is by no means elementary. The title may be designed to suggest that the author knew a great deal more than is actually printed).

† *History of Elementary Mathematics*, by F. Cajori. Macmillan & Co.

The last expression in brackets tells us something about the "state" of the working substance; it is what the mathematician calls a "function" of the state. Now experience shows that this function can be made use of in all sorts of ways; and so, instead of the cumbrous expression in brackets, it is written as ϕ, and given the name "Entropy." There cannot be much difficulty in following this. But the academic mind loves to introduce Entropy as a special brand of the black art; and it is usually done in the following form:—

"*Definition*: If a body A at temperature (absolute) τ gives out to another body B, also at temperature (absolute) τ, a quantity of heat defined by Q, then A is said to lose entropy $\frac{Q}{\tau}$ and B is said to gain entropy $\frac{Q}{\tau}$."

This almost certainly produces a state of mental confusion, for it suggests the idea that entropy is something concrete instead of being a mere mathematical function. A young officer complained to me once that nobody had ever succeeded in explaining to him the meaning of entropy or of $\sqrt{-1}$. I could not help suspecting that, in the case of entropy, this failure was due to a fixed belief that it was something that could be poured out of a can!

$\sqrt{-1}$ receives very ponderous treatment in most text-books, under the heading of "Unreal Quantities." Now it may be unreal to the mathematical mind, but, if it is to be of any kind of use to the Engineer, it has got to become real, and without its aid a blunt spot will be left on the tin-opener. The Engineer writes "i," or in electrical work "j," which is both real and simple.

A very common case, in which it turns up, will be quoted.

An ordinary vibration, or "Simple Harmonic Motion," as it is called (such as the motion of a pendulum, or of a weight hanging from a spring) is distinguished by the fact that acceleration is always proportional to displacement; so the equation of motion may be written:—

$$\frac{d^2x}{dt^2} = -\mu x \qquad \text{(notice the sign).}$$

or

$$\frac{d^2x}{dt^2} + \mu x = 0,$$

or, in a more convenient form

$$\frac{d^2x}{dt^2} + p^2 x = 0.$$

This is solved by substituting $x = e^{mt}$,

whence $m^2 + p^2 = 0$, or $m = \pm i p$, and the whole solution is

$$x = Ae^{ip} + Be^{-ip}.$$

If the expressions for sin x and cos x* are known it will be easily realized that the solution can be written in the more useful form

$$x = P \sin pt + Q \cos pt.$$

This gives all possible information about the motion. Most practical cases are such that the motion starts from rest, when one term disappears we have $x = Q \cos pt$ simply.

Now suppose that, tending to check or "damp" the motion, there is some kind of friction which is proportional to the velocity; the equation becomes

$$\frac{d^2x}{dt^2} + q\frac{dx}{dt} + p^2x = 0,$$

and, going one step further, let the point of support of the spring or pendulum be given a "forced" motion of simple harmonic nature; then the right-hand side of the equation, instead of being 0, takes the form Q cos pt, and the whole equation, by a little simple algebraical juggling, may be written

$$A\frac{d^2x}{dt^2} + B\frac{dx}{dt} + Cx = Q \cos pt.$$

This has a stodgy look, but again, if the trick is known, the whole solution can be written down at sight. If the trick is not known (and obviously there is no time this afternoon to teach tricks), this statement and what follows must be taken on trust. If the simple vibration with which we started is one that occurs n_0 times per second and the forced vibration given to the point of attachment occurs n times per second, then after the damping effect has died away (which it does very soon in practical problems) the final steady motion is given by

$$x = \frac{Q \cos 2\pi nt}{4\pi^2(n_0^2 - n^2)}.$$

This shows that, if n_0 and n are nearly equal, x becomes nearly equal to infinity, which means that the motion becomes enormously magnified. This is the condition usually known as "resonance," and its importance can hardly be over-emphasized. It is probably at the bottom of most structual failures and accidents in the past, which at the time, seemed unaccountable.

Modern "wireless" depends completely on it; the rolling of a

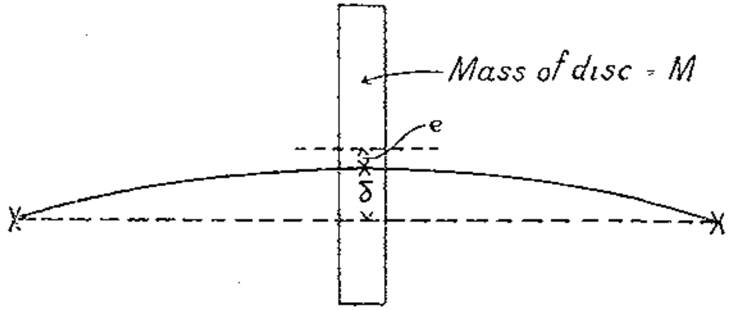
* $\sin x = \frac{e^{ix} - e^{-ix}}{2i}$; $\cos x = \frac{e^{ix} + e^{-ix}}{2}$.

ship at sea; the danger of marching across a suspension bridge without breaking step; these are some of the innumerable examples that might be quoted.

But without mathematics I do not think this subject can be studied or understood in the slightest degree.

The phenomenon known as the "whirling" of a shaft provides a simple and instructive example of a similar kind.

*Suppose we have a disc fitted on a long slender shaft, which is rotating freely in bearings. It is well known that the disc does not remain concentric with the shaft, nor does the shaft remain quite straight.



Let the centre of gravity of the disc be e distant from the shaft, and let the shaft bulge an amount δ.

Then the centrifugal force required to maintain an angular velocity w is

$$M(\delta + e) w^2.$$

This is supplied by the whippiness of the shaft, and the equation of motion may be written

$$M(\delta + e) w^2 = K\delta,$$

where K is some factor depending on the physical properties of the shaft,

$$\delta (K - Mw^2) = Me w^2.$$

$$\therefore \qquad \delta = \frac{Me w^2}{K - Mw^2},$$

then if $K - Mw^2 = o$, or $w = \sqrt{\frac{K}{M}}$, δ tends to become infinite;

* This example was suggested to me by Professor C. E. Inglis, to whom I owe a deep debt of gratitude for much other help in the preparation of this paper. Any small knowledge, and all the great enjoyment that I have gained in the study of practical mathematics are unreservedly due to Professor Inglis and the Staff of the Engineering Laboratory, Cambridge.

that is to say "whirling" occurs. After this critical value is passed, and w grows larger, δ becomes negative; and when w is very large indeed, δ becomes approximately equal to $-e$.

This theory controls design in modern high-speed work; such as, for instance, the Laval Turbine. It shows that speed must be run up through a definite "critical" value before the load is put on; and, secondly, that the shaft must be "whippy": such shafts are, in fact, made as whippy as possible, consistent with the horse-power they have to transmit; a result that would be difficult to anticipate without the aid of mathematics.

These are just a few examples that are typical of the sort of every-day work that confronts an engineer; and I hope it will be agreed that there is nothing very terrible in the mathematics that are needed to deal with them. Certainly there is nothing that is not well within the powers of anybody who has achieved a commission in the Royal Engineers.

Mercifully it is no longer necessary to struggle through intellectual sloughs of despond such as I referred to earlier; there is a large and ever-growing number of text-books written by and for practical men, and they are at the disposal of all who care to study them.

I have spent a considerable time in abuse of mathematicians. The remainder of this lecture shall be devoted to reminding you of a few of the wonderful things that mathematicians have actually done for engineering. And let me say at once that, if our subject this evening was the contributions made by Engineering to the advancement of pure Mathematics, there would be nothing more to say; for the balance is all on one side.

I have already referred to wireless telegraphy. Sixty years ago Clerk-Maxwell produced the electro-magnetic theory of light, and worked out mathematical equations which still remain the last word in wireless theory; these also form the pivot of the whole of the modern mathematical theory of the Universe: the commonly called Einstein theory. It remained for engineers to discover practical means of using Clerk-Maxwell's work; and, as is well known, it took them a considerable time.

The Michell thrust-block is a classic example of its kind. A thrust-block provides the connecting link between the body of a ship and its engines. Everyone knows what a troublesome thing a bearing can be, even in small engines; when one is dealing with the transmission of huge horse-power, such as that required for a fast cruiser, the difficulties are enormous, and, before Michell's invention, the thrust-block was one of the most involved, bulky and expensive parts of a ship's mechanism. Everyone knows, too, that the laws of solid and of fluid friction are diametrically opposed; whilst those of friction between two surfaces, separated by a film of lubricant, are different from either, and are of an involved character.

A very great mathematician and engineer, Osborne Reynolds, worked out the mathematical theory of lubrication* a good many years ago; but not in a form that made it immediately applicable to practice. An Australian consulting engineer, Michell, extended this theory, and succeeded in working out the exact mathematical relations for a film of lubricant in use under practical conditions.† He arrived at perfectly amazing results; but, when tested in practice, they were found to be completely confirmed. It is impossible for me to attempt any description of the theory, but some of the practical effects may be of interest.

The oil film acts like a ball-bearing, and was found to reduce friction to 1/20th of that in a flat thrust.

The old-fashioned multi-collar horse-shoe type for one class of battleship was 25 feet long; the Michell block that replaced it is 7 ft. long, and just one-third of the weight.

The old type could only be designed to transmit pressures of 20–50 lbs./sq. inch; the Michell block transmits 200–300 lbs./sq. inch. Another feature is that, before the advent of the Michell block, it was impossible to know the actual thrust produced in a ship. At first it was only feasible to specify "indicated" horse-power; later the Thring-Hopkinson torsion meter made it possible to measure shaft horse-power; but, with the Michell block in use, it is quite simple to measure the actual thrust. As an example of a recent test:—The 37,000 horse-power engines of H.M.S. *Hood* were found to give a dead thrust of 100 tons.‡ The possible applications of pressure film oil lubrication must be almost limitless and one may expect in time a revolution in thrust and journal bearing design. I have already heard§ of a motor car in which the piston transmits thrust direct, without the intervention of any connecting rod.

A very well-known mathematical triumph is in connection with the submarine telegraph cable. I believe that the first cable that was laid failed to give any result, and the whole question was put before that great man, Lord Kelvin. He reduced it to a mathematical equation and showed how to find solutions for any given conditions. As a result, before the Atlantic cable was laid, it was known exactly how long it would take a signal to get across, and how much its intensity would be reduced in the passage. Endless time and huge sums of money must have been saved by Lord Kelvin's work.

A most interesting case, in which the mathematician and the

* For a summary of this, see *Engineering*. July–December, 1915.

† See *Engineering*. January–June, 1920. Also *Proc. of Inst. of Naval Architects*. April, 1919.

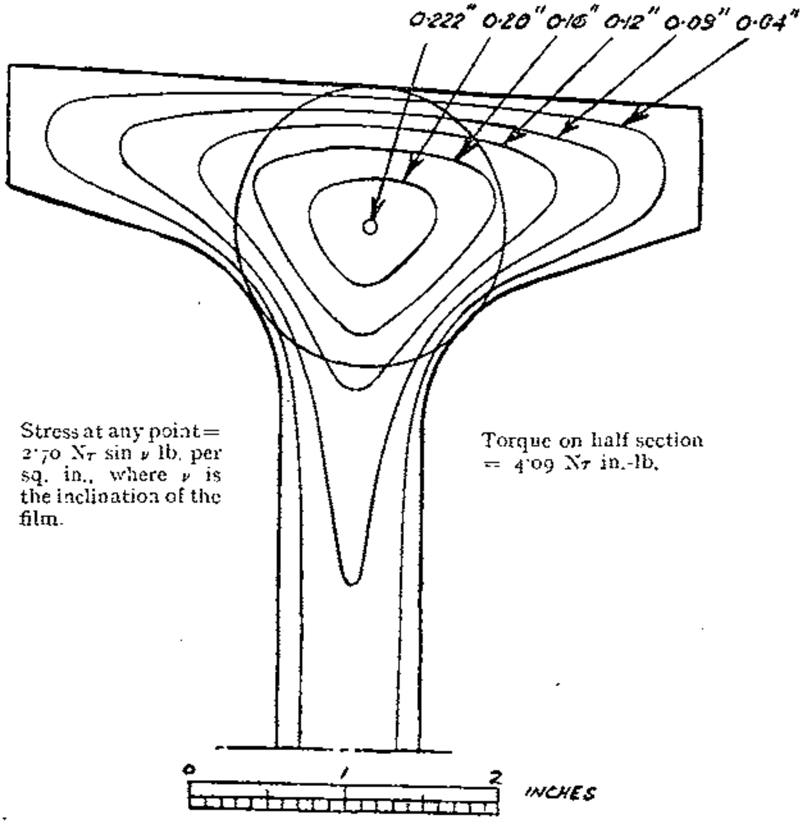
‡ These figures were given me by Mr. T. C. Wyatt, Fellow of Christ's College, Cambridge.

§ Also from Mr. Wyatt.

engineer together succeeded where mathematics alone had failed, is provided by the work of Messrs. Griffith and Taylor in solving torsion problems by the use of soap films.* Anyone who has studied the mathematical theory of elasticity knows that, when an elastic bar of uniform cross-section is twisted, the equations representing the stresses that are set up can only be solved in the case of a very few simple sections. Now in aircraft design many parts, such as, for example, airscrew blades, have a very complex section ; and there is no known mathematical means of finding either the stresses or the torsional stiffness. By what seems a freak of coincidence, however, the torsion equation of an elastic bar has precisely the same form as the equation representing the displacement of a soap film, due to a slight pressure acting on its surface, the film being stretched across a hole in a flat plate of the same shape as the cross-section of the bar. Mr. G. I. Taylor, a Cambridge mathematician, who was working at the Farnborough Aircraft Factory during the war, followed this up, and showed that the curvature of the soap bubble would represent the rate of variation of shear stress in the section, and that the volume of the bubble would give the total torque required for a given twist. Mr. A. A. Griffith, an engineer working at the R.A.F., designed a very simple apparatus for producing and measuring the soap bubbles ; and together they investigated a large variety of cases, from which they were able to enunciate various new theorems of great practical interest and value. Comparison with direct torsion experiments showed that the percentage error in the soap film measurements was very small, and well within practical requirements. By plotting the contours of the bubble the stress distribution is illustrated graphically. Mr. Taylor very kindly gave me permission to reproduce an example, which represents the section of a wooden aeroplane wing spar. The picture brings out clearly one of the new theorems which resulted from the work. It is that the maximum stress occurs at or near the points of contact of the largest inscribed circle, while there is an unstressed fibre at or about the centre of that circle. The simplicity of the apparatus has to be seen to be believed, and it can, of course, be used with equal facility for the most complicated and irregular sections. I find it difficult to explain why this method has not received more universal appreciation. Probably it is due to the comparatively limited number of structural problems in which it is required ; it is also true that mathematicians have lately been succeeding in finding solutions of equations which had previously defeated them. I believe that Messrs. Griffith and Taylor have further developed the method to deal with the shear stresses due to bending.

* See *Proc. of Inst. of Mech. Eng.* December, 1917.

Lines of Shearing Stress in the Torsion of a Wooden Spar to scale.
The figures give the heights of the contour-lines of the corresponding soap film.



My final example is concerned with work that is actually in progress at the present time. A subject that has always worried engineers is the exact nature of the stresses set up in a railway bridge by loads moving across it. The problem is a very complex one, and is closely connected with that of "forced vibrations," which I spoke of earlier; but it is extraordinarily difficult to find out anything definite about these vibrations. In old days a new bridge was tested by noting its deflection under load; a very incomplete test, but the best that could be devised. Recently meters have been perfected by means of which the actual strains in the various bridge members are registered. This is a great advance, and, by taking enough observations under varying conditions, it should be possible to arrive at useful conclusions. But such practical investigation, unsupported by theory, is a kind of groping in the dark, and can only lead to empirical formulæ, which may or may not prove to be what are really wanted. If mathematical confirmation can be provided, then the results become conclusive. This mathematical work is being done at Cambridge, where the same problem was attacked seventy-five years ago* by a very famous mathematician, Professor (later Sir George) Stokes. His problem took into account the mass of the moving load, but not of the girders; consequently his results had little or no bearing on the practical problem, where the mass of the girder may be as large as, or even larger than, the mass of the moving load. Stokes noted the weakness of his method in several respects, but does not appear to have carried the investigation further. Professor Inglis started by making similar assumptions,† the reason being that this enabled a differential equation to be written down without great difficulty. But he has gradually realized that a closer connection with reality is obtained by considering the girder to have mass, but the advancing load to exert a steady downward force on the bridge; or, in the case of the driving-wheels of a locomotive, a pulsating force. The reason for this is that the bulk of the mass of the train is spring-borne.

Working on these lines, good progress has been made, and finite conclusions, which are not too complicated to cope with, have been arrived at.

There are really two distinct problems involved; the effect of the moving load, and the impact effect. The first one is finished, and Professor Inglis has most kindly given me the accompanying graphs (see *Plate* on p. 92), which show that, given perfectly smooth running, the effect of the moving load is scarcely different from that of a statical load. Smoothness of running is, of course, never completely attainable, but it varies greatly under different conditions; *e.g.*, the movement of an electric engine is far smoother than that of a steam locomotive, in which the balance weights and other causes produce a considerable impact effect. The impact problem is not yet finished, but enough has been done to prove how highly unsatisfactory is the custom of multiplying by a fixed "live load" factor.

It may interest experts to know that the whole mathematical mystery is locked up in a partial differential equation of the form:—

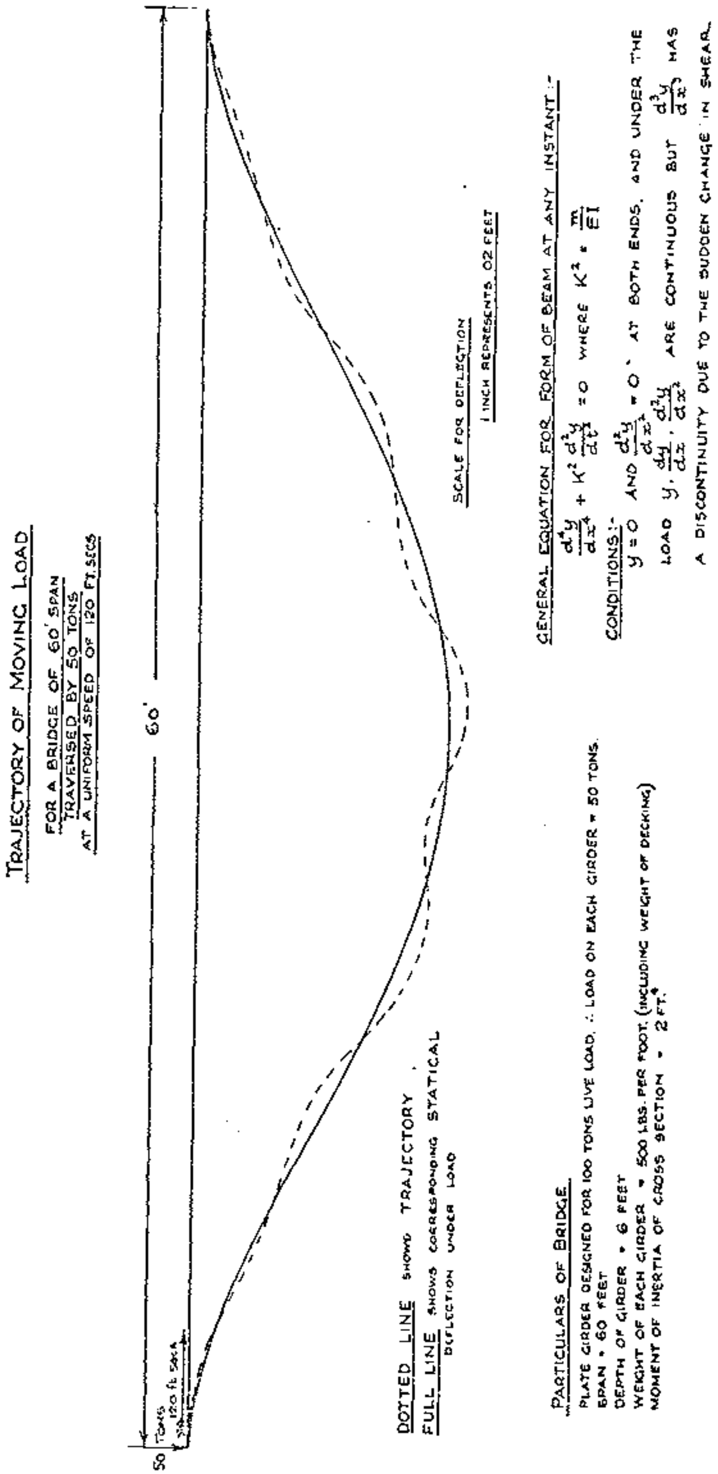
$$\frac{\partial^4 y}{\partial x^4} + K^2 \frac{\partial^2 y}{\partial t^2} = 0, \text{ where } K = \sqrt{\frac{m}{EI}},$$

subject to 1 shear and 4 end conditions.

Perhaps it is hardly necessary for me to say that this class of mathematics does not come within the "every-day" category;

* This was about the time when the Britannia tubular bridge over the Menai Straits was being built. Theoretical knowledge was extremely hazy, and this great bridge was designed in accordance with experiments made on models, which were tested to destruction.

† He had not heard of Stokes' work until he had completed his own and realized its failings. In looking for confirmation of his own solution of an involved equation he found a reference to a paper by Stokes, in which exactly the same solution was arrived at.


TRAJECTORY OF MOVING LOAD
FOR A BRIDGE OF 60' SPAN
TRAVERSED BY 50 TONS
AT A UNIFORM SPEED OF 120 FT. SECS
60'
50 TONS
120 ft secs
DOTTED LINE SHOWS TRAJECTORY
FULL LINE SHOWS CORRESPONDING STATICAL DEFLECTION UNDER LOAD
SCALE FOR DEFLECTION
1 INCH REPRESENTS ·02 FEET
PARTICULARS OF BRIDGE
PLATE GIRDER DESIGNED FOR 100 TONS LIVE LOAD, ∴ LOAD ON EACH GIRDER = 50 TONS.
SPAN = 60 FEET
DEPTH OF GIRDER = 6 FEET
WEIGHT OF EACH GIRDER = 500 LBS. PER FOOT. (INCLUDING WEIGHT OF DECKING)
MOMENT OF INERTIA OF CROSS SECTION = 2 FT.⁴
GENERAL EQUATION FOR FORM OF BEAM AT ANY INSTANT:-
$\frac{d^4y}{dx^4} + K^2 \frac{d^2y}{dt^2} = 0$ WHERE $K^2 = \frac{m}{EI}$
CONDITIONS:-
$y = 0$ AND $\frac{d^2y}{dx^2} = 0$ AT BOTH ENDS, AND UNDER THE
LOAD $y, \frac{dy}{dx}, \frac{d^2y}{dx^2}$ ARE CONTINUOUS BUT $\frac{d^3y}{dx^3}$ HAS
A DISCONTINUITY DUE TO THE SUDDEN CHANGE IN SHEAR.

nor can such equations be manipulated by a tin-opener. Professor Inglis, for all his light-hearted talk of tin-openers, is a mathematician of a very high order.*

The last equation was quoted in order to provide the mathematicians among my audience with some of the mental stimulus, which I fear may have been lacking in the lecture. For the rest of us I think the moral is that the Engineers' every-day type of mathematics has got more than one aspect to it. Besides enabling us to handle ordinary problems for ourselves, it has got to provide us with the knowledge to recognize our own limitations, and the wit to make use of the extended powers of others.

When old Euclid was Professor of Mathematics at the University of Alexandria, he was one day asked by a pupil who was just starting Geometry: "What do I gain by learning all this stuff?" Euclid summoned a slave, and said: "Give the lad some coppers, since he should make a profit out of what he learns." Let me remind you that all of us, as officers of the Royal Engineers, receive a number of coppers in return for stuff we are expected to have learnt. I am convinced that without mathematics we can neither earn those coppers, nor be worthy of the honourable title of Engineer.

* I ought to add that every one of the great men quoted in these examples was a member of Cambridge University. Ever since the days of Newton, Cambridge has led the world in the advancement of mathematical and physical sciences.

A GLIMPSE AT THE MACHINERY OF REVOLUTION.

By CAPT. L. CHENEVIX-TRENCH, C.M.G., D.S.O., R.E.

WE in England fortunately know very little of revolutions and how they are managed; it may, therefore, be interesting to look a little behind the scenes, at the events which culminated in the German revolution of the 9th of November, 1918.

Before there can be a revolution, the masses of the people must, by some means or another, be brought to the right frame of mind.

In Germany the numbers of people who voted for Socialist candidates for the Reichstag had risen from 352,000 in 1874 to 4¼ million in 1911, and in 1914 there were over 100 Socialist deputies.

On the 5th August, the day before the Reichstag assembled to vote war credits, the German Social Democratic party met to decide what policy it should follow, and by 78 votes to 14 decided to agree to the credits.

Scheidemann headed the majority, and Karl Liebknecht the minority. From this date the majority Socialists were absorbed in the war-party, and Liebknecht and his handful of followers constituted practically the only anti-war influence in the whole Empire. For war itself they had but little hatred; they opposed it mainly because the government and all their political enemies supported it; and some of them probably even welcomed it for the opportunities it might be expected to bring to upset the existing order of things.

In all belligerent countries much the same split between patriotic and revolutionary Socialists occurred and in every one of them the latter were at first heavily defeated. Karl Liebknecht followed in the footsteps of his father Wilhelm in 1870 and, like him, voted against war credits and raised the cry of "peace without annexations or indemnities."

During the latter part of August he attempted to raise some peace meetings, but was dissuaded therefrom by his friends, who thought that, in the then state of public opinion in Germany, he would probably be lynched. He did, however, again cast his vote against the second war credit on 2nd December, 1914. His speech for that occasion was refused admission to the Reichstag records, but a few hundred copies of it were privately circulated. It was shortly after this that he, Franz Mehring and Rosa Luxembourg sent their New Year's greeting to the London "Labour Leader," apologizing for the part played by the German majority Socialists. The latter retorted by solemnly censuring Liebknecht and his followers for their attitude.

Growing bolder, Liebknecht made a speech at New-Kölln, advocating the class war not after, but during, the great war. Two months later his speech was reproduced and circulated, with the result that he was conscripted for the Landsturm Ordnance Corps, while his most active colleague, "Red Rosa," was imprisoned, and Franz Mehring's newly founded paper, *The International*, was suppressed. This firm action by the Government had a very damping effect on the revolutionary movement, which was not yet strong enough to stand many such shocks.

Rosa, however, managed to smuggle out of prison a number of articles which were entitled "Letters of Junius." These were fairly widely circulated both in Germany and abroad, and served to keep things going.

In reading these letters one cannot help being struck by the great difference in quality between them and our own home-grown stuff, such as appears in the *Communist* and similar publications. The German writings strike a much higher note than our own. Though "loot" and "something for nothing" is the ultimate aim of both, in the former this aim is very skilfully concealed by appeals to the intellect, which would have but little effect on the British Reds.

Rosa's arrest was due to the way in which she accused the authorities of conniving at brutality to recruits, and it is said that she had over 900 men prepared to vouch for over 40,000 specific acts of ill-treatment. The Government rightly considered her a very dangerous person, for, though her appearance was perhaps not of much assistance to her, she had a power of speech which could, in a few moments, whip up her audiences to frenzy. During most of 1915 Liebknecht's military duties kept him fairly quiet, though he did manage to speak occasionally in the Reichstag, and certainly once at an open-air meeting. Early in 1916, however, there began to appear, at intervals of two or three weeks, a series of letters over the signature "Spartakus." These were usually inspired, if not actually written, by Rosa and Liebknecht.

On the 13th January the Majority Socialists formally expelled Liebknecht from the party, thus providing further evidence of the perhaps not unfortunate split, which exists between the Socialists and Communists. Nevertheless he continued to speak in the Reichstag, in and out of season, and seems to have been allowed a wonderful latitude before being called to order. On the 1st May, 1916, being Labour Day, Liebknecht addressed a mass meeting in Berlin. His speech had been previously printed and circulated, and it is curious that the authorities allowed the meeting to take place. At its conclusion, however, he was at once arrested, tried, and sentenced to two and a half years' penal servitude. On appeal the sentence was increased to four years and one month, together with six years' loss of civil rights. On June 28th, as a result of the circulation of his speech in his defence, and of the publication of his sentence, a strike of 55,000 munition workers took place in Berlin, and others in the country.

These strikes were repressed by the authorities without much severity, and a few of the revolutionary leaders were taken for military service. This, combined with the loss of Liebknecht, sufficed to keep the movement quiet for the rest of 1916, which was devoted to propaganda.

The rather primitive duplicating methods hitherto used were found unequal to the growing demand for literature, and a regularly printed journal entitled *Spartakus* was now widely circulated.

The Russian revolution of the spring of 1917, though not nearly thorough enough for the German Independent Socialists, as Liebknecht's party was called, was of great value to them, to be held up as an example of what could be done. The numerous extreme left groups, which had been forming all over the country, began to draw more together and a feeling of some confidence was engendered which found expression in quite a number of strikes.

One of the largest of these, in April, 1917, was a protest against the reduction of the bread ration. Government, however, succeeded in putting down the trouble without very much difficulty, and once more the movement was driven underground. The Revolutionaries now directed their efforts still more to propaganda, and claim that as a result of this the value of the two youngest recruit classes was very much diminished.

Strikes organized for the 2nd September, 1917, were, nevertheless, almost complete fiascos, partly, probably, because of counter-propaganda issued by the Government throughout the factories and workshops.

The next impetus which the movement received was through the success of Lenin and Trotski in November, 1917. Though Ludendorff has declared that the dispatch of these men to Russia was a matter with which he and Hindenburg had nothing to do, its effects on the German army were most serious, and numbers of men, infected with the virus of Communism, penetrated into the country from Russia.

At the end of January, 1918, the Independent Socialists felt themselves strong enough to arrange for a big strike as an echo of those which had taken place in Austria, a fortnight before. The notices calling the strike were issued in the name of the "Executive Committee of Workers' Councils," of which we now hear for the first time. As showing how good their organization was, it is worth noting that the notices calling the strike for the 28th January were not issued till the 27th.

Some of the Committee wanted to issue the notices on the 24th, but were over-ruled, because the Government might thus have time to prepare counter-measures. This strike was a great success;

over a million workers came out, 600,000 of them in and about Berlin. It was planned to last three days, but went on for a week. A good deal of rioting took place and many people were killed. Among the 40,000 men and women arrested was Kurt Eisner, who subsequently became Minister-President of Bavaria.

In April, 1918, the Government took advantage of the military successes in France, to reduce the bread ration and postpone the Prussian electoral reform bill. These measures were not actively resisted, except by pamphlets, which now appeared in ever-increasing numbers. The troops, particularly those on the lines of communication, were specially catered for, the literature intended for their perusal being on a much lower level than that issued in other directions. The officers were held up to ridicule and contempt, and equal pay, food and accommodation were demanded for all ranks. This pamphleteering continued till the final break-down and, reinforced as it was during 1917 and 1918 by propaganda from abroad, undoubtedly contributed very largely to the formation of a public opinion suitable for the action of the actual revolutionary executive committee.

This committee came into being on the 9th February, 1918. On that date the U.S.P. (Unabhängige-Sozialisten-Partei) lost its leader, Richard Müller, by arrest. The committee asked Emil Barth to take his place, and he consented to do so on his own terms, which were as follows:—

The committee was to call itself the "Revolutionary Committee" and to act up to its name. The party was to aim at Revolution. It was to be under his unquestioned leadership, with all subordinate leaders nominated from above, and not elected from below. The strictest secrecy was to be maintained as to the existence of the central committee, which would deal almost solely with the main question of when the revolution should be attempted. All other business was to be carried out by sub-committees, each so organized that no one man could give away more than a small amount of information to the authorities.

Some of the subjects with which these committees were to deal were:—

- Money;
- Arms and ammunition;
- Intelligence about the enemy, under which heading police, troops and the Majority Socialists were grouped;
- "Storm-troops";
- Supervision of their own comrades;
- Labour, etc., unions, and so on.

The sub-committees were to meet once a week and were to keep touch with the factories and workshops by means of men nominated, not elected, to represent them. Barth demanded unhesitating self-sacrifice from the leaders, as the only thing which could justify their demanding it from the rank and file, and finally declared that he would accept the leadership if unanimously elected.

The vote was then taken, and 17 of the 18 cards were marked with his name. The eighteenth card was unmarked, but one member, Heinrich Maltzahn, appeared no more at the committee meetings and Barth accordingly took the lead. His first steps were to get his organization perfected, and in this he met great difficulties.

In consequence of the January strikes the Government was very active, and reports spoke of little but arrests and courts-martial. So much repression was carried out that at one time it looked as if the movement was going to break down again, but, driven forward by Barth, as soon as limbs were cut off they were pushed out again, and the organization gradually rendered almost invulnerable.

Much of his energy had to be devoted to heading off the "Spartakists," who believed in demonstrations likely to provoke repression. Barth did not agree with this sort of action, which, he said, only resulted in the loss by arrest of the most active and energetic of his men. He believed in thorough preparation and organization, careful choice of opportunity, and one single and vigorous stroke. Jogisches, the then leader of the Spartakists, had many a conference with him, but though they never actually quarrelled, they could not come to any agreement.

As an example of the order which was growing up in the organization it may be mentioned that a regular scale of separation allowances was laid down for the families of men in prison. A wife got 25 marks a week with 5 marks for each child, and 30 marks a month as lodging allowance.

In April, 1918, some of the more hot-headed of his followers thought that a good moment had arrived, but Barth would not allow any move. They must wait, he said, till defeat had loosened the discipline of the army, and then strike their blow before the defeated and disorganized troops had had time to flood the country. He foresaw that, in the latter event, any government which might be formed, would only survive a very short time.

Some difficulty was met with in the provision of arms, and his reports complain of the profiteering prices which had to be paid for them. Hand grenades, too, were hard to come by, but money overcame all difficulties and soon a good stock of weapons was built up. There seems always to have been plenty of money, and though its source is not disclosed, there can be little doubt as to where it came from. Treasurers were generally very honest, for though the funds were kept under various names in different banks, they were never mis-applied. The formation of so-called "Storm-troops" was a most dangerous task. It began in August, 1918, after the failure of the July offensive in Champagne. One at least had to be formed in every big factory, and it was only the knowledge that the extreme penalty for any indiscretion would be exacted, by the Committee if not by the Government, that kept their existence a secret. The Majority Socialist in this, as in many other matters, constituted the greatest danger to the Revolutionaries. The blow dealt by the British Army on the 8th August showed that Barth's time was drawing near, and he stiffened up his organization till, by the time the Reichstag re-assembled on the 22nd October, he was ready for anything.

The Spartakists arranged a demonstration for this day. At first he would have nothing to do with it, but subsequently, in order to keep control as far as possible in his own hands, withdrew his opposition and ordered a few factories to take part. Only about 8,000 men came out and, after a few brushes with the police, dispersed quietly when Barth passed the word for them to do so. As a result of this demonstration, Liebknecht was released from gaol, whereupon another took place, about 20,000 strikers joining in and drawing Liebknecht through the streets of Berlin in a carriage filled with flowers.

When he and Barth met, it appeared immediately that they were not in accord. He thanked Barth for what he had done while he had been in prison and said that he would now resume the leadership and show how a revolution should be made. Barth begged him most earnestly not to act wildly, and spent the next two days in urgent and anxious endeavours to bring him into line and avoid wasting all the good work of the last eight months. Eventually Liebknecht consented to come to a general committee meeting and talk the matter over. This he did, but annoyed and alarmed the committee by bringing with him four friends, unknown to the committee, and in spite of his having been specially asked to come alone. He made an impassioned speech, which was, however, more suited to a mass meeting of his constituents than to a group of hard-headed business-like conspirators, and concluded with reproaches for their idleness during his absence.

Barth replied very tactfully, though he must have been furious. He attributed Liebknecht's misconception of the situation to his long and gallant service in prison and recalled how the first demonstration of May-day, 1916, had only led to his arrest and suppression of the movement for 11 months; how the second, in April, 1917, had been followed by eight months' subjection, and so on; demonstration followed by repression and repression followed by inaction. He pointed out how the morale of the masses followed the military situation and concluded by demanding discipline and no independent action.

After an inconclusive discussion the meeting was adjourned till the 28th. Barth was much troubled by Liebknecht's indiscretions, and on one occasion threatened to shoot him if he gave any more trouble. The discovery by the police of a store of hand grenades' and the arrest of an important "storm-troop" leader showed that things were approaching a crisis.

It was on the 28th October that the mutiny among the sailors broke out in the 3rd Squadron, and by the 31st the whole fleet was in revolt. Information about this seems only to have reached the capital piecemeal, and though no doubt it would, in itself, have sufficed to bring about the revolution, almost as soon as it actually occurred, the U.S.P. seems to have carried its preparations forward with little reference to events in the Navy.

Probably much bloodshed was for the moment thereby avoided.

A certain Lieut. Beerfelde was for some time the technical military adviser to the U.S.P., but he had for some time been in prison, and it is not till now that it was thought necessary to find a successor for him. Eventually Ledebour produced a certain Lieut. Waltz (*alias* Lindner). He was not altogether trusted, though if he was to be of any use he had to be told enough to make him dangerous. Care was, however, taken to keep from him the exact location of the house chosen as headquarters for the day of revolution, which was now carefully prepared and stocked with 100 rations. On the 1st November Barth proposed that the 4th should be *der Tag*. All provincial reports were good, and everything seemed ready, particularly in the Army and the troops round Berlin. On the 2nd the matter was further discussed, plans were gone over carefully, maps marked and dispatch riders and guides all told off. Then the committee's courage began to fail; the more they looked at it the less they liked it, and eventually, much to his disgust, Barth had to agree to a postponement till the 11th. He personally was having a particularly trying time, since he dared not go into his own house, though he knew that his two children were very ill. He describes how the first intimation he had of the death of one of them was, when passing down the street seeing a coffin being carried into the house. The postponement was not a simple thing to arrange, particularly in so far as the troops were concerned, but by strenuous efforts it was managed. Apparently the co-operation in Austria, which had been arranged, could not be altered. However that may be, the Austrians did not wait, but went ahead independently. In the result this had no ill effects, but if they had been suppressed the task of Barth would have been made much more difficult.

On Wednesday, the 6th November, when a conference of the principal "storm-troop" leaders was being held, warning was given that the house was being watched. Barth let everyone out by a back way, then, in a spirit it seems of pure bravado, went himself to the front door, where he was met by a Lieutenant with three lorry-loads of troops. He appears to have so annoyed the young officer that he was kicked down the steps and told to clear off—which he did.

On Friday, the 8th, another meeting was called, but before it met, Barth rang up several of the more important men, only to find that they had been arrested. He decided to act at once, and called the "storm-troop" leaders, and such of his colleagues as he could get hold of, to a meeting at eight o'clock that evening. After posting outposts all round the quarter, to ensure that the police could not approach without warning, he took the chair and spoke as follows:—

"Comrades, the meeting is opened. Däumig, Müller and Liebknecht have been arrested. I ask for power to act at once. Those in favour hold up their hands. Those against? Thank you; the motion is carried unanimously.

"Now—I dictate. To-morrow is the day.

"I dictate a second time. No one of you is to go home to-night.

"I dictate a third time. From 6 a.m. to-morrow you are not to go about alone, but always in pairs, so that one can watch the other. This is not mistrust, it is merely prudence. Now the meeting is adjourned, while I write orders for to-morrow."

He then drew up the proclamation calling a general strike for the next day and ordered 30,000 copies to be ready by 4.30 a.m. Next he put the finishing touches to his already prepared orders, but had no sooner done so than a dispatch rider arrived with a complete set of the Government orders for counter-measures.

These showed that the plans had been given away, and a completely fresh set had to be made out; by dint of feverish work they were ready by midnight, and were then gone through with the "storm-troop" leaders. The necessity for most vigorous action was impressed upon them. Violence was to be avoided as far as possible, but if anyone refused to come out of the workshops he was to be persuaded with a pistol to his nose! Anyone offering resistance or even arguing was to be shot at once; but no violence!

Columns were to be formed with the employees from each factory or group of factories, with one-third of the "Storm-troops" in front, one-third behind, and one-third distributed along each side, to keep the formations intact, and prevent looting. The danger of allowing looting to break out was very thoroughly understood by all the leaders, and very little of it occurred during the early days of the revolution.

The route to be followed by each column was carefully marked on maps and explained to the men told off as column guides. Any police who attempted to oppose the column were to be attacked at once by the "storm-troops," but if they then cleared off they were not to be pursued. Soldiers, if armed, were to be invited to join the "storm-troops" leading the column; if unarmed they were to fall in in rear.

Factory gates found closed were to be broken open, and delegates sent into every barracks to fraternize with the troops; particular care was to be taken to do nothing likely to provoke them. If the troops declared for revolution their officers were to be placed in arrest in barracks, for their own protection. Every dispatch rider and guide was to arrange for an efficient understudy to take his place if necessary, and dispatch riders were to bring reports hourly from each column, of which there were eleven, to headquarters. These reports were to be short and in writing and were to state :—

The names of factories visited and the numbers of workmen in them;
The numbers which came out on strike;
The numbers which joined the column;
Details of any collisions with troops or police with approximate casualties;
Numbers of troops joining the columns;
The position of the column at the time of reporting, and the position it was expecting to reach in an hour's time.

The first reports were to be sent in at nine o'clock. Rendezvous for troop leaders for issue of hand-grenades were arranged, each leader being ordered to bring a carrying party with sacks or baskets.

The meeting then broke up.

On his way to his headquarters the police made an attempt to arrest Barth, but his escort drove them off, and by six o'clock he was sitting alone in the obscure house which had been chosen, waiting for the storm to burst. Till ten o'clock he heard nothing, then reports began to come in, showing all going as well as, or even better than, he had hoped. At 11.15 he issued orders for the advance to the final objectives, the War Office, Town Hall, Wilhelm Strasse and Reichstag buildings, which were duly taken almost without resistance. The Kaiser announced his abdication and the revolution had begun. Barth's work was done. He joined with Scheidemann in the provisional government which was immediately formed, but things did not go the way he wished. He proved himself more and more out of sympathy with his colleagues and after a few months retired into private life. Some of his one-time colleagues were less fortunate, Kurt Eisner, Rosa Luxembourg and Karl Liebknecht all meeting their end in the turmoil and bloodshed which reigned in Germany in the early part of 1919.

ENGINEER FIELD PARKS IN MESOPOTAMIA.

By MAJOR F. C. MOLESWORTH, R.E.

SOME interesting articles on the subject of the supply of engineer stores to armies in the field have appeared in the *R.E. Journal* lately. The following notes on Engineer Parks with the Mesopotamian Expeditionary Force may prove useful.

The campaign in Mesopotamia can be divided into three portions: first, a period of uninterrupted success, beginning with the landing at Fao on November 6th, 1914, and ending with the battle of Ctesiphon on November 22nd, 1915; secondly, a period of reverses, beginning with the retreat from Ctesiphon, and ending with the fall of Kut on April 29th, 1916; and lastly, a resumption of successes, which lasted till the Armistice. Of these, the present article deals with the first two only, as the writer was invalided in June, 1916.

In common with all administrative services in all theatres of war at that period, it was, for engineer parks, a time of trial and error. It is these trials and errors, however, which contain the most valuable lessons for the future, and on these early mistakes was built up the organization which succeeded.

The force to be served grew from two brigades at the date of the occupation of Basra to two divisions in April, 1915, after which its strength remained stationary until after the battle of Ctesiphon, when one all-British and two mixed Divisions were added.

The arrangement by which engineer stores were supplied to forces based on India was by means of engineer field parks, six of which existed in peace time, that is to say, the stores were kept in Ordnance charge in certain arsenals, and stationery and books in M.W.S. Offices. The personnel was found from various sources on mobilization.

The list of stores was based on the Tirah campaign of 1897–98, and had undergone little alteration as the result of subsequent expeditions. The list was contained in *Army Tables, Engineer Units*, from which it appeared that a Field Park was intended to serve a division of all arms. The list was fairly comprehensive, but the quantities therein, when the stores did arrive at Basra, represented in most cases only a few days' consumption. It is only fair to state that the preamble in *A.T.* stated that the list was only intended to facilitate the selection of equipment for any particular operation.

The personnel was laid down as :—

1 B.O.
2 B.N.C.O.'s.
2 Indian N.C.O.'s.
12 Indian artificers (followers).
12 Indian Khalasis (*i.e.*, superior coolies, also followers).
1 Indian clerk.

However, mobilization of the Field Park (No. 5) did not take place until late in November, 1914, and consequently a good deal of improvisation had to take place; the British personnel did not reach Basra until early in December, the stores did not fetch up until early in January (they were delayed in the Shatt-al-Arab owing to quarantine) and the Indian personnel arrived as late as January 26th. But early in November, as soon as the destination of the 6th (Poona) Division, then mobilizing, was known, the purchase of a large quantity of engineering stores was ordered. These were obtained in Bombay, and loaded on the *Ganges*, which sailed soon after the headquarters of the division.

Basra was hopelessly lacking in open spaces big enough to dump any quantity of stores. The Shatt-al-Arab river was bordered by continuous date-palm groves extending two or three miles back. As an Arab saying puts it, " The date-palm does best with its feet in water and its head in hell," and consequently all the date-groves were, naturally or artificially, below H.W.M. Perpendicular to the river were canals, primarily for the irrigation of these date-groves, secondarily for navigation by flat-bottomed boats called *ballams*. The canals were bordered by *bunds*, often wide enough only for foot-passengers, and, as experience subsequently proved, very liable to be breached at spring tides. A rather wider *bund* banked the river. There were no metalled roads, and communication parallel to the river was only possible by narrow paths winding through date-groves, crossing the canals by precarious bridges. It was, in fact, easier and quicker to go any distance by *ballam* instead.

Reports late in the campaign on the port of Basra commented adversely on the congestion of small buildings along the river-front, but the authors did not realize the cause thereof, namely, that at the beginning of operations the river *bund* and its immediate neighbourhood constituted the only practicable space for building; inland was an uninterrupted series of date-groves whose very existence depended on their periodic inundation.

It was not only a case of establishing a base, it was one of creating dry land to put a base on. Almost the only localities above H.W.M. were occupied by Arab villages.

The *Ganges* arrived in the stream on November 27th, five days after the occupation of Basra, and began discharging stores. These were placed in charge of the writer, assisted by a R.E. N.C.O. and an Indian sapper. It was at first proposed to use the tennis court of the German Consulate as a park—the park eventually occupied 70 acres, but, before any stores were dumped there, R.E. H.Q. was moved to what was afterwards known as "Engineer House," and the park was placed on the site of a demolished Arab reed-mat village.

The discharge of the *Ganges* was by no means easy.

There were no berths or piers for ocean-going steamers; in fact, there was only one pier, and that a very small one, in the whole of Basra.

The lighters, a species of boat of about 30–40 tons, called *Muhailahs*, were in charge of Arab captains, to whom instructions could only be given through the medium of very second-rate interpreters; the *Muhailahs* used, therefore, to make for the shore and drift downstream until commandeered. As building operations were in progress in many parts of Basra, many *Muhailahs* were unloaded by working parties and lost sight of. But the bulk fetched up at Engineer House, and the Field Park began to function.

In early days there was naturally a struggle between various services for space. The Field Park had to fight with the Ordnance, Wireless Telegraphs, and Indian Base Depôt for space, and the result was a jig-saw puzzle. High ground, as stated above, was very limited. Indeed, as it proved afterwards, all our ground in that neighbourhood was liable to flood.

The Wireless shortly discovered that they wanted to spread earths over the greatest part of the park, the result of which was that trenches had to be cut and stacks resorted. As more stores arrived, the park had to expand, which could only be done inland into date swamps. Of course, the filling in of these swamps was taken in hand early, but earth had to be brought by boat and the process was very slow, besides which the Field Park had to compete with other sites as regards supply of earth, and was naturally a poor second to locations for troops. The spring of 1915 produced some extremely high tides. There were no records to go by, but the fact that these floods destroyed fruit-trees on the river bank, which must have been 10 or 15 years old, showed that they were exceptional. *Bunds* were heightened, but serious floods occurred through the breaking of some of them, besides which water seeped up through the ground. Eventually the E. and M. Company undertook the pumping-out of the area, but the trouble recurred in the spring of 1916. Although by that time the earthed area had been largely increased, the total area of the park had increased very much more, and the result was that the greater part of our timber yard was 2 ft. deep in water.

Here it may be remarked that rain turned the soil into mud of a glue-like consistency. After showers, which were frequent during the cold weather, the park therefore became a marsh.

A greater danger was fire. Fortunately there was only one. This originated in the Telegraph area, and in the hopelessly congested state of the river front area spread rapidly and was within a few yards of the park magazine, the eaves board of which had actually started smouldering, when its progress was stayed. A very small amount of Field Park stores was destroyed.

Mention has been made of the one and only pier in Basra. This, though of the flimsiest construction imaginable, served to land an incredible amount of stores, until it finally gave way, but meanwhile a longer and better pier, running out far enough to take *Muhailahs* at almost any tide, had been built. From this a 2-ft. gauge tramline, made chiefly from scraps discovered in neighbouring yards, was run into the park behind, helping materially in shifting stores. More piers, and further extensions of the tramline, followed as the park expanded.

The first office of the Officer Commanding Park consisted of empty barrels with corrugated iron sheets laid across, the second of a portable magazine, 6 ft. cube internally, in which explosives had come from India, the third, a brick building with a mud-on-corrugated-iron roof, was constructed by park labour, and served to house H.Q. until July, 1916; workshops, stores, godowns, section offices, magazines, and other buildings were made, or adapted from existing buildings, the size increasing as the Force expanded, and the style improving as it was realized that we were in for a long campaign.

There was no official manual in existence which gave any indication of the purpose for which engineer field parks existed. However, we presumed that their purposes were to replenish equipment of engineer units and to supply engineer stores to all formations, and acted accordingly.

What exactly were and were not engineer stores was a question which constantly cropped up between us and the Indian Ordnance Department and the Supply and Transport, and, in fact, continued to the end of the campaign. Peace-time regulations were, of course, a guide, but a most confusing one. For instance, in peace time the S. and T. supplied oil cooking-stoves and the M.W.S. those for all other kinds of fuel. The M.W.S. supplied hip-baths and the Ordnance and S. and T. all other kinds. Was this rather anomalous procedure to continue on field service? Again, there was no distinction in *A.T. Engineer Units* between our own equipment and stores for issue; four tent lanterns were included in the list, presumably for the use of the park staff, but there was nothing to differentiate their purpose from that of, say, the 750 lbs. of gun-cotton we carried; consequently we received indents for both. Units, too, were not unnaturally hopelessly ignorant of our functions, and it is difficult to think of an item which we were not asked, at one time or another, to supply. The terms " Field Park" conjured up visions of leafy shades and grassy slopes, and so demands for hay, straw and grass were not uncommon ; a demand was received for artificial flowers to decorate the G.O.C.'s Christmas dinner table ; but perhaps the strangest of all was that made by a Political Officer for 10 lbs. of chrysolyte ; no one knew what chrysolyte was, and its only known use was for one of the foundations of the New Jerusalem (*Rev.* xxi, 20), and consequently the indentor was asked for what purpose it was required. He would not, however, divulge it. Chrysolyte was eventually procured from India, and found to be raw asbestos.

Demands from Units did not err on the side of modesty. In some cases it was possible to provide a scale, *e.g.*, two 400-gallon tanks per battalion. Later on, when a Works organization was started on L. of C., indents from Units for building materials were *vetted* by the local Works officer before stores were issued.

The employment of local Arab labour was begun within a few days of the inauguration of the Park, at first through a contractor, but in a very short time, directly.

Skilled labour—carpenters, blacksmiths, masons, etc.—was on the whole satisfactory ; an interpreter was needed at first, but in a surprisingly short time the British ranks learned enough Arabic to carry on. It may be remarked that, until March, 1915, most of the building work in Basra was supervised by the field park staff. Labour was paid—always by an officer—on 10-day muster rolls.

An increasing amount of local labour, men, women and boys, was needed for loading and unloading. By the beginning of 1916 practically all the casual labour in Basra was employed by the various departments along the river front, with the result that the labourer selected that where work was easiest and hours shortest : the park fared badly. As a result, the whole control of such labour was taken over by a local British firm, and though the result was not entirely successful, at least it ensured that we got our share.

Naturally, as the force expanded, further personnel had to be obtained from India. The strength of British W. and N.C.O.'s was doubled by May, 1915, and by June, 1916, was several times its original size ; Indian N.C.O.'s were got out similarly. Two more officers were added in March, 1916. Indian Storekeepers and an Indian Accounts establishment were also added. Several stray Indians applied for work and were taken on, and some Armenians —deserters from the Turks—were added.

Unfortunately, sickness in the summer months reduced our numbers ; it was no uncommon thing for a Britisher to be taken direct from work to hospital and thence to India. One very hot day in 1915, more than half the supervising staff reported sick, mostly with heat-stroke. The dislocation to accounts resulting may be imagined. The devotion of many of them to their work, when they ought to have reported sick, was beyond all praise. By June, 1916, one I.N.C.O. only remained of the staff who had originally come out with the park, and the second lot, who came in May, 1915, were beginning to disappear.

As the park expanded, organization into sections became necessary; those eventually adopted were:—

A. Stores received from Ordnance.
B. Workshops and furniture.
C. Timber, bridging material and bulky stores.
D. Hardware and small stores.
E. Dispatch of stores.
F. Office and accounts.
G. Receipts of stores from India.

As soon as the numbers available allowed, sections A–D were placed under an officer named O.C. E.F.P., and sections E and G under another called the "Embarkation Officer."

For supply of stores we were dependent on:—

(*a*) Captures from the Turks.
(*b*) Local purchase.
(*c*) Indents on India.
(*d*) The Ordnance.
(*e*) The E.F.P. Workshops.

As regards (*a*), several Turkish depôts were found in Basra, but the Arabs and then the field companies S. and M. got there first, and left, generally speaking, only a gleaning of heavy or unserviceable articles. The best find was the naval workshop on Ashar creek, but, in December, 1915, we had to hand it over to the Royal Indian Marine, who, much to our disgust, began sending us contingent bills for stores we got from them which had been there at the time of our handing over. The question was referred to the Accounts, who upheld the action taken by the R.I.M., and thereafter two branches of H.M.'s Forces engaged in smashing the Turk had to bill each other for stores, to the great complication of accounts. Presumably, however, we satisfied some white *babu* in India.

Another find was in the godown attached to the German Consulate in Basra, where some 20,000 cub. ft. of timber was discovered; this was eventually paid for to an organization called the "Hostile Trading Co."

(*b*) Local purchases were made very largely in early days. There was a number of British and other firms with large stocks. These were taken over as required, and the firms replenished them from India. This procedure was encouraged, as it ensured that there was a large reserve handy; it saved us from further encumbering our scanty stacking ground; and as such stores were delivered direct where required, it saved us the trouble of unloading. The price was at first arranged by bargaining, but later, contracts were made for a period of three months at a time for:—

(i) Furniture.
(ii) Reeds and reed-mats.
(iii) Hardware.
(iv) Bamboos, *chandals* (*i.e.*, poles) and pickets.

The first lot of tenders opened nearly all read "5 per cent. lower than anyone else," but the contractors soon learned to quote figures.

With the exception of (iv) above, no contract for timber was made. This was because no one contractor could possibly have imported and stored the enormous quantities required. Any stock of timber imported was bound, sooner or later, to be taken over, at prices regulated from time to time by the B.G. R.E. or D.W.

As regards (*c*), orders for stores from India were sent by monthly indents, supplemented by special telegraphic ones. At this time, the only organization was the establishment of A.C.R.E. Bombay (the late Lieut.-Colonel Watson, V.C., R.E.) who, without any addition to his normal staff, undertook the purchase and dispatch of stores valuing several lakhs of rupees monthly. The average time taken from dispatch of indent to receipt of goods was at first about six weeks. This compared most favourably with the time taken by the Ordnance to comply with our indents, which was often nearer six months. It was, however, impossible in the early months of the campaign to get invoices, and usually the only intimation we got was the ship's bill of lading, which was by no means perspicuous—for instance, "iron plates" might mean loop-holed plates, plain or corrugated iron sheets, or even electrical stores.

(*d*) The stores obtained from Ordnance were mostly standardized patterns of tools, *i.e.*, "Vocabulary stores." We indented monthly, and what Ordnance could not supply on the spot, they ordered from India.

(*e*) Manufactures in workshops included a vast variety of articles of furniture, hand-grenades, portable ramps for steamers, grave-boards, plane-table stations for use in marshes 4 ft. deep, ice-chests, punkahs, Sibley stoves, etc.

At Basra, units had to send parties and transport to draw their own stores, though exceptions were made in the case of hospitals. But after the occupation of Kurnah on December 9th, 1914, the dispatch of stores up river had to be thought of. Consignments were sent on river steamers, or more often on a barge tied to a steamer, with an I.N.C.O. in charge. Later on, as the Force spread up the Tigris, Euphrates and Karun, and to Bushire, 200 miles away across the Gulf, it was impossible to send anyone up, and stores were consigned under a way-bill. After the occupation of Amara in June, 1915, it was usually impossible to obtain passage by steamer and a contract was made with Messrs. Lynch Bros. on a tonnage basis for transport in *muhailahs*. During the attempted relief of Kut, practically all the *muhailahs* available were kept with the relieving force for use in the event of an advance. Most of them were empty, but to return them to the base would have given Turkish airmen a hint that a forward move was not intended, and it became practically impossible to send up any engineer stores unless a G.O.C. up river specially asked for space to be allotted on a steamer. After the fall of Kut, matters righted themselves, and we sent up 800 tons during May, 1916.

With this extension of our activities, the question of the affiliation of field parks at out-stations came up. The first to be formed was in 1916 at Ali-al-Gharbi, where a convoy of *muhailahs*, which just failed to get into Kut, had discharged cargoes. This park fed the Tigris corps, but for the reasons stated above, could not be replenished and practically dwindled to nothing. The parks at Kurnah and Amara, which supplied stores chiefly for local use, were soon afterwards added, and in May, 1916, a park was established at Magil. A timber depôt was also formed at Sarraji, two miles downstream from Basra. These parks were under an officer or barrack warden or N.C.O.

The system of accounts produced long correspondence with the Controller of Military Accounts. Here again no definite instructions existed. The accounting for stores was a task of great difficulty, complicated by the fact of our start without staff, by the delay in getting invoices from India, by constant sickness and casualties, and by the fact that accounting had to take second place to getting stores off. In fact, in "C" section we never got square with timber.

Contractors from whom local purchases were made produced bills, which were sent to the Controller of Military Accounts for payment; but increase of work, combined with shortage of staff in his office, gradually lengthened the time it took for a bill to get through from one to six weeks, by which time contractors were becoming restive. The Controller of Military Accounts eventually agreed to pre-audit payments, after which things went smoothly. A form, borrowed from the Supply and Transport, was introduced with a purchase order on one side and bill on the other—an immense saving of labour. The amount spent locally, chiefly on purchase of timber, amounted by May, 1916, to several lakhs of rupees.

An imprest account for small payments was also kept.

Mention has already been made of the extraordinary system by which we and the R.I.M. billed each other for stores transferred. The Accounts people insisted on our extending the system to the Navy, the Basra Municipality, the Customs, Port Administration and several other organizations to the enormous complication of accounts. The Basra *vilayat* administration we had to bill with 24½ per cent. supervision charges. We sent, by order of the Controller of Military Accounts, the D.D. Works a debit for all the stores we issued to Works organizations, but what happened to these debits, or for what purpose they were called for, we hadn't the least idea.

A few notes on particular stores may be of interest :—

Barbed Wire.—Demands for barbed wire far exceeded supplies, and we had to send constantly increasing indents to India. *A.T. Engineer Units* provided 28 cwt. 1 qr. 18 lbs. of barbed wire, with a rather smaller quantity of plain wire. A footnote stated that these were intended for entanglements, frontage of one Army Corps —an allowance of a little over a foot per rifle. It is only fair to say that No. 5 Field Park brought out a larger amount. At the time of the attempted relief of Kut, we had a standing order on India for 30 tons monthly. Each consignment should be accompanied by about one-tenth of its weight of plain wire, about 12 S.W.G., for stays, and, if screw pickets are not available, by about one-hundredth of its weight of 20 S.W.G., for binding.

Bombs.—The Field Park manufactured hand-grenades of the McClintock pattern. In spite of several improvements it was found that they seldom detonated properly on muddy ground, and that they were difficult to light in damp weather. Manufacture was given up when Mills and other patterns came into use.

Bricks.—The usual pattern available was about 9 in. × 9 in. × 2½ in. ; reeds were used for fuel, and consequently the bricks were usually underburnt. The local method of building a wall was to build two skins of bricks in *juss* (to be described later), filling the space between with bats. We had a contract for supply of bricks, which the Works organization took over on arrival.

Juss.—The local substitute for mortar was an impure form of plaster of Paris called *juss* ; it made excellent plaster.

Matting.—Enormous quantities of matting were required for hutting. In Mesopotamia mats were made from reeds.

Sandbags.—Mention should be made of a consignment of about 50,000 sandbags, sent out by some well-intentioned but misguided Red Cross Society, which had mouths just big enough to insert a hand.

Water Tanks.—A 400-gallon tank, measuring 4 ft.×4 ft.×4 ft., is a trade article in India. This is an inconvenient size for carriage on Army Transport carts, and a 200-gallon tank, 4 ft.×4 ft.×2 ft., was found better for the purpose. Brass taps are very liable to be stolen by Indians ; they should be sent separately (complete with back-nuts) in burglar-proof cases.

Timber.—In the early stages of the war, little use was made of Indian timber. The timber commonly used in Bombay is teak ;

softer and less expensive woods are eaten by white ants there. Teak is quite unsuited for field work. The timbers of N. India, *deodar, chir,* etc., were almost always cut to sleeper sizes, too short for field use. Local merchants imported *punak, saraia,* and other species from Singapore, and it was those kinds that we used most of. *Chandals* (long poles) were imported from Zanzibar. Occasionally a firm imported a shipload of deal from Scandinavia, which we took over bodily.

The following are notes made for future guidance :—

Engineer reconnaissance should include items of interest to park officers, such as local stocks of engineering materials, firms who are likely to stock such, notes on local skilled and unskilled labour, stating current wages, and what seasons of year labour may be hard to get (*e.g.*, in Iraq labour was scarce during Ramzan, the Mussulman month of fasting), particulars of local timber and other building materials.

Glossaries in military reports should include technical engineering terms.

H. Q. of the engineer park should be at the base, dispatch of stores to which should be undertaken by an officer in the country whence stores are sent, *e.g.*, at Bombay in the case of Indian overseas expeditions. He should have ample powers of local purchase, and must be *ex-officio* on the Embarkation staff and acquainted with shipping or railway regulations as the case may be. Each consignment should be accompanied by a priced invoice, and each package should be marked with indent number and item number of indent.

The most suitable organization is a base park at the base, with advanced parks close behind fighting formations, and smaller parks at posts on L. of C. The O.C. Field Parks should be under the D.W. on L. of C.

The strength of the base park, of course, varies with the amount of stores to be kept, but the following functions have to be considered :—

(*a*) Receipt.
(*b*) Custody of stores.
(*c*) Dispatch.
(*d*) Manufacture.
(*e*) Local Purchase.
(*f*) Accounts.
(*g*) Personnel.

(*c*) should be in charge of your best officer ; as pointed out by the author of the " Supply of Bulk Stores in War," engineer stores come off worst when there is a transport shortage, and you want a wide-awake and pushful officer to seize every opportunity of forwarding the goods. If officers are short (*a*) and (*c*) may have to be under one, and (*b*), (*d*) and (*e*) under another. Local purchase may be arranged for by a separate organization, in which case you will want an inspection section. If it remains a park function, it is imperative to see that you are not competing with other departments.

Duties of the officer i/c parks should include frequent visits to the front to consult officers using his stores.

(*a*) Receipt of stores should arrange for superintendence of unloading (a railway or port function, but a park representative must be there to see that cement barrels are not dropped 20 ft. into a lighter) and delivery in park.

(*b*) Custody of stores should include inspection and testing (in the case of explosives, arrangements must be made for testing every three months), not neglecting care of machinery, and collection and stacking of materials for dispatch, at places selected by the section (*c*). This section will generally have to be divided into convenient sub-sections.

(*c*) Dispatch to take over stores stacked by (*b*) and load; each consignment to be way-billed, and, whenever possible, accompanied by a representative. This section to be responsible for delivery to consignee.

(*d*) Manufacture includes repair of salvaged articles. Articles manufactured or repaired to be handed over to (*b*)—except in compliance with urgent indents, when they would be handed over to (*c*), and information sent to (*b*).

(*e*) Local Purchase arranges contracts for stores, which should include delivery in the sub-section of (*b*) concerned, and inspects same. Local Purchase officer to keep himself informed of stocks in possession of local firms, and must see that he is not raising prices by competing with any other part of the Force.

(*f*) Accounts. Sections (*a*) and (*e*) keep accounts of receipts and issues. (*f*) section checks and coordinates these, submits bills for local purchase to C.M.A., and controls imprest. *N.B.*—Section officers pay their own local labour. In dealing with oriental labour it is important that men are paid by the officer who employs them.

(*g*) This section performs adjutant and quartermaster duties for enlisted or enrolled personnel, and coordinates demands for outside military or local labour.

Advanced parks should be organized similarly; but, of course, on a smaller scale.

In moving warfare, it is a good plan to have an ever-ready park available for dispatch to or with any force, *i.e.*, personnel should be detailed, stores earmarked and transport calculated.

Orders for the organization of the force will detail establishment of the park; the stores to be obtained will probably be left to the discretion of the C.R.E. It is most unlikely that the stores will be ready at the same time as the fighting troops, but, in any case, a skeleton formation should accompany the Force to the spot where it is intended to form the Base park, to stake out a claim for ground,* reconnoitre for engineer stores, arrange for local purchase, etc. It will be as well if a part of the personnel, with a few stores, accompany this advanced party to open up the workshops.

Among the first demands to be made on the park will be : notice boards, incinerator bars, coffins, water-tanks and troughs.

Standing Orders for the parks should contain :—

(*a*) Sanctioned war establishment.
(*b*) Organization and duties as detailed above.
(*c*) Financial powers of officers regarding purchases, contracts and writing off losses.
(*d*) Instructions *re* care of machinery, testing of explosives.
(*e*) List of reports and returns.

It is a useful ideal—one we never managed to attain in Iraq—to have a catalogue for the use of all indentors, giving illustrations, weights and uses of every article supplied. But to get this out, and keep it up to date, would take a whole-time officer and a large clerical and drawing staff.

* The author of the *Supply of Bulk Stores in War* gives 1000 tons to an acre as a working figure.

CROSS-COUNTRY TRACTORS.

BY CAPT. AND BT. MAJOR G. LE Q. MARTEL, D.S.O., R.E.

THE suggestion that cross-country tractors should be extensively used for military purposes was first made by a R.E. officer, Capt. and Bt. Major S. H. Foot, M.C., R.E., in February, 1918. This officer pointed out that both man-power and shipping had become of vital importance in the prosecution of the war, and that both these factors were seriously affected by the retention of the great quantity of horse transport in France. At that time there were half a million horses in France, and some 80,000 tons of fodder per month had to be shipped from overseas to maintain these animals. This transport could not be replaced by motor lorries because vehicles at the front were required to go over country tracks and bad roads which were passable to the horse, but not to the ordinary motor vehicle. The suggestion was that the whole of this form of transport should be carried out by light tractors.* Major Foot produced the following points in support of his suggestion :—

(*a*) If tractors were substituted for horses, the tonnage required for the petrol supply would be half the tonnage for the supply of fodder in the case of the horse transport. But this is on the supposition that the tractors would be in full use every day. The horses had to be fed every day, although a large amount of the horse transport was idle for certain periods; with tractors there would be no consumption during idle periods. The saving to the tonnage in shipping would, therefore, be considerably more than 50 per cent.

(*b*) As regards man-power, the saving would be in the neighbourhood of 50 per cent. also. The actual saving in drivers between horse transport and tractor transport would, of course, be much greater than 50 per cent. in the case of the artillery, but this figure allows for repair, manufacture and replacement of tractors.

(*c*) The tractors could negotiate many places which are impassable to horses, and as they would normally move clear of the roads, they would suffer less from shell fire and night bombing. The latter is a most serious consideration with horse transport. The replacement of casualties among horses occupies a considerable amount of tonnage and shipping.

* The word "tractor" is used throughout this article to denote a vehicle which travels under its own power on tracks, and either carries or tows a gun or any other load.

This suggestion was taken up and the question of the supply of suitable tractors was opened. The supply of these tractors was an engineering problem of the first magnitude and no very definite progress was made before the armistice.

After the armistice the question of replacement of horse transport by tractors was discussed very fully in many military journals. It has been pointed out that the difficulty of transport in the forward area had a large share in the failure of most of the offensives in the latter part of the great war. During the long period of trench warfare the great armies just existed on a perfected system of road and rail transport; but after the initial stages of an offensive, the railways were non-existent in the forward area, and the roads very much damaged; it is, therefore, hardly surprising that every offensive was seriously affected by difficulties in transport. In open warfare the vulnerability of transport which is tied to roads is also very serious, particularly if the enemy possesses an active air force. Then again, in warfare against an uncivilized enemy the one great problem has always been the difficulty of transport. A suitable type of cross-country tractor would solve all these problems, and all thinking soldiers are now convinced of the desirability for this change. Moreover, the tractor which brings with it economy in tonnage and man-power also brings economy in expense, and this is a matter of primary importance under peace conditions.

But now we are faced with the first great problem connected with this question. It is never possible for an army in peace to retain all the transport which it requires in war; the expense would be far too great if this were attempted. Before the war our transport consisted of lorries and horse-drawn vehicles and we could mobilize from civilian resources without any great difficulty. The horse is now dying out in this country and being replaced by motor vehicles on wheels, and the latter would not be suitable for the transport of the army in the forward area. But if we adopt a form of light tractor instead of the horse-drawn vehicle, how shall we mobilize for war? The provision of tractors on a war scale for the whole army and the upkeep of these tractors would entail a prohibitive expense. If we retain the horse transport, we shall be faced with the great difficulty of the supply of horses for war, and if we adopt tractors, there is at present no known source of civilian supply, because the present commercial or agricultural tractor is quite unsuitable for this form of military transport.

This brings us to the second great problem connected with the whole question. Even the latest commercial tractors show great inefficiency compared with the lorry on the road. They are limited to about five miles an hour maximum speed, and at this speed they consume about three times as much petrol per ton mile as a lorry. This inefficiency is mainly due to the method of steering adopted.

This method consists of applying all the engine power to one track and using a brake on the other track so as to force the tractor to skid round to the desired angle. The inner track stops momentarily while the skid is taking place; Fig. 1 shows the plan of a tractor and the shaded part shows the portion of the underneath of the track which is resting on the ground. The thin lines show the position taken up by the tractor when it is swung through an angle of thirty degrees. This method of steering is known as skid steering, and it is quite obvious that it absorbs a large amount of power. When driving one of these tractors, a very perceptible check can be felt whenever the tractor is taken round even a slight curve. This accounts for part of the low efficiency of the commercial tractor. But this method of steering brings with it a further defect. The track has to be made very strong and heavy to stand the stresses set up by this skidding, and a strong track means a heavy track,

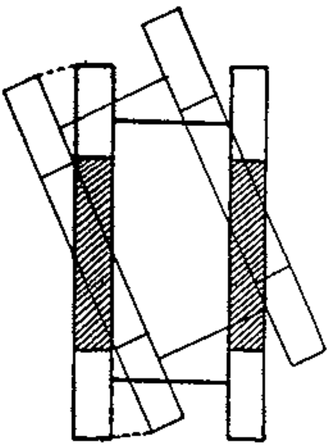


FIG. I

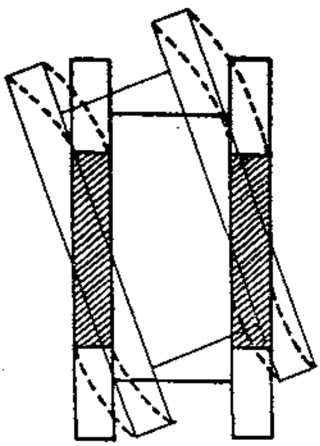


FIG. 2

which, in turn, means extra friction on the rollers, a heavy form of transmission and a powerful engine. This accounts for the remainder of the low efficiency of the commercial tractor. Moreover, a heavy track imposes a limitation on speed, for the transmission losses increase very rapidly at the higher speeds with a heavy track. For agricultural work a low speed is sufficient, and so much power is absorbed by the work of ploughing, etc., that the additional loss due to friction and skid steering is of no great account. But for military purposes we require a reasonably low petrol consumption, and the army would hardly be satisfied with maximum speed of 5m. p.h. It is, therefore, of the first importance to produce some improved method of steering. This comprises the second problem, and although we have made some progress in this direction, which will be described later, we have not yet produced a satisfactory tractor for military purposes.

These two problems, therefore, place us in a curious position. The horse is dying out and we possess no suitable alternative form of tractor at the moment. Moreover, even if we had reached the design of a thoroughly satisfactory tractor, we could not afford to construct them on a war scale for the army.

Assuming that the satisfactory tractor will be eventually produced (and there is little doubt on that point) the solution of our difficulties lies in stimulating the commercial market. On basic principles, the tractor should have a great future. There are, at present, four known forms of transportation (if we exclude such primitive methods as horses, camels and coolies). We will examine them each in turn.

Railway Transport.—This suffers from three disabilities. It is restricted to one dimensional movement and stores have to be carried or carted to the line of the railway. It entails a large initial expense in the provision of the permanent way. This initial expense is a considerable deterrent in opening up new country. Finally, the railway is limited to a definite maximum load, and hence its efficiency is limited. If it were possible to double the maximum load of trains in England, a great saving in running costs could be effected; but this cannot be done without a prohibitive expense in enlarging tunnels, rebuilding bridges, etc.

Lorry Transport.—This suffers from the same limitations as railways. In addition, the upkeep of roads incurs a very heavy expenditure. If it were possible to use, say, one 9-ton lorry, instead of three 3-ton lorries, the running costs would be considerably reduced. But the roads will not carry a 9-ton lorry.

Sea Transport.—This has the great advantage of two-dimensional movement, and is not restricted to any permanent way. Nor is the size of the ship limited. The ship has, however, to displace a large weight of water as it progresses, and this imposes a distinct limit on the speed of the ship for economic transport purposes.

Air Transport.—This is in the same position as sea transport, but the aeroplane has to fight constantly against gravity, and this consumes a definite portion of the energy.

With tractor transport we find none of these limitations. No permanent way is required, the tractor can move to any desired point, and there is no limit imposed on the size of the tractor. As a result, we find a definite demand for tractor transport from the Colonies, and there will be a ready market as soon as an efficient tractor is produced. Land which is at present valueless, owing to lack of roads and railways, will become valuable, and the cost of transport will fall rapidly in the colonies with the introduction of tracked vehicles. If we can stimulate this market we shall be able to draw on the export trade of this country for war. There is a further possible source of supply. We spend some 50 millions of money a year on the upkeep of our roads in this country and the damage to them is almost entirely due to the commercial lorries. If we could produce and universally adopt a tracked vehicle which is as efficient, or nearly as efficient, as the lorry, we would save the greater part of this 50 millions. The saving effected would enable us to subsidize the replacement of the commercial lorry by the tracked vehicle. Cars and light vans on wheels could still be used, because they do practically no damage to the roads. This step is not within the bounds of possibility at the moment, and it is too early to say whether it will eventually be possible, but it is well to remember that the mechanical engineer is seldom defeated by any problem, and the production of a tracked vehicle as efficient as a lorry is only a somewhat intricate mechanical problem.

We can now turn to the problem of producing a tractor with an efficient method of steering, for this is the crux of the whole problem at present. An entirely new method of steering was suggested about 3 years ago by the Superintendent, Tank Design Department. He suggested that the tractor should be suspended on a particular type of rope springing, and that the track should be constructed with lateral flexibility. In this way, he suggested, that the tractor would be able to negotiate easy curves without skidding. Fig. 2 shows a plan of a tractor which is constructed in this way. When the power is applied to one track only, the tractor swings through an angle, but the portion of the track which was resting on the ground remains in that position. Thus the track takes on an " S" form shown by the dotted lines As the tractor proceeds, it lays the track on the new alignment so that no skidding need take place. The tractor can, of course, only swing through small angles in this way, or describe easy curves, without skidding. A further advance consists of pivoting the front horns of the vehicle so that the track can be laid in a sharper curve. Alternatively it may be possible to negotiate sharp bends by the use of two pairs of tracks of which the front pair can be pivoted like the forecarriage of a cart. Each of these pairs of tracks would, of course, need lateral flexibility so that they could be laid in a curve, but by using two short tracks a much sharper curve could be laid. Experimental models which have been constructed on these lines have shown a great increase in efficiency over commercial tractors, and this is mainly due to the skidless steering and the light tracks which can be used.

But these experiments have naturally been accompanied by numerous minor difficulties ; broken tracks and minor troubles have been frequent. Nor will the whole problem be solved in a few months. Any invention, such as a military tractor, passes through three stages :—

(a) *The stage of applied research* in which we seek to learn the various methods by which the problem can be solved, *i.e.*, what different types of track can be used, and how do they compare in efficiency?

(*b*) *The design stage* in which we design the actual machine (a tractor in this case) to fulfil different requirements and test this design to discover and remedy any weak points.

(*c*) *The production stage* which must never be entered until the design has been most thoroughly tested in every possible way. History is full of examples in which a machine has not emerged from the production stage for two or three years, owing to undue haste in the design stage (the omission of some test which would only have occupied a few weeks).

As regards the tractor we are still in the stage of applied research. Unfortunately the requirements of the moment and research for the future became confused after the war, with the result that little progress was made. The position is now much better. For our immediate requirements we are constructing track vehicles (tanks and tractors) on lines which have been well tested. The result is that we shall have tanks which are sound and reliable, but no great improvement on the war tank. With tractors we shall get reliable machines, but not efficient from the point of view of economic transportation, and they will have no commercial use. The research work for the construction of efficient tractors is being taken up by civilian firms and great progress is being made, especially in the direction of skidless steering. There is every likelihood of a really efficient tractor being produced within the next two years. The French have stimulated great interest with their Kegresse machine. By using front wheels and short tracks on the rear axle they have eased the problem of steering, but they do not employ a track with lateral flexibility, and their present machine is limited to fairly light loads. There is every reason to hope that the British civilian engineers will produce a machine which will far exceed the capabilities of the French within the next year.

In the meantime, we must retain our horse transport until the problem of producing an efficient tractor has been solved. The horse is dying slowly, and we have several years of grace before we reach the stage when we cannot mobilize our horse transport. But when we have solved this problem we shall then have to turn to the first problem which was outlined at the beginning of this paper. This problem is entirely one of mobilization. We shall not be able to keep more than a small proportion of army tractors in time of peace, and our successful mobilization will depend on the extent to which the commercial world has adopted tractor transport. We shall have to change our transport gradually. The artillery is an arm which lends itself pre-eminently to tractor transport. The saving in men and fuel or fodder is very great, and this saving should enable us to build a fairly large number of tractors. By equipping artillery brigades with tractors we can reduce very largely the number of horses required for mobilization, and we could keep the peace scale of tractors very near the requirements for war. As horses become scarcer we shall be forced to transfer more horse transport to tractor transport, but by that time the tractor may be a commercial article, which will solve the problem of mobilization. We have also eased the problem of mobilizing the horses by transferring the B echelon of the D.A.C. of a division to motor vehicles; though unfortunately the most suitable vehicle for this purpose—the 30-cwt. lorry—is only used in small numbers in this country, and is not very easy to obtain for mobilization. The conversion of a brigade of artillery from horse transport to tractor transport is being tried experimentally, but no great progress has yet been made.

The conclusion may be summed up as follows:—

(*a*) The tractors and tanks which we build for our immediate requirements must be constructed on the lines of the agricultural tractor and the war tank. They will, of course, be an improved model, and will have a somewhat higher speed, but they will not provide an economic form of transportation. A reliable machine cannot be produced at the moment, which will have the very high speed which has been attained by a few experimental machines.

(*b*) The research work, which was not done at all thoroughly by the government department during the last four years, is being taken up by civilian firms, and there is every prospect of a great advance being made in an economic form of cross-country traction. Many different types of track and transmission will be tested, and we shall be able to collect the necessary data to enter the design stage in the construction of really efficient tractors and fast tanks. We must endeavour to persuade commercial firms to take up this work, and to standardize parts as far as possible so that the commercial tractor may be suitable if required for war.

(*c*) We shall have to start by using tractors for such work as that of replacing the horse teams in the horse and field artillery, for a greater saving is produced by this replacement than by replacing the horses in, say, infantry transport. This saving may enable us to maintain a high percentage of the requisite artillery tractors in time of peace. The difficulty of the supply of horses on mobilization will be considerably eased by the mechanicalization of all artillery units.

(*d*) This difficulty of the supply of horses may be further eased by converting a proportion of second-line transport from horse transport to light lorries, if the supply of light lorries remains available.

(*e*) We shall be able to construct a certain number of tractors for supply work in warfare against uncivilized countries. In places such as India or Mesopotamia, the saving effected by the use of tractor transport will easily pay for the capital cost of these vehicles.

(*f*) The complete conversion of all horse transport to tractor transport, which brings with it enormous military advantages, can only be undertaken if the engineering industry of this country takes up the construction of tracked vehicles for use in the colonies or at home, and thus provides a source of supply for mobilization in the event of war.

PROFESSIONAL NOTES.

ENGINEERING.

Well Boring Operations at Tidworth during the Summer, 1922.

Owing to the drought of 1921, it was decided to sink a bore at Tidworth, to ensure an adequate supply of water.

The chief factors which governed the estimated size of the bore were :—

(*a*) The average consumption of water, which was put at about 300,000 gallons a day, and

(*b*) The water table level at which the existing well would fail to meet these requirements, namely about 250 ft. above Ordnance Datum.

It was thought that the bore would probably have to be sunk some 500 ft. before the necessary yield could be obtained ; and the water would have to be raised by means of an air compressor plant. It was estimated that the bore should be ten to twelve inches in diameter at the top to allow for the possible necessity of reduction in diameter during sinking.

A Conference was held at the War Office on the 12th April, at which it was decided to carry out the work by a detachment of one serjeant and five sappers who were under instruction in well boring at the S.M.E., Chatham, and that the plant to be used would be supplied from stock. This decision ultimately governed the size of the bore, which was fixed at 8 ins.

There were two alternative sites for the bore, in the valley of the River Bourne, or in the downs near the existing well. The former site had the advantage of being some 70 ft. nearer the water level, but had the disadvantage of requiring additional outlay in mains and pumping plant. The latter site was chosen, the height at the surface being 450 ft. above O.D.

As the sapper crew from Chatham were not fully qualified as well borers, the services of Mr. G. T. Palmer, ex-serjeant, Royal Engineers, and an employee of the Mersey Docks and Harbour Board, and formerly in charge of No. 3 Water Boring Section, R.E., in France, were obtained to supervise the work. The D.O. in charge of the work was Major E. A. H. James.

Mr. Palmer and the R.E. crew under Serjeant Gough, R.E., reported at Tidworth on the evening of the 6th of May.

The drilling plant (supplied by the S.M.E., Chatham), consisted of a "Star" pattern well borer of the percussion type.

Boring was begun on Friday, the 9th of June, and water was reached 325 ft. above O.D. on the 19th of June. Sand was reached at 428 ft. from the surface (22 ft. above O.D.), on the 21st of July. This sand, though not of normal appearance, was presumed to be the green sand, a presumption which has since been confirmed by the Geological Survey, and it was decided to test the yield of the bore at this depth before considering the necessity of going any deeper. The number of days on which boring had taken place was 18, and the greatest depth bored in a day of eight hours was 50 ft. The remainder of the time between the 9th June and the 21st July, namely, 12 working days, had been spent as follows:—

Tool dressing	3 days
Making cutting shoe and sinking casing ...	5 ,,
Delay owing to defective belt	2 ,,
Repairs to drilling plant	2 ,,
	12 ,,

Saturday mornings were spent in cleaning down plant, men's quarters, etc.

The bore was lined to a depth of 181 ft. The strata bored through were chalk, with various proportions of flint and with indications of a great deal of clay shortly before reaching the sand.

Tests were carried out with a Lacey Hulbert air compressor obtained from the R.A.O. Depôt, Woolwich.

This compressor gave 130 cub. ft. of free air a minute, and was run at a maximum pressure of 125 lbs. per sq. inch.

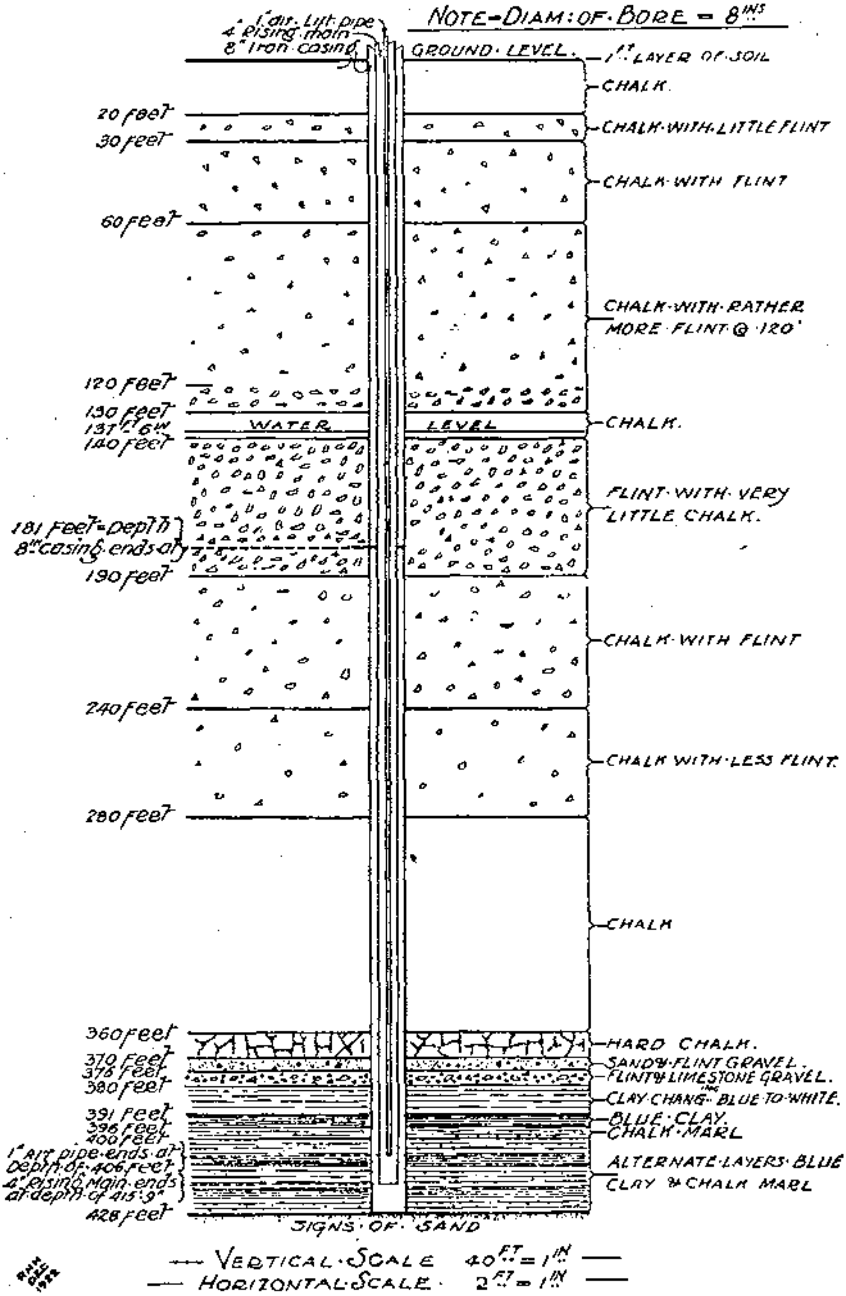
It arrived on the 15th of August, but, owing to the delay in the arrival of special fittings which had to be purchased, no test could be made till the 6th of September. The compressor was fitted up in the old Pumping Station at Chalk Pit, and 672 ft. of 6-in air pipe was laid from the compressor to the bore, the intention being that the large-size pipe would act as an air container. For the first test a 6-in. rising main was used with a 2-in. air pipe inside. The submergence ratio was rather over 60 per cent. Water was brought to the surface between the rising main and the bore.

A 4 in. × 1 in. air lift was substituted for the 6 in. × 2 in. In taking out the 6-in. rising main, two lengths were left at the bottom of the bore owing to a faulty thread giving way. These lengths were later very neatly and quickly recovered by Mr. Palmer by means of a conical wooden plug dropped into the 6-in. pipe and left

— TIDWORTH —

NEW·WELL·BORE·HOLE·NEAR·CHALK·PIT·WELL

SECTION·SHOWING·STRATA·& DEPTHS·OF·BORING CASING ETC



to swell for 24 hours. The next test was carried out with a 4-in. × 1 in. air lift. The bottom of the rising main was 417 ft. from the surface and the bottom of the 1-in. air pipe was 404 ft. from the surface. The starting pressure was 125 lbs. and the running pressure 105 lbs. per sq. inch. The test lasted twenty minutes and water was obtained at the rate of 5,000 galls. per hour. The water level at starting was 137 ft. 6 in. This dropped to 170 ft. after one minute's run and rose again to 165 ft. after ten minutes' run (all distances measured from the surface). The water-level returned to normal level twenty minutes after pumping ceased.

It was thought that a 4 in. × 1½ in. air lift might give better results. A flow at the rate of 11,000 gallons per hour was obtained for 2½ minutes, then a pause of 4½ minutes took place before water started flowing again. It was decided to revert to the 4 in. × 1 in. pipes, and they were replaced by the 22nd September.

The water-level at Chalk Pit Well was at this time considerably above that at the same date in 1921, and it was decided to cease work, but to leave the bore and the compressor ready for work in case the necessity should arise. The drilling plant was dismantled, all spare piping returned to store and the site cleared.

The total cost of the work was under £700, of which the principal items were as follows :—

Civilian Labour	£275
Fuel	£25
Transport, etc.	£25
Material	£360

THE ELVERSON OSCILLOSCOPE.

WHEN mechanism is operating at high speeds, it is difficult to study any fault in the movement of the parts. The Elverson Oscilloscope (described in *Engineering* of 8th December, 1922) is an instrument which enables mechanism running at normal speeds to appear slowed down or stopped.

The operation can easily be understood if one imagines the seconds hand of a watch viewed by flashes of light at intervals. If the flashes occur every minute, the hand will appear stationary, but if they are at a slightly less interval, the hand will appear to be moving very slowly in a counter-clockwise direction.

In the Oscilloscope, the illumination is provided by an incandescent bulb filled with neon. The ordinary incandescent lamp is not suitable, as, with it, an appreciable time is taken in raising the filament to incandescence and cooling it down again.

The contact-breakers which regulate the illumination are operated by the mechanism being studied, through gears. There are two distinct gears provided, one of which gives the exact speed of the mechanism to the interrupter, and the other a speed one-hundredth or one-thousandth less. The use of the first enables a "stationary" examination to be made, while the second gives an apparent motion of one-hundredth or one-thousandth of the actual value.

Any mechanism can be studied by this instrument, and by its use faulty gear wheels, bouncing action with cams, lag in the closing of valves, and so on, can easily be detected. It has further uses in crankshaft balancing and the measurement of torsion in a shaft.

C.C.A.

Fastenings for Portable Structures.

The experiences of the recent war have proved that hutted buildings of the *démontable* type are, in certain situations, of immense value, not so much for the reason that such huts can be dismantled and re-erected on a new site, but rather because the initial erection can be carried out in a minimum of time and with no skilled labour.

The parts can be made in workshops in England and shipped to the seat of war, where they are held ready for erection as soon as the need for a new hospital, depôt, or other camp may arise.

In the past, the majority of such huts have been of the "panel" type; that is to say, they are made with the walls, and often the roof and flooring, in sections, or panels, which could be bolted together, the use of bolts enabling the hut to be rapidly dismantled when necessary. Some of the German sectional huts are fitted together with steel clips, but these are liable to damage in transport.

Panel huts are usually supplied with the covering and floor-boards already fixed, to save time in erecting and to keep the various sections rigid during transport.

If a portable hut could be designed in which there were no panels, but in which the wooden members could be fitted rigidly together without the use of nails (which makes dismantling difficult), it would have many advantages over the "panel" type, for the following reasons:—

1. The members could be "bundled" and so a good deal of space economized in packing.
2. Each hut could be in a separate bundle. There would then be no risk of some vital part going astray. With panel huts, all the panels of one type (*e.g.*, floor panels) are usually packed together to save space, and these may easily get separated from the "roof" and "wall" sections.
3. In many situations, covering material is not required to be sent out from home, as it is obtainable locally. If panels are not covered they must be crated or boards nailed across, to keep them in shape during transport.

4. Panels easily get out of shape and damaged.
5. Damage to one member of a panel may make the whole panel unserviceable.

A portable hut with separate wooden members has not been found satisfactory in the past owing to the impossibility of making the hut sufficiently rigid without complicated scarf joints for fixing together the sections of the top and bottom rails which run the whole length of the building. Further, there are practical difficulties in bolting the various members together.

A new fastening has recently come on the market which may be useful for the type of hut which has just been described. This is called the "Steelgrip" fitting and is illustrated in *Figs.* 1, 2 and 3. It was originally designed for bedsteads and portable furniture, but has been found useful for very many other purposes, where wood or metal members have to be fastened together and disconnected later, and when the fastenings need great strength and rigidity.

These fittings are stamped from sheet steel. The two parts of the fastening are called the post plate and the rail plate respectively. *Fig.* 1 shows the back of the post plate or "tongue" fitting, which is fixed by screws so that the tongue fits tight against the framework. *Fig.* 2 illustrates the front of the post plate with counter-sunk holes for screws. The post plate is made of two superimposed stampings which are spot-welded or riveted together, but in some of the smaller patterns, one stamping is used and folded over. *Fig.* 3 shows the rail plate or "slot" fitting which is in one piece. The complete joint secured to the woodwork and assembled is shown in *Fig.* 4. In the fitting illustrated, the rail end must be grooved to provide a passageway for the post plate, but another pattern avoids the necessity for the grooving by having turned over flanges at the sides of the rail fitting, which provide a passage for the post plate.

The fittings are made in sizes ranging from ½-in. to 6-in., stepping up by quarter inches. The metal is a good quality of mild steel which may be finished black, plated, or rendered rustless by some process such as sherardizing. Rustless steel may be used. The fittings can be attached to wood by screws, or to metal by riveting or spot welding. When fixed, they occupy very little space and there are no projecting parts which are liable to be broken in transport.

The two members are locked instantaneously, and a blow from a mallet is all that is required to dismantle. When locked, the joint is extremely rigid, and has great strength in every direction (except that in which the dismantling takes place). In cases where there may be a risk of the fitting working loose in the direction of dismantling, a nail half-driven into the woodwork after assembly will prevent this. No tests have yet been made of the ultimate strength

"STEELGRIP" FASTENING FOR PORTABLE STRUCTURES.

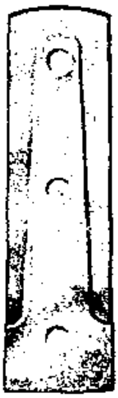


FIG. 1.

FIG. 2,

FIG. 3.

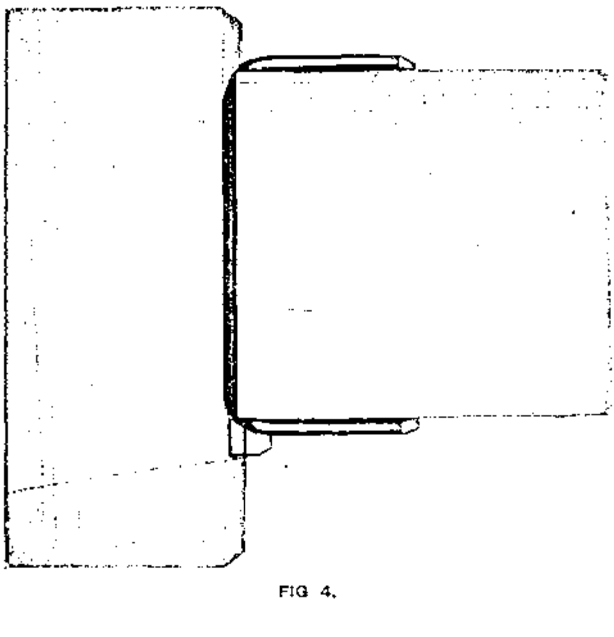


FIG 4.

of the joints of various sizes, but it is probable that the wooden members will be found to fail before the joints.

In addition to portable buildings, there are many uses to which these fittings may be applied where strong and rigid joints are required, and where rapid assembling and dismantling are needed. Possible military uses include portable furniture, movable shelves and racks, portable latrines, ablution benches and meat safes.

The fittings are obtainable from the "Steelgrip" Fittings, Ltd., of 32 Alfred Place, Tottenham Court Road, London, W.C. 1.

C.C.A.

Storage and Transportation of Portland Cement.

The deterioration of Portland Cement during transportation and storage has been thoroughly investigated recently by the United States Bureau of Mines, with the object of discovering a means of preventing it. The results are given by Mr. W. M. Myers, Assistant Mineral Technologist of the U.S. Bureau of Mines in *Engineering* of December 1st, 1922.

This deterioration is due to partial hydration by absorption of moisture from the atmosphere, and the amount of deterioration varies directly with the degree of hydration. This depends naturally on the time of storage, but during transportation varied climatic conditions may be met, which will have a bearing on the deterioration.

Experiments have shown that cement stored in a shed in cloth sacks may lose 20 per cent. of its original strength after three months' storage, 29 per cent. after six months, 39 per cent. after one year and 60 per cent. after two years. These figures point to the necessity of using cement as soon as possible after it has been ground.

Deterioration is minimized when the cement is stored and transported in bulk, but for small quantities, the use of barrels is much better than bags or sacks, which give undue exposure to the air. Further, sacks are difficult to handle, and liable to be torn by hooks, thus exposing the cement directly to the atmosphere.

The possibility of storing and transporting unground clinker and grinding it at its destination is also discussed, but this project would obviously only be practicable where very large quantities are required.

C.C.A.

New British Standard Rolled Steel Sections.

The original list of British rolled steel sections published by the Engineering Standards Committee in July, 1904, has been revised, and a new list of *British Standard Rolled Steel Sections for Structural Purposes (Revised July*, 1920) is now obtainable, price 1s. (Crossby, Lockwood & Son). The new sections are designated N.B.S.B. (New

British Standard Beam), N.B.S.U.A. (New British Standard Unequal Angle), etc., and, owing to the omission of the less commonly used sections and the insertion of certain new ones, the numbering throughout each series has been materially altered.

The main differences between the two lists are in the dimensions of the beams and channels. These alterations have been introduced in consequence of the fact that modern rolling mills are able to produce sections on a commercial scale which approach more nearly to the theoretically perfect profile. The thicknesses of the webs have in most cases been reduced and in some there is a corresponding increase in those of the flanges. A new series has been included in the revised list called *Heavy Beams and Pillars* (N.B.S.H.B.) which consists of wide-flanged beams primarily intended for use as struts and columns. It should be noted that, except for the fact that all the web and flange thicknesses have been changed, it is only the three heaviest beams in this list that do not occur in the old series. A later publication in August, 1921, contains the moments of inertia and other properties (in both British and Metric units) of the new beams and channels.

The new equal angles (N.B.S.E.A.), unequal angles (N.B.S.U.A.) and Tees (N.B.S.T.) are the same as the old sections except for small changes in the radii of the corners. Many uncommon sections have been omitted, but very few additions have been made A certain number of standard thicknesses are still adopted for each section, but other thicknesses can be ordered if required. The properties other than the dimensions and sectional areas of the new angles and Tees have not yet been published, but can be obtained with quite sufficient accuracy from the old list

It will, of course, be some years before the rolls for producing the old sections are worn out and existing stocks expended, but it is worthy of notice that most large firms are already prepared to supply the majority of the new sections. By specifying the new channels and beams there is no doubt that an appreciable saving can be made in steel structures owing to the more economical shape of many of the profiles.

E.F.T.

SURVEY.

By Colonel H. ST. J. L. WINTERBOTHAM, C.M.G., D.S.O.

SINCE the war surveyors throughout the Empire have been busy on somewhat curtailed programmes. Some very interesting maps have been received, none the less, particularly from the Gold Coast, which is beginning to inaugurate its own printing establishment. The last field season has produced an excellent output, and it is a little difficult to say whether to congratulate more heartily His Excellency the Governor of that colony on his survey establishment, or the survey establishment on its governor. In the Federated Malay States there is a considerable programme of work for the future which should occupy the staff for some twenty odd years. Meantime, they have produced, amongst others, a map at eight miles to the inch, showing administrative features and relief in brown hill shading. The War Office is arranging for the printing of several sheets for Uganda, which help to fill up a rather wide gap in our mapping of East Africa, and Trinidad is now being surveyed. One can only hope that other West Indian communities will follow suit. In one recent case (1920), a map of a colony made in 1806, and republished with corrections in 1824, was reprinted as it stood. The maps of foreign stations in which garrisons are maintained are, one by one, being gridded in the system which is sometimes called "Lambert's" and sometimes "the French." It did so happen that the French were using it, at the time of its adoption by the Allies, on maps constructed on a Lambert conical orthomorphic projection, but the grid is not a legacy from this famous old mathematician, neither does it follow precisely the form in which it was used by the French. The process of fitting the new grid on to old maps is not without its sad moments. One discerns many discrepancies between trigonometry and topography.

The International 1/1,000,000 map which Sir Charles Close rescued. in 1909, from the stage of international discussion and placed upon a practical and working basis, continues to make steady progress. There are now 40 sheets of this International Map published, nine of which appeared in the period of the 1922 Report. The outstanding feature of this report is its witness to the size and value of India's contribution. The International 1/1,000,000 Map has exerted a good deal of influence upon the small scale map of to-day. For example, the 1/2,000,000 maps of Africa which are being produced by the Geographical Section of the War Office, in collaboration with the Service Géographique de l'Armée of Paris, are based upon the international projection and sheet lines, as is also the War Office 1/4,000,000 of Asia, of which several sheets have already appeared.

In 1919, the International Committee on Aerial Navigation began its work and entrusted the making of maps suitable for airmen to the hands of a sub-commission. This sub-commission is following the sheet lines of the International 1/1,000,000 Map, but not the projection, for which it has adopted the Mercator. At first sight the adoption of this projection, which has been used so largely and so unsuitably by the Atlas makers of Great Britain, was resented by the geographical world. The matter was discussed at the last meeting of the British Association for the Advancement of Science, but as the audience at that time was not prepared to criticize the proposal in detail, a discussion at the Astronomical Society was held on the 2nd February. This discussion was opened by Colonel Jack (Director-General of the Ordnance Survey), and it was presently realized that the problems of aerial navigation and the express desire of those engaged in it had made the decision a matter of necessity. The Sub-Commission for Aeronautical Maps has recently approached the Central Bureau of the International 1/1,000,000 Map, which is situated at Southampton, in the Ordnance Survey buildings, with a view to securing its services as an intermediary between itself and the nations which adhere to international aeronautical agreement. These international air maps consist of a series known as the "general," on the Mercator projection which we have mentioned, and at a scale at the equator of 3 cm. to one degree of longitude, and of another known as the "local," at some much larger scale. For these "local" maps the idea is to take the suitable survey of the country in question, which would be the ¼ in. to 1 mile in England, or the 1/200,000 in France, and to publish it in a form suitable for use from an aeroplane. The Geographical Section of the General Staff is engaged on preparing samples of the sheets of both "general" and "local" series, as approved by the Sub-Commission. It is a matter of some amusement, endeavouring to cater for the general taste of airmen. No two of them appear to look at country in precisely the same way and when, after repeated efforts, a map had been made, of which the Sub-Commission for Aeronautical Maps approved, a private letter was received from a distinguished foreigner who said that he could make neither head nor tail of it from the air. No doubt, it will take many years before we come to the final form. Meanwhile, after repeated meetings, a measure of agreement has been reached and some of the more important sheets, covering important flying routes, are to be published.

Considerable interest is being taken now in the question of mapping from air photographs. One may say, indeed, that interest in this subject is re-awakening. During the war, survey from air photos had an abnormal development. Time was the essential factor and ground surveyors were naturally unable to penetrate the enemies' lines with impunity. The only answer then was to survey from air photographs. But immediately after the Armistice the future of this new method of survey was jeopardized by the over-confidence of those who understood little of its difficulties and of its relatively high expense. An experimental survey was carried out in India at Agra, which showed how little the problem of taking photographs in the most helpful way for the surveyor had been thought out by pilots. In fact, it soon began to be realized that it would prove very expensive to map from photographs as they were then taken, and for this reason no official British survey has made any definite movement in the matter. Areas of exceptional difficulty have, however, been done in this way. There was, for example, a survey of the Nile, in order to establish the periodical changes in channels, banks, etc., and there is a project afoot to map the Irrawadi Delta. At the instigation of Colonel Jack, a committee called the "Air Survey Committee," composed of members nominated by the War Office, the Air Ministry and the Ordnance Survey, was called into being in 1921, in order to discuss the future of mapping from air photographs, mainly, and naturally, with an eye to war. This Committee has evolved certain new cameras and instruments which are nearing the stage of practical experiment. It is hoped that they will provide the means of surveying and contouring a strip of country (say 50 miles wide), which is neither triangulated nor surveyed in any other way. The School of Aeronautics at Cambridge has also interested itself in the question and has tackled that side of it for which the navigator is responsible. In the course of its research, this school has arrived at very valuable conclusions and has now proved that an airman can, if he is properly trained, give us, not only single photographs, but strips of photographs with, relatively speaking, extremely small errors in scale and of distortion due to tilt. The Ordnance Survey have also found air photographs of value in their search for those archæological features which appear upon their maps. The present interest in this question is exemplified by the fact that no less than five lectures are being given this winter on the subject. Two of these lectures are to be at the Royal Geographical Society, one at the Royal Institution, one at the Royal Photographical Society and one at the S.M.E., Chatham. The conclusion that most surveyors are coming to is that photography from the air is so great an advantage for certain classes of survey that it must be employed. On the other hand, it is impossible to do without a triangulation, or some form of control, and in easy and hilly country topography on the plane-table goes so fast and so economically as to make its use inevitable. If we must have air photography, however, and we must also have the photographer to develop the photographs, and the surveyor to provide triangulation, and occasional topography, it will be necessary, probably, to combine these three in the person of a surveyor who can fly. One can imagine him in the future flying to his next observing station, photographing on his way home, and, perhaps, making a detour to cast an eagle eye upon any plane-tablers of whose zeal he may feel distrustful. The amount of transport, of mule flesh, etc., that the use of such an aeroplane would save, would, in itself, almost pay for its purchase and upkeep, providing that it were of a type which could be left out, if needs be, in any weather, or, at any rate, be taken to pieces and stowed away in some quite humble and cheap tent aerodrome. It is interesting to note that the Air Ministry is thinking seriously of the design of such an aeroplane at the present moment. The advantages to be gained in this way, shall we say, in the surveys of portions of Australia, would seem to make an experiment well worth the while.

In the instrumental world there have been one or two things of note. There was an exhibition of electrical, optical and other instruments at the Imperial College of Science in January. At this exhibition Messrs. Casella & Co. showed a micrometer theodolite in which the readings of the two micrometers were visible in the same eye-piece. In the course of an afternoon's observing it is quite possible that one may have to walk round one's theodolite some two or three hundred times in order to read both micrometers. Messrs. Casella & Co. are therefore to be congratulated on saving so much time. Messrs. Watts & Sons, of Camberwell Road, have produced a bubble which keeps an invariable length under all temperatures. I saw this bubble tested with a blow pipe. Curiously enough, its construction appears to be the happy result of a process of trial and error. Nobody, apparently, is in a position to state why it behaves in so amiable a fashion. No particular harm is done, however, if it really is invariable, and, if it is so, it means that it will be easy to add a mirror device which will show one end of the bubble in conjunction with a division of the scale. A touch on the screw, without moving position, will then bring it correct without having to proceed to a thorough re-levelling of the instrument.

From a scientific point of view, the fact of the greatest recent interest to surveyors is the appearance of the Ordnance Survey Report on the "Second Geodetic Levelling of England and Wales. 1912–1921." Since the days of Clarke no work of such geodetic importance has been published by the Ordnance Survey. That an undertaking of such national importance should have been begun, completed and described in print by one and the same Director-General is in itself a notable fact, but when one remembers the 4½ years of war effort which intervened, it becomes much more remarkable. The network includes three mean sea-level observatories—Newlyn, Felixstowe and Dunbar.

There is reason to believe, from the results of this levelling, that mean sea-level at Dunbar is several inches higher than it is at Newlyn, a fact due, at least in part, to general meteorological causes.

MEMOIRS.

LIEUT.-GENERAL SIR JAMES BEVAN EDWARDS, K.C.B., K.C.M.G., COLONEL-COMMANDANT R.E.

In Lieut.-General Sir Bevan Edwards, who died in London on 8th July, 1922, the Empire lost one of its builders whose work is too little known. A fine and distinguished type of the older order of soldier, with a record deserving of larger setting than it has yet received, the strands of his life were of the very texture of the Empire's story blended of the battle-field and the Council Chamber. Far-sighted and progressive, keen in all he undertook, fearless in the acceptance of responsibility, warm-hearted and loyal, his directness of speech reflected his strength of character as surely as innumerable acts gratefully remembered reflected the tenderness of his nature. Those who at times opposed him most were among those who loved him most. To all who knew him well he leaves cherished memories of cheery comradeship and ideals stoutly fought for.

Sir Bevan was the son of Samuel Price Edwards, of Buncrana, Co. Donegal, at one time Collector of Bombay.

He was born on 5th November, 1834, and was educated at a school on Shooter's Hill and at the Royal Military Academy, Woolwich, where he became Senior Under Officer and distinguished himself in athletics by winning a two-mile race. He received his commission in the Royal Engineers on 22nd December, 1852, and, after the usual period at Chatham, was sent to the Isle of Wight, and was employed on the projects of the defences of Freshwater, under Major-General Sir Frederick Smith, C.R.E., South Western and Sussex District, from whom he received generous praise in a C.R.E.'s Order of 11th July, 1855, when he and Captain (afterwards Sir Lothian) Nicholson left England for the Crimea. It had naturally been a matter of considerable disappointment to young Edwards that he was not sent out in the earlier days of the struggle, and even now he met with so many unfortunate delays on the voyage that he did not land in the Crimea until after the fall of Sebastopol. He was, however, fortunate enough to be employed on the demolition of the docks, where he came under Russian artillery fire, and in due course received the Crimea and Turkish medals. In June, 1856, he was moved to Corfu and spent an enjoyable time shooting and yachting, making trips to the neighbouring islands and to the mainland in Albania. On hearing of the outbreak of the Mutiny in India he hastened home on leave, *via* Trieste, and, volunteering for active service, was posted to the 21st Co., Royal Engineers, with whom he landed in Bombay in November, 1857. The Company received orders to join the Central India Field Force under Sir Hugh Rose. While marching towards Mhow the Officer Commanding the Company, Captain G. Neville, was killed near Ratgurh by a round shot and Edwards received the command. He took part in the siege and storming of Chaudairee, for which action he was mentioned in dispatches, and in the battle of the Betwa. In the storming of the city of Jhansi on 3rd May he was in charge of the ladders of the successful left escalading column. After the fall of the city the Force marched to the Jumna and met with further resistance at Koonch, Goolowlee and Calpee. It was then broken up, but the 21st Company saw further service under Sir Robert Napier at Gwalior and in the pursuit and capture of Tantia Topee, who for a time was a prisoner in their quarter guard, as they were the only Europeans employed in the pursuit. For his share in the suppression of the Mutiny Edwards was three times mentioned in dispatches and received the medal and clasp, the brevet of Major in 1860 and the C.B. in 1877. In Sir Hugh Rose's dispatch of 18th April, 1858, the following extract, referring probably to the battle of Betwa, is worthy of quotation :—" The enemy, simultaneously with their attack on my right, had advanced with equal vigour against my right centre, guarded by part of the 25th Bombay Native Infantry, who, despite a most gallant resistance, were driven back by over-powering numbers, which afforded an opportunity to Lieut. Edwards, commanding the 21st Company of the Royal Engineers, which I had placed in support of the 25th, to charge with his Company, most successfully, the very superior force of the rebels, routing them with loss and pursuing them till out of reach. . . . The 21st Company fight as well in the field as they work in the trenches, and are worthy of their distinguished Corps." At the end of hostilities the Company was ordered to Dagshai, and from July to December, 1859, Edwards spent six months' leave on a tour in Thibet, Ladak and Kashmir. He travelled from Simla northwards to the Indus, and shot yak and ovis ammon near the Pangong Lake ; he then journeyed through Leh to Srinagar and, after spending some time shooting bear and bara singha in Kashmir, he returned to Dagshai *via* Chamba. Soon after this he was ordered home. At Calcutta he found Sir Robert Napier preparing his expeditionary force for China, but Sir Robert told him that there was little chance of fighting, so that he made no attempt to cancel his orders and duly arrived in England, where he was at first employed at the War Office and later to the command of the 2nd

Yours sincerely
J. Bevan Edwards.

(By kind permission of "United Empire.")

Company R.E. at Aldershot. In 1863 he was ordered to Canada, but exchanged into a company under orders for China, and arrived at Hong Kong in December after a five months' voyage round the Cape. Pressing on to Shanghai he joined Gordon's Ever-Victorious Army in time to take part in its last sanguinary action, the siege and capture of Chang Chowfu, for which he received a gold medal. He remained in the neighbourhood for some time, employed on survey work, and later made an interesting tour to Tientsin and Pekin and to the Great Wall before he returned to Hong Kong. In 1866 he returned to England and became Major of the Training Battalion at Chatham. About this time Major Edwards published a pamphlet suggesting " An Organization for the Army of England." Space will not allow of even a short summary of his proposals, but they included the concentration of a larger number of battalions in England, their organization with other troops into *corps d'armées*, short service during wartime, the formation of depôts and facilities of expansion from peace establishments. A letter exists from Sir John Burgoyne in which the veteran Field-Marshal, still in harness at the War Office, gives his opinion of the proposals. " It is a very important question, and one of very great difficulty, and on which you enter into competition with many others. . . . My feeling is, what you all appear afraid to meet, that *additional* means are among the things needful, and *additional* expense will be necessary to make us secure against the enormous preparations making in the rest of the world . . . your arguments about the Colonies may be true in the abstract, and that many *should* defend themselves, but it has not yet been so *decided*, and they look to us to protect them ; and when the emergency arrives they will cry ' Shame ! ' upon us not doing so."—An interesting comment in view of the important part played by Sir Bevan in later years towards making some of the greatest of the Colonies self-defensible. In 1868 he lectured upon the same subject at the Royal United Service Institution and in 1871 he published another pamphlet, *A National Army, or How to Solve the Problem of To-day*, in the preface of which he was able to say that " since the following pages were printed Mr. Cardwell, as Secretary of State for War, has brought forward in the House of Commons the new scheme of Army reorganization proposed by the Government, the main features of which tend towards the fulfilment of the proposals put forward in this pamphlet," and, he might have added, in his previous publications. At the end of 1867 he was selected to escort a Japanese prince on a month's tour in the British Isles, and after that he was moved to Portsmouth, where he remained for ten years. In 1868 he married Alice, daughter of R. Brocklebank, who died in 1899. In 1871 he became Lieut.-Colonel by brevet. In 1877 he was sent by Sir Lintorn Simmons, then Inspector-General of Fortifications, on a secret mission to select a harbour suitable for a coaling station between Malta and Port Said. It has been explained recently by Lord Sydenham that Sir Lintorn was opposed to the Prime Minister, Disraeli's, policy of annexing Cyprus, and sought for a harbour, which would entail less responsibility and expense. Edwards' instructions suggested the harbour of Tristoma in the island of Scarpanto, or Symi Island, near Rhodes. He sailed in H.M.S. *Salamis*, Commander F. W. Egerton, R.N., on 4th May, and, after calling at Malta, examined and reported upon the two harbours already mentioned, but selected as more suitable Port Vathy in the Island of Stampalia. Needless to say, Sir Lintorn did not succeed in converting the Prime Minister to his views, though, as Lord Sydenham writes, it is doubtful if Cyprus was of any real use to us.

In October, 1877, Edwards was promoted Lieut.-Colonel and Brevet Colonel. He served for short periods in the Northern District and at Shorncliffe, and had spent some time on half-pay when in February, 1885, he was sent to Suakim as Commanding Royal Engineer of the Suakim Field Force, under the command of Sir Gerald Graham, V.C. He was present at the action of Hasheen, the attack on Convoy on 26th March, and the action of Tamai. Sir Gerald's dispatch does justice to the unfailing assistance rendered by his C.R.E. in carrying out the many engineering operations which had to be undertaken, including the construction of zarebas, forming defensive posts at various places, the clearance of dense bush, formation of ground for the railway and development of the water-supply. The services of the balloon detachment, under Major Templer, which, however, were generally baffled by the high wind, received notice and also those of the telegraph service, and the fighting of the 17th and 24th Companies, R.E., and of the Madras Sappers, at MacNeill's Zareba on 22nd March, where, in spite of heavy losses, they contributed to the heavy defeat of the enemy. The campaign was over in June and Colonel Edwards returned to England, and, having received the substantive rank of Colonel, was appointed Commandant of the School of Military Engineering at Chatham, a post which he held until March, 1888, soon after his promotion to Major-General. Many of the officers of the Corps who distinguished themselves in the Great War received their early training during his period of command, and these remember him as an admirable Commandant, keen on work, keen on improving the organization of the S.M.E., and also a keen lover of cricket, who repeatedly played in the S.M.E. XI and could be counted upon to make a few runs and take a wicket or two in every match. In March, 1889, General Edwards took up the command of the Troops in China, but he remained in Hong Kong for only a few months, as his services had already been asked for by the Colonial Office to inspect and report upon the local forces of the Australasian Colonies and to advise the respective Governments as to the uniform organization of these forces with a view to mutual co-operation on emergency. The orders to carry out this duty reached him at Hong Kong in May, he arrived at Brisbane in July and his Report on the six colonies of Australia was dated from Sydney in October. After reporting separately upon the conditions which he found existing in each colony, he concluded with his proposals for their organization for joint action, in which he recommended that there should be a federation of the forces, under a Lieut.-General, a common system of organization and armament, a common Defence Act, a federal Military College for the education of officers, a federal Small-arm Factory, Gun Wharf and Ordnance Store. Rifle Clubs should be extended and a uniform gauge of the railways instituted. Each colony had small Permanent Forces of garrison artillery and submarine miners, and these he proposed to amalgamate into a uniform "Fortress Corps." In the course of his tour General Edwards was brought into contact with many of the leading colonial statesmen, and it is certain that his earnest conversations and letters added considerable weight to the movement in favour of the federation of the colonies. At any rate, his visit did much to clear the air and to inculcate sound principles of defence. A month later he had completed his inspections in New Zealand, where he recommended the amalgamation of the districts into four and the organization of field forces, "small in peace, but capable of great expansion in war," in each district. For domestic reasons he was obliged to resign the command in Hong Kong in the following spring (1890) and was not employed again. In 1891 he became Lieut.-General and K.C.M.G., in 1903, Colonel Commandant of the Royal Engineers, and, in 1912, K.C.B. He represented Hythe in Parliament from 1895 to 1899. In 1901 he married Nina, daughter of John Balfour, of Steephurst, Petersfield, and widow of Sir R. Dalrymple Elphinstone, who died in 1916, and, in 1918, he married Amy Ann Courtenay, daughter of the late J. N. Harding, of Buzzacott, N. Devon. The activities of his later years were devoted whole-heartedly to the service of the Imperial Institute, in which he held the office of President of the Council from 1909 to 1915. One who was closely associated with him in this work writes: "He spent his life as an Engineer in matters civil as well as military; he wanted to get things done; keenly conscious as he was of the necessity and utility of propaganda, he was chiefly concerned with results. Material—political or physical—existed for him only to be used for construction. . . . The secret of his success is to be found partly in his capacity for work, partly in his power of organization and de-centralization. . . . He never spared himself, but he imposed upon others the performance of the tasks which he regarded as peculiar to their office. He indicated the object to be kept in view, he was prepared always to advise and superintend, and the manner in which he got things done by committees, colleagues and subordinates, was the best tribute to his genius for organization."

F.E.G.S.

COLONEL FRANCIS JEREMY DAY.

THE death took place in London, on 13th November, 1922, of Colonel F. J. Day, late R.E., who from January, 1884 to June, 1889, held the appointment, then an active one, of Secretary of the R.E. Institute, and Editor of this Journal. Colonel Day was born in 1846, he received his first commission in 1868 and retired as a Brevet Colonel in 1899. His last appointment was that of C.R.E., Guernsey. He was not fortunate enough to take part in any of our little wars; indeed, his only foreign service consisted of comparatively short periods at Bombay and Ceylon. Colonel Day married, in October 1871, Sarah, third daughter of the Ven. Archdeacon Randell, Vicar of St Mary Redcliffe, Bristol, and his three surviving served in the war. He will be remembered as a zealous and painstaking officer and a genial and kindly companion. The files of the old foolscap *Pickaxe* bear testimony to his industry as an editor, and members of the Institution may remember with gratitude that his generous services on their behalf on various committees ceased only as recently as in 1921, under the pressure of his last fatal illness.

F.E.G.S.

COLONEL CHARLES KNIGHT WOOD, O.B.E.

COLONEL Charles Knight Wood died on the 12th instant, after a short illness, at Bodenham, Herefordshire, aged 71 years; and was laid to rest by his wife at Humber Church.

From his boyhood he was a remarkable athlete, excelling in running, jumping (his best was 21 ft. 7 in.), Association football, cricket, lawn tennis and other games and sports, a good horseman and expert canoeist. He and Von Donop formed a redoubtable wing pair in the R.E. Officers' team which carried all before them in the early seventies, finally winning the Association Cup for All England. He was a fine and versatile actor and had artistic tastes and pursuits.

A few days before he was taken ill with broncho-pneumonia he had been taking, with his customary success, the leading part in a play, produced for a charity, at the Kemble Theatre, Hereford.

He entered the R.E. in January, 1872, and retired in December, 1904, serving abroad in Bermuda, Malta, North and South Africa.

Colonel C. K. Wood, Retired, R.E.

In the Soudan War of 1885, he did fine work on the Telegraph Service : eventually, on the illness of other officers, having charge of about 1,200 miles of line.

At the outset a very important and urgent matter had to be settled on which the military and civilian Telegraph authorities held distinctly opposite views. The day after his arrival in the country, which was entirely new to him, "C.K.," as he was always known and spoken of, started up the Nile on a donkey to inspect the wires and offices, putting up with sheiks, covering 42 miles in one day on his donkey, and conclusively establishing the military view, which was fully confirmed by the later war experience.

In the Boer War he served in Natal, under Sir Redvers Buller, who appointed him Chief Engineer to his Force; and on two occasions Sir Redvers said to the present writer : "Your brother has done me right well—right well." He received a Brevet Colonelcy for his services.

After he had retired, Colonel Wood was appointed Secretary to the Herefordshire Territorial Association at its initiation and only gave up this work when he was past 70.

During the Great War he did hard and valuable work—in fact, during his whole life he put his whole heart into whatever he had to do.

C.K. was very enduring : in his 52nd year he bicycled 162 miles across England by a route he had never travelled.

Ever cheerful and kindly, his influence for good in his parish—both religious and social—was very marked : indeed, his vicar in speaking of him said : "He was father and brother to me, and fellow-worker."

He was loved by many friends near and far, and a blank is felt in not a few houses. The Bishop of Hereford in writing of him said "The influence of such a man is of the highest value to the whole neighbourhood. He will be grievously missed ; his genial manner and sterling character had won him respect, and, indeed, affection."

E.W.

CORRESPONDENCE.

THE EMPLOYMENT OF DIVISIONAL ENGINEERS IN CONJUNCTION WITH OTHER ARMS IN WAR.

A Lecture by Bt. Major G. E. H. SIM, D.S.O., M.C., *p.s.c.*, R.E.

To the Editor, R.E. JOURNAL.

SIR,

In the interesting lecture, entitled as above, reproduced in the December number of the *R.E. Journal*, there is a debatable point affecting co-operation of the Royal Engineers and their most recent offspring.

The system of providing good intercommunication for divisional engineers described, appears to be contrary to the general policy of intercommunication in the Army. It is stated that an "*independent* system of engineer communications" is necessary.

For efficiency in intercommunication, as in every other branch of engineering, certain principles must be adhered to. Two of these are Economy of Force and Avoidance of Divided Control. Any independent systems of intercommunication within a formation violate both these principles. The function of the Royal Corps of Signals is to furnish all requirements for intercommunication in the Army, except within units—in the case of R.E., within companies. If divisional signals, as suggested in the lecture, "cannot adequately supply" the needs of R.E., the matter should be put right by altering divisional signals. To give the C.R.E. and field companies permanently their own motor-cyclists must be uneconomical. Under most conditions there would be no useful work for them, unless "signals" were boycotted. On other occasions, other means of communication might be more effective. Messages, except between C.R.E. and field companies, might circulate partly by "independent" dispatch-riders and partly through divisional signals. Such a procedure would lead to confusion. Control would be divided.

As a normal practice, the "independent dispatch-rider," like the "direct telephone line" is undesirable. The extra men employed for such purposes would, if pooled with other personnel engaged on similar work, produce better results. There are occasions, however, when it is necessary to depart from the normal practice. A large proportion of the resources of divisional signals may be placed at the disposal of an individual commander. The arguments set out for divisional control of engineers apply equally to the control of the entire intercommunication system by O.C. Divisional Signals under the direction of the General Staff.

The signal system of divisional artillery is cited in support of the "independent" system for divisional engineers. Artillery brigade signal sections form part of divisional signals and do not, as before the war, belong to R.A. Headquarters. This shows that the principle of independent R.A. signals is not intended.

The post-war establishments of divisional signals provide more personnel at divisional headquarters than older establishments. The solution to the problem appears to be *liaison* between the C.R.E. and O.C. divisional signals. The former would then be relieved of any anxiety about the transmission of his orders to field companies and their reports to him.

Yours, etc.,

H. C. B. Wemyss, *Bt. Major, R. C. of S.*

Barrule, Woodlands Road, Camberley.

THE MATHEMATICAL CONCEPTION OF THE UNIVERSE.

To the Editor of R.E. Journal.

Sir,

I read with great interest Colonel Mantell's article on "The Mathematical Conception of the Universe," in the *R.E. Journal* for December, 1922. May I point out, however, that Colonel Mantell appears to have gone astray as regards Einstein's interpretation of the Michelson-Morley experiment. He states that from the "experimental fact that light moves at one and the same velocity in every direction, regardless of the ether-flow, it is possible to show . . that every body which is in motion contracts along the direction of its motion." That is not so. On the contrary, the Michelson-Morley experiment shows that either

(*a*) The velocity of light is a constant for every observer, whatever his speed relative to the source of light (or, as Colonel Mantell puts it, that light moves at one and the same velocity in every direction regardless of the ether-flow ; or

(*b*) That a moving body contracts in the direction of its motion.

Hypothesis (*b*) was put forward by FitzGerald and developed by Lorentz, as phenomena, such as the aberration of light, which were held to prove that the motion of light in the ether was independent of the earth's movement, seemed to rule hypothesis (*a*) out of court. This hypothesis, however, presents many difficulties, not the least being that of supposing that a body contracts by an amount depending only on its velocity and irrespective of its chemical composition and physical condition. Einstein, on the other hand, accepts (*a*) under the name of the "Principle of the constancy of the velocity of light," ignores the ether and only takes account of *relative* motion. According to him a body only *appears* to contract, to an observer in relative motion, and that irrespective of the motion of the body relative to the ether or to anything else but the observer. It is only in the case of an observer, on, say, the sun, who has measured the speed of light in his own system to be 186,000 miles per second, and the speed of the earth in its orbital motion round the sun as 18 miles per second, and therefore concludes the velocity of the ray of light, which he sees passing along the Michelson-Morley apparatus on the earth, to be 186,000 ± 18 miles per second; that it is necessary to assume a contraction, as the gain of velocity of 18 miles per second on the outward journey does not counter-balance the decreased velocity on the return journey. If this observer on the sun were aware that (as Einstein asserts) the velocity of light on the earth relative to Michelson is still only 186,000 miles per second, he would have no reason to suppose that there was any contraction.

To quote Professor Eddington (Romanes Lecture, 24th May, 1922): "The point is that every electron, at rest or in motion, is a perfectly constant structure; but we distort it by fitting it into the space-time frame appropriate to our own motion, with which the electron has no concern." The same applies to any material body.

J. S. BISSET, *Major, R.E.*

Sierra Leone, 8-1-23.

BOOKS.

HISTORY OF THE GREAT WAR.

Based on Official Documents. By direction of the Historical Section of the Committee of Imperial Defence.

MILITARY OPERATIONS.

France and Belgium, 1914.

Compiled by Brig.-General J. E. EDMONDS, C.B., C.M.G., R.E. (retd.) *p.s.c.*

Reviewed by Major-General H. F. THUILLIER, C.B., C.M.G.

THIS first volume of the official history deals with the landing of the B.E.F. in France, its advance to Mons and first contact with the enemy, the retreat to the Seine, and the battles on the Marne and the Aisne. It ends with the stabilization of the situation on the Aisne and the transfer of the B.E.F. to the left of the Allied line in Flanders. The opening movements of the latter are only given in outline, the full story being reserved for the next volume.

It is doubtful whether any other phase of the Great War will offer a story of more absorbing interest than this one, of which General Edmonds' narrative gives a clear, complete and vivid picture. There can be no doubt that the operations described will rank among the greatest achievements of the British Army. They were carried out under great disadvantages. The hasty mobilization and concentration resulted in the units being composed of reservists to the extent, on the average, of more than half their strength, and in their being hurried to the theatre of war before all ranks could resume their acquaintance with their officers and comrades or practice anew their duties as soldiers. The troops were immediately pushed by forced marches to the battle, confronted with greatly superior numbers of the most renowned army in Europe and called upon at once to undergo the severe ordeal of an enforced and prolonged retreat in the face of a more numerous and active enemy. They sustained this retreat for thirteen days, short of food and sleep when they began it and all through it. In numerous encounters with the enemy, both on the large and small scale, they more than held their own, hit him hard and marched away from him. At the end they were still an army, unbeaten and formidable. Then they turned in their tracks, advanced and took an important and decisive part in the battle of the Marne. Following up the retreating enemy to the Aisne they performed the remarkable feat of forcing a passage frontally, without possibility of manœuvre, across that river.

Truly does General Edmonds say " only those who have commanded British infantry can have any conception of what it can accomplish." These operations may be looked on as a crowning glory of the old regular army before it gave place to the great national levies called into being by the inspiration of Lord Kitchener. They were the culmination and fruit of the years of training and preparation that preceded the war. Other, more vast, more sustained, and even more critical, battles took place in later stages of the war, but to the participants in the retreat there is some quality of the essential drama of war which distinguishes these early operations from all the others and which makes those whose duty at that period held them elsewhere,

> " Think themselves accursed they were not there,
> And hold their manhoods cheap."

like King Henry's countrymen after St. Crispin's day.

Marshal Foch has said that great results in war are due to the commander and that history is right in making generals responsible for victory, and for defeat. To Sir John French, therefore, is due credit for the successful issue of these operations, carried through, as the narrative shows, under exceptional difficulties, arising, on the one hand from the instructions he received from the Government in regard to the necessity of avoiding serious losses, and on the other from the incompleteness of the *liaison* with the French armies with which he was co-operating. There were other factors, however, which contributed greatly to the issue. Of these the greatest undoubtedly was the resolute leading of the subordinate commanders and the steadfast courage and endurance of the rank and file. As General Edmonds says, " the soldiers astonished even those who had trained them by their staunchness, their patience, their indomitable cheerfulness under incessant hardship, and, in spite of a fire which no human being had ever before experienced, by their calm, cool courage at all times." But a study of the operations convinces one that even these qualities would not have ensured escape from the dangers that constantly threatened the force but for the presence of another factor, namely, the strategic blunders of the German leader, von Kluck.

Napier, in his *Peninsular War* is fond of quoting the maxim, " War is not a conjectural art," and of illustrating it by examples of commanders who acted on conjecture and were led to disaster. If there ever was a commander who treated war as a conjectural art it was surely von Kluck, and his senior colleague von Bulow was not entirely free from this tendency also. We know from von Kluck's own book that he laboured under the misapprehension that the B.E.F. had landed at

Dunkirk, Calais and Boulogne, and that he was continually hoping, by turning movements, to cut off its retreat in the direction of those ports. This delusion continued to possess him till after the battle of Le Cateau. Day after day his orders show him bent on these encircling movements against an enemy whom he had failed to fix. At Le Cateau he conjectured that the British were facing east, whereas they were facing north, and after that battle he dispatched his cavalry and his 2nd Corps on a wide movement in a wrong direction on the assumption that the British would retreat westward and also gave Smith-Dorrien's Corps a twelve-hour start in its retirement southward.

These eccentric movements caused a gap between the First and Second German Armies and undoubtedly helped the B.E.F. to escape their foes. The subsequent action of von Kluck in ignoring the threat of Maunoury's Sixth Army and exposing his right flank to the B.E.F. as he moved south-east against the French Fifth Army gave the opportunity for his defeat in the battle of the Marne. All these matters are clearly brought out in General Edmonds' narrative, which explains the situations on the German side as well as on that of the British. The mistakes committed by the former are clearly exposed, but it cannot be said that a similar frankness is shown in regard to the British decisions. It will be a pity if the official historian is not permitted to comment at all on the wisdom, or otherwise, of the British strategic and tactical movements, since a history which criticizes one side and not the other must lack somewhat in balance. We should like to have had an impartial opinion on some of the points which have hitherto been obscure, such as :—Was General Smith-Dorrien justified in taking the risk entailed by standing and fighting at Le Cateau? Was Sir John French unduly slow in committing the British forces to the attack at the battle of the Marne? or, to take a case of minor tactics, how did it come about that the 1st Cavalry Brigade failed to picquet the heights overlooking its billets at Nery and so got a disagreeable surprise?

Although these cases are not judicially commented on, the description of the events brings out certain points we did not know before and furnishes the materials for forming our own judgments on certain matters. For instance, the situation during the night of 25th–26th August as it presented itself to Sir Horace Smith-Dorrien is given in detail. The gamble involved in his decision to stand and fight was an immense one. Was it unavoidable? We see now the state of disorganization in which the units of the II Corps arrived in the neighbourhood of Le Cateau during the course of that night, having been delayed all day by the congestion on the roads and the rear-guard fights with the closely pursuing enemy. We see that the position reached by the enemy's leading troops was such that the II Corps could not hope to continue its retirement without fighting unless it started before daylight. We see also that at 2 a.m. many units of the 3rd Division were only just coming in and that at 4 a.m. the rear-guard was only just arriving, dead-beat. We may therefore accept the conclusion that the decision to stand and fight was forced on the II Corps Commander by the circumstances. But one cannot help asking why he had to stand and fight *alone*, that is, without the support of the I Corps on his right.

The consequences of this isolated action were that a frightful risk was run of a disaster of the first magnitude. That this was avoided was primarily due to the mistakes made by the enemy. The German III Corps failed to press its attack on the exposed right flank of the British II Corps. The frontal attack was not maintained with sufficient vigour to prevent the defenders breaking off the fight, the pursuit was hesitating and slow and the German cavalry were sent in a wrong direction. These things saved the II Corps, but they accentuate the error that allowed one wing of the British Army to fight without the other.

Foch's dictum previously quoted is a sound one. When a failure occurs the cause may usually be traced in the orders or dispositions of the supreme commander. The British Army was caught with its wings widely separated when in contact with an enemy superior in numbers. We know that the original separation of the I and II Corps was due to the geographical conditions, *i.e.*, to the obstacle presented by the Forest of Mormal. But sound strategy would appear to dictate that once that obstacle was passed it was imperative that the two wings should at once be brought together again at all costs. Even had this involved a battle it would have been better to have a battle with the army united than to have one with only half the army, as actually happened.

The action taken was not well calculated to bring about a union. The decision that the II Corps should continue its retreat on the 26th in a south-westerly direction would tend to increase the gap between it and the I Corps, which was already some ten to twelve miles away to the north-east. The orders to the I Corps—directing it to the Busigny area—may have been conceived with the idea of effecting union,* but to carry them out the I Corps would have had to disengage itself from its contact with the enemy and make a flank march of 16 or 18 miles across the enemy's front. Such movements do not get done in war, and this one was not. The I Corps, instead of retiring S.W. on Busigny, retired south on Etreux and thus increased the gap between the two Corps to 18 miles. This gap was only slowly reduced day by day and did not finally disappear till the 1st September. All this time the British Army ran the risk of having one of its wings overwhelmed without being able to receive assistance from the other.

The oft-debated point as to whether the British Army was late in its arrival at the battle of the Marne, seems to be clearly brought out by this narrative. A distinguished Admiral, after reading it, summed up the question in a conversation with the writer of this review by saying :—" The British Army was evidently still going full speed astern when the French had begun to go ahead." This seems to state it quite accurately. If the British, on the morning of 5th September, instead of taking that last march in retirement towards the Seine, had

* O.O. No.8 directs that I Corps should connect with II Corps at La Sablière. Where is La Sablière ? None of the maps mark it. Even in this history we have not got the ideal map for illustrating a campaign, *i.e.*, one that contains *every* name mentioned in the text *and no others*.

advanced, they would have gained 48 hours. If they had even halted they would have gained 24 hours. An examination of the clear maps and sketches illustrating the situation daily from 4th September onwards show what an opportunity was lost. Very likely they would not have progressed any faster than they did, as the resistance would have been greater, but they would have held and fixed the German II and IV Corps and enabled Maunoury to envelop their right flank.

If one should ask how it happened that the British Army was going astern when it should have been going ahead the answer is not easy to find. The order containing General Joffre's intention to advance only reached British G.H.Q. at 3 a.m. on 5th September, too late to stop the rearward march that day which had already begun (the great heat of the day had led to marches being carried out at this early hour). Sir John French is said, however, to have had an " inkling " the afternoon before. Was it enough to have warranted his arresting the retirement ? Who can say ? If we follow Foch's precept and put the responsibility on the supreme commander, we must put it on Joffre. He must have known of his own intentions, and if he did not make them clear to his ally till it was too late to stop the British movement, he cannot well be acquitted of responsibility for the result. In actual fact it was probably another example of the very imperfect *liason* between the Allied Armies which prevailed throughout these early days and was almost entirely overcome later.

There are numerous other problems of great interest which emerge from a study of General Edmonds' pages. The detail given in them is enough to give a very clear picture of the situation on any day, almost at any hour, yet the broad outlines are not blurred and we get a clear idea of the whole. Even if we wish that it had been possible to give the reasons why this or that action or decision was taken, we must admit that the manner in which authorities for the various statements are quoted gives one complete confidence in the accuracy of the facts stated. The succeeding volumes will not be in such detail as the first, but if they maintain the high standard set by it we shall be in possession of a history of the war which should combine authentic accuracy with human interest in an unusual degree for compilations of this nature.

THE NEW ZEALANDERS AT GALLIPOLI. By Major FRED WHITE, D.S.O., New Zealand Engineers.

THE NEW ZEALANDERS IN FRANCE. THE NEW ZEALAND DIVISION, 1916–1919. A popular history based on Official Records. By Colonel H. STEWART, C.M.G., D.S.O., M.C.

THE NEW ZEALANDERS IN SINAI AND PALESTINE. By Lieut.-Colonel C. GUY POWLES, C.M.G., D.S.O., from material compiled by Major A. Wilkie, Wellington Mounted Rifles.

(Printed and published under the Authority of the N.Z. Government by Whitcombe and Tombs, Ltd., Auckland, Christchurch, Dunedin and Wellington.)

These volumes, which form part of the *Official History of New Zealand's Effort in the Great War*, have been presented to the Institution of Royal Engineers by the High Commissioner of New Zealand, and are a valued addition to the Corps Library at the Horse Guards. They are described as a "popular history" series, but they are more than this, and will all be read with great interest and instruction by military readers, as giving an intimate account of very many actions brilliantly and heroically carried out. As Earl Haig writes of the Division in a Foreword to the second volume, "Its record does honour to the land from which it comes and to the Empire for which it fought."

F.E.G.S.

THE NEW ZEALAND TUNNELLING COMPANY, 1915-1919. Edited by J. C. NEILL, Associate Otago School of Mining. (Late Lieut. N.Z.T. Company). Whitcombe and Tombs, Ltd., Auckland, N.Z. 9/6.

Reviewed by Major-General R. N. HARVEY, C.B., C.M.G., D.S.O., A.D.C.

THE book opens with the letter written to the O.C. of the Unit, by Lieut.-General Sir Alexander Godley, K.C.B., K.C.M.G., on their departure from France, a generous appreciation of their work. It was always a matter of regret that the New Zealand Tunnelling Company could not be allocated to the New Zealand Expeditionary Force, but the exigencies of mining work on the front forbade this arrangement being made.

The birth of the Company, its training, its voyage home, round The Horn, narrowly escaping the German Raider *Möwe*, are well sketched.

It is of interest to R.E. officers to know that the original Commanding Officer, Major (now Lieut.-Colonel) J. E. Duigan, D.S.O., *p.s.c.*, was an officer of the Royal New Zealand Engineers before that Corps was disbanded and amalgamated with the Royal New Zealand Artillery to form a Coast Defence Electric Light Section, in 1909. As a New Zealand Engineer officer, Major Duigan came to England about 1907, and went through a course of E.L. at Gosport, and then through a course at S.M.E. His pleasant recollections of his experiences at the schools ensured a welcome at his Mess for all R.E. officers.

The Company arrived in France shortly after we had taken over the line between Arras and Loos from the French in 1916, and was a very welcome addition to the Tunnelling Force. The section of the line they took over just north of Arras was almost without defensive mines, the French system being to sink listening chambers just below the front parapet, and when the Germans were heard working too close, the line was retired.

Lieut. Neill describes how the British methods were introduced and perfected with complete protection to the infantry above. This was not accomplished without great risk and much hard work, and the New Zealand Tunneller soon showed that he could beat the Boche both in footage and cunning. In the early chapters claims are made on behalf of the mining methods of the Unit, in respect of timbering, size of gallery, and inclined shafts as against vertical shafts. As Inspector of Mines I had ample opportunity to study every variety of method and I found that every Company of the 35 under me had its own peculiarities as regards these items. It is quite impossible to convince a miner that any system is better than the one he employs, unless you can point to loss of footage, increased risk of damage by the enemy, or difficulty of getting rid of spoil.

This unit could drive its big galleries (6 ft. × 3 ft.), use timber from any source at all, and make inclined galleries without losing mining effect, and, therefore, their methods were found to be good, but not necessarily better than those of other units in other sections.

The footage of this unit was always good. I remember a case of one serjeant doing 21 ft. of 6 ft. × 3 ft. gallery; he was working at the face continuously for 17 hours in very broken chalk.

The construction of the Arras Tunnels is now history. It is very well told, and was a piece of work which redounded to the credit of the Unit, and in connection with this work was the construction of the Russian Saps leading from the Tunnels out into "No Man's Land," hardly less important and much more dangerous.

After the battle of Arras the Company had a variety of work, road-making, dug-outs, machine-gun emplacements. The destruction of damaged shells was also entrusted to this unit. 13,000 18-pounder and 4·5 in. shells were packed into a disused mine gallery and detonated with 45 detonators in series on each of two electric circuits. The detonation was completely successful. On another occasion, the remnants of the dump which exploded at Wanketin, some 60,000 shells, were similarly treated.

In the first battle of Cambrai, the company was used for bridging, which was all well done, and in the winter, 1917–18, they formed a Rugby football team which was never defeated and won the championship of the region and the 4th Division Cup and medals.

The German offensive, March, 1918, found the Tunnellers still in the Arras sector, where they were employed in saving the situation, digging and making reserve lines. Later on in the general advance they assumed general engineering duties.

In this capacity they constructed in the VI. Corps Area, bridges at Havrincourt, Noyelles, Solesmes and Maubeuge, under the C.E. VI. Corps, as well as many others under the C.E. XVII. Corps. The Hopkins Bridge over the Canal du Nord at Havrincourt, was a remarkable piece of work, and carried out with complete success by Capt. J. D. Holmes, D.S.O. It is true that the designer visited the bridge just as all preparations for launching had been made and foretold that a period of four hours would be required. He unfortunately was unable to stay to see the launch actually carried out, and where his prophecy failed. As a matter of fact the failure of the rollers was a difficulty which could only have been got over by an engineer of considerable experience, and but for the resourceful inspiration of Capt. Holmes, the bridge would never have been launched. As it was, when it was safely launched and the tackles removed, it was found that one steel rope had been flattened by the strain and the bolt of one of the main shackles had been bent double. From this it can be understood that failure was very narrowly averted.

I have a vivid recollection of watching Capt. Holmes and a trusty party of 12 men making fast the off-shore end of the bridge, half way across a gap 93 ft. deep, in failing light and blinding rain. The launch was completed next day.

The leading principle of this Company was that no difficulty or unusual circumstance in connection with bridge building, or any other work, was allowed to interfere with successful achievement. There are two misprints which should be corrected: Major-General Sir William Liddell's name is spelt Liddle and the C.E. of the VIth Corps is twice named as C.R.E. IV. Corps.

Lieut. Neill must be congratulated on the production of this volume of 156 pages in which the birth, life, work and compliments thereon are so admirably and succinctly recorded. His story is told simply, accurately, with no exaggeration, but rather understating the importance of the works on which the Company was employed. The illustrations are excellent.

The spirit of the book is like the work of this most efficient unit, it goes with a bang from start to finish.

RAILROAD CONSTRUCTION.

By Walter Loring Webb. 7th edition. 1922. Chapman & Hall. 30/-.

Reviewed by Major and Bt. Lieut.-Colonel W. G. Tyrrell, D.S.O., R.E.

The first edition of this work saw the light of day in the year 1900, since when seventeen thousand copies have been issued, which speaks well of its reception by the engineering profession, and the book will probably be found in constant use in all countries where English-speaking engineers construct and maintain railways.

Many of the methods advocated and the materials described are more or less peculiar to practice in the United States, while the section on rolling stock is entirely so.

The work as a whole suffers from two defects:—(1) In common with nearly every work on the subject, the various sections are not presented to the student (for whom it is, apparently, primarily intended) in the order in which he will have to deal with them in practical work later on.

For instance, skill in the conduct of railway reconnaissance and preliminary survey can only be acquired after years of experience and hard work. Yet these matters are presented to the budding engineer, at the very beginning of the work, together with illustrations of examples of problems of such difficulty that they would not normally be tackled by engineers of under 20 years' experience. Also nothing is said of the difficulties and requirements of maintenance, without a sound knowledge of which, competence in construction cannot be expected. (2) In a book of some six hundred pages, which attempts to cover the vast amount of ground covered by the whole of railway construction, the subject can only be dealt with generally.

If detail be introduced, each of the twenty-five chapters will rapidly swell into a fair volume in itself. It is a pity, therefore, to see numerous items dealt with most minutely, as they are apt, for this reason, to gain undue prominence in the beginner's eyes, which will be correspondingly blinded to items of equal importance which are treated generally.

As an adjunct to a course of instruction this book is to be strongly recommended, but it should not be used as a self-instructor. The experienced engineer will appreciate and welcome this new edition.

The chapters on alignment, earthwork and trestles are particularly useful, and the section on railway economics as affecting location (Chapters XIX to XXIII) is a thoroughly sound short treatise.

The tables and formulæ, at the end of the book, are primarily intended for outdoor use, and should therefore be published separately.

BALISTIQUE INTERIEURE.

By LE GÉNÉRAL GOSSOT AND M. LIOUVILLE. (J. B. Baillière et fils. Price 40 fr.; cloth, 50 fr.)

Reviewed by Lieut.-Col. J. M. WADE (late R.E.)

IN this treatise formulæ for "Interior Ballistics" are derived by mathematical analysis.

"Interior Ballistics" comprises the relations between pressure, weight of charge, duration of combustion, velocity of the gas for various data, *i.e.*, calibre, length of bore, etc., up to the instant the projectile leaves the gun. Ballistics being dependent upon experiment, a portion of the book is devoted to an exposition of the methods employed for practically determining the pressure developed by propellants, and other details, and from the results of the experiments numerical values are assigned to the constants appearing in the formulæ.

The analysis is of a very high order and, though the subject is rather outside the interest of most R.E. officers, it merits the most careful study by the scientific artillerist.

I gather that the work will be followed by a sequel on "Exterior Ballistics."

THEORY OF WAVE TRANSMISSION.

Reviewed by Lieut.-Col. J. M. WADE, late R.E.

By GEORGE CONSTANTINESCO. (Walter Haddon. Price, 10s. 6d.)

THE methods of transmitting energy known and practised by engineers can broadly be divided into two classes: (*a*) Mechanical, including hydraulic, pneumatic and wire-rope methods; (*b*) Electrical.

All methods of transmitting energy through a liquid, as heretofore applied, depend on the continuous transmission of pressure through it, so that the pressure applied at one end can be utilized at the other; in such forms of transmission the liquid merely acts as a connecting rod.

Suppose that we have a very long helical spring AB enclosed in a pipe, and that the end A is given a simple harmonic motion by means of a rotating crank; at each shock the spring near A will be compressed but will expand subsequently, the effect of the impulse, however, will travel along the spring with definite velocity. The inertia of the coils of the spring remote from A provides the resistance required for the compression of the spring near A; on cessation of the impulse expansion takes place in both directions, so that a wave of pressure and displacement will move along the spring. Under certain conditions the motion of the end A can be reproduced at B, and this motion of the end B can be used to rotate a shaft.

In this method of transmitting energy it is to be observed that the elasticity of the medium (a spring in the example quoted) is directly utilized.

Now liquids, though at one time thought to be, are not actually incompressible; they possess a definite measure of elasticity under compression, and when enclosed in long pipes their elasticity under certain conditions can be utilized for the transfer of energy by the transmission of impulses, and the principles involved in such transfer do not differ materially from those briefly outlined in the case of a spring. In the treatise of wave transmission by Mr. Constantinesco the foregoing principle is made the basis of a mathematical discussion concerning the transmission of energy through liquids enclosed in long pipes by impulses. The subject is fully, clearly and very ably discussed, and though, perhaps, outside the field of interest of most R.E. officers, is well worth study by those engineers who specialize in power transmission.

REPORT ON THE PALK MANUSCRIPTS (HISTORICAL MANUSCRIPTS COMMISSION.)

(H.M. Stationery Office. Price, 12s. 6d.)

THIS Report on some 470 letters addressed to Sir Robert Palk from the time when he relinquished the governorship of Madras, in 1767, down to the end of 1786, has been prepared at the suggestion and with the co-operation of the India Office by Colonel H. D. Love (late R.E.), and must have been a labour of more than ordinary interest to one who has spent many years of his life in the Madras Presidency. Palk himself had an exceptional career. He went out to India first in 1747 as a Naval Chaplain, and after occasional duty on shore he obtained the remunerative appointment of Paymaster and Commissary in the Field to the Madras Government, and eventually became Governor of the Presidency for three-and-a-half years. Fortunes were made rapidly in those days in India, and Palk lived for his last thirty years in England in wealth and comfort and became Member of Parliament and a Baronet. His correspondents were of all classes, British and Native, from Warren Hastings and Admiral Sir Edward Hughes downwards. There is one letter from James Rennell in which he mentions his "General Survey of Bengall, Bahar, our part of Oriza and the Provinces of Allahabad and Awd," but it is tantalizing to find that the arrival of Major-General Sir Archibald Campbell to take up the Governorship of Madras occurred at the very end of the period of the letters. The editing has been done very thoroughly; there are copious personal notes and a complete index. As an example of these old-world documents one may quote from the letter of an Agent (not Cox): "So, as it can't be better, why you must e'en be content 'tis well as it is—

Si fortuna vestra te tormento,
Let sperato te contento."

F.E.G.S.

THE MYSTERY OF MR. W. H.

By Colonel B. R. Ward, c.m.g. (Cecil Palmer. 7s. 6d. *Illustrated.*)
Reviewed by Lieut.-Colonel M. W. Douglas, c.s.i., c.i.e.

The tercentenary of the publication of the First Folio of Shakespeare's plays will no doubt be commemorated by literary appreciation and criticism; and two members of the Corps of Royal Engineers are already in the field, Lord Sydenham with an article in the January number of the *Nineteenth Century*, and Colonel B. R. Ward with this work. By the courtesy of the Editor, the first two chapters have been republished from the *National Review*.

Colonel Ward enters the lists of the Shakespearean Controversy convinced that Shakspere of Stratford was not the author of the Shakespearean plays and poems. In "Mr. W. H." he describes a series of Shakespearean discoveries, principally connected with the *Sonnets* and supported by inferences strengthening the hypothesis put forward by Mr. J. T. Looney in 1920 (*Shakespeare Identified*) that Edward de Vere, 17th Earl of Oxford, and Shakspeare are identical personalities. His conversion came through reading Mr. Looney's book, and that by Prof. Abel Lefranc (*Sous le masque de William Shakespeare*, 1919) which proved to him that Lord Derby, the son-in-law of de Vere, was also concerned. We read that "our earle of Darby is busye in penning commedyes for the commoun players." As de Vere had lived in Hackney for the latter years of his life, Colonel Ward made a pilgrimage to Hackney. He began his quest with the *Sonnets* published on the 20th May, 1609 as *Shake-speare's Sonnets* and prefaced by the following dedication:—

> "TO THE ONLIE BEGETTER OF THESE INSUING SONNETS MR. W. H. ALL HAPPINESSE AND THAT ETERNITIE PROMISED BY OUR EVER-LIVING POET WISHETH THE WELL-WISHING ADVENTURER IN SETTING FORTH." T.T.

It is generally admitted that the initials "T.T." stand for Thomas Thorpe the publisher, and those of "W.H." for William Hall, a stationer and procurer or "begetter" of manuscripts, who had "procured" and published in 1606 *A Foure-fold Meditation* by Robert Southwell. The coincident collocation of letters "Mr. W. H. all" strengthens this view. Mrs. Stopes had suggested that "the dedication reads like a wedding wish." The interest centres around King's Place, now Brooke House, Hackney, where Lord Vaux had lived and had sheltered Southwell, a Jesuit suspect. Lord Vaux died in 1595 and his house had been occupied thereafter by the Earl and Countess of Oxford. The Earl died there in 1604, and, in 1609, the Countess of

Oxford had sold King's Place. There was no theory extant to support the procuring of the *Sonnets* by "W. H." from either Shakspere or Bacon. Whence, therefore, had William Hall procured them, and the *Foure-fold Meditation*? Was he married in Hackney and a Hackney man?

Following this train of thought, Colonel Ward searched the parish registers, where he found that "William Hall and Marjorie Gryffyn were joyned in matrymonye on the 4th August, 1608" or nine months before the publication of the *Sonnets*. This relevant fact led to the inferences:—That William Hall of the dedication was a Hackney man and had been married there; and that he had procured both MSS. from King's Place, the *Foure-fold Meditation* in 1606, the *Sonnets* in 1609. Further, that the words "our Ever-living Poet" referred to an author not living at the time of publication, a point fully discussed in an *Appendix*. This latter inference granted, the conclusion remains, supported by other links, that de Vere was the author of the *Sonnets*; as other claimants, Shakspere and Bacon, were then alive. Again, *Sonnet* 125 begins:—

> "Were't aught to me I bore the canopy,
> With my extern the outward honouring,"

It is believed that this sonnet was written shortly after the death of Queen Elizabeth; and Oxford, as Lord Great Chamberlain, would have been among the six Earls who "bore the canopy" at the funeral.

It is reasonable to accept that William Hall of the dedication and William Hall of Hackney are identical; the further inferences will depend on our individual sense of probability. During the first 38 years of his life, de Vere was royal ward, courtier, poet, and favourite of Queen Elizabeth. He possessed a company of players and was regarded as one of the best writers of comedy of the time. Then came his trial and the crisis which impelled him to deplore "the loss of his good name" and to withdraw from the Court and Public. From 1588 until his death in 1604 he lived in retirement, generally in the neighbourhood of Hackney. It is shown that this period coincides approximately with the periods of Shakespearean publication and the growth of prosperity of the Stratford man. The publication of the First Folio in 1623 is also in harmony with the de Vere theory; and was possibly undertaken by the Earl of Derby as literary executor for his father-in-law on behalf of Oxford's three daughters, "the Grand Possessors" of the MSS. Whereas also neither Shakspere nor his heirs and executors were in any way associated with the publication of the First Folio, most of the names mentioned were of persons who, in some way, had been connected with de Vere; and the Earl of Montgomery, one of "The Incomparable Paire of Brethren," to whom the Folio was dedicated, was his son-in-law.

Mr. Andrew Lang, in his vindication of the Stratford man, *Shakespeare, Bacon and the Great Unknown*, wrote in reply to Sir George Greenwood, "What Mr. Greenwood's great unknown was doing at this period (1599 to 1605) neither does he know nor do I know but he only. He no doubt had abundance of leisure." It is unlikely that de Vere, with his strong literary bent, was idle during his seclusion. Is it possible that Colonel Ward has provided the answer? He has doubtless solved "the mystery of Mr. W. H." but leaves the reader to solve the greater "mystery of Mr. W.S.," or Shakspere of Stratford.

We read (*Puttenham*, 1589) that in her Majesty's time . . . "are sprung up courtly makers (poets)" . . . who are "loath to be known of their skill . . ." and suffered their efforts to be published anonymously . . . "of which number is first that noble gentleman Edward Earle of Oxforde." The custom of collective writing by collaboration is described by Mr. Lang, and literary piracy was rampant. The following thoughts are suggested. That de Vere wrote the *Sonnets*, *Hamlet* and certain plays, some in collaboration possibly with Bacon, Derby and others. That, owing to the discredit attached to play writing, and, in de Vere's case, to the shadow which persistently falls across his life, the authorship was suppressed. That Shakspere of Stratford, the jovial actor, manager or broker, and even writer of some skill, was paid to produce the plays and even take credit as Shake-speare the author. Thus did he become rapidly prosperous and retire to Stratford in middle age. Here again our reflections will, however, depend on the personal equation of our belief. The book is an interesting record of research, as well as the manifesto of "The Shakespeare Fellowship" which has been organized by Colonel Ward, with Sir George Greenwood as President; and should be studied by all who are of an open mind on the question of Shakespearean authorship.

THE DRAYSON PROBLEM.

HIS IMPORTANT ASTRONOMICAL DISCOVERY. *By* ALFRED H. BARLEY. Exeter. William Pollard & Co., Ltd., Bampfylde Street. 1922. Price, 1s. 6d.

Reviewed by Colonel B. R. WARD, C.M.G. (late R.E.).

APPENDIX No. XII of Guggisberg's popular history, *The Shop*, informs us that Captain A. W. Drayson, R.A., was on the Military Topography Staff as an Instructor from 1858 to 1867, and as Professor of the same subject from 1867 to 1873.

It was during the period of his instructorship that an incident occurred which led to a discovery so fundamental and far-reaching that it determined the whole course of his subsequent life, and was the starting point of a voluminous literature which Mr. Barley summarizes in the pamphlet under review. The incident which was destined to have such far-reaching results occurred in one of the Shop class-rooms after a lecture on Astronomy by Captain Drayson. He had been discussing the problem of the Precession of the Equinoxes and the Obliquity of the Ecliptic—problems whose very titles are enough to terrify, but which are far less alarming when considered geometrically rather than analytically—and the explanation he had given of Precession was the usual one which has been given ever since the time of Newton, namely, that the pole of the heavens describes a circle round the pole of the ecliptic. At the close of the lecture one of the cadets enquired if the distance between the pole of the heavens and the pole of the ecliptic had always been the same. "No," was the reply; "it was formerly somewhat greater, and it is subjected to an annual diminution of about half a second, which is termed the 'Decrease in the Obliquity of the Ecliptic.'"

"Did you not say, just now," pursued the enquirer, "that the precession of the equinoxes was caused by the pole of the heavens moving in a circle round the pole of the ecliptic?" "So it is." "Then what is the centre of that circle?" "The centre? I told you, the pole of the ecliptic." "But you have just told us that the pole of the heavens is decreasing its distance from the pole of the ecliptic. How, then, can this be the centre of the circle which is being described by the pole of the heavens?"

The only reasonable answer to this question is that "someone had blundered," and that some point, other than the pole of the ecliptic, must be the point round which the pole of the heavens is travelling. Eventually Drayson found that the central point in question is not the pole of the ecliptic, but a point six degrees from it.

To understand this in a general way is by no means difficult, if it is considered as a problem in solid geometry, but to prove it by analytical methods is by no means so simple. Mr. Barley has, however, not shrunk from the task, although the calculations occupied seven years instead of the seven days he first allowed himself for the job.

How geological evidence of the last Ice Age confirms the truth of Drayson's discovery, and how disbelief in Drayson's new centre is following precisely the history of disbelief in the new centre discovered by Copernicus in 1544, is set out in this very interesting pamphlet.

It is curious to notice that Shakespeare, sixty years after the Copernican discovery—in the character of Hamlet, writing to Ophelia—thus expresses his belief in the old Ptolemaic system:—

> "Doubt thou the stars are fire;
> Doubt that the sun doth move;
> Doubt truth to be a liar,
> But never doubt I love."

Francis Bacon, great scientist that he was, similarly never faltered in his condemnation of the Copernican theory. The older he got the more obstinately did he refuse to entertain the idea that the sun was the centre round which the Earth and the other planets revolved; and as he died in 1626, eighty-two years after Copernicus had made his famous discovery, it is hardly surprising that in this year of grace, 1923, less than seventy years after Drayson's discovery, no astronomer or mathematician of any eminence has yet ventured to accept the new centre.

POINTS OF VIEW.

By The Right Honourable The Earl of Birkenhead. (Hodder & Stoughton). Price, £2 2s. 0d.

This book contains an able defence of Lord Kitchener, by one who claims his friendship and even intimacy, against the grave criticisms and inaccuracies expressed by Lord Esher in his book *The Tragedy of Lord Kitchener*.

"Someone—I cannot remember who—a long time ago dismissed a German biography, of which Chatham was the victim, as the effort of an owl blinking at an eagle. Lord Esher is not by any means an owl. But his monograph leaves upon the mind the painful expression that, in just perspective, he has failed to understand and value an indomitable Englishman, who was his friend, and who died for England."

THE GOLDEN HAMMER.

By A. W. Marshall. (Percival Marshall & Co.) Price 3s. 6d.

A little book of "Engineering Stories," originally published in *The Model Engineer* or in *Junior Mechanics*, intended for juniors and evidently written as an introduction to the practical "Model Engineer" series of handbooks.

F.E.G.S.

MAGAZINES.

REVUE MILITAIRE GÉNÉRALE.

(*August–October*, 1922.) *Could We Continue to Fight?*—In the August and September numbers appears a very interesting article by M. G. Marul, which is the translation of a German article by Adolf Köster. An editorial note mentions that this will be of great historical importance, since Herr Köster is well qualified to write of Germany's condition in the autumn of 1918, when he was Home Minister of the Reich.

Herr Köster's object is to controvert what he calls the "Ludendorff Legend," that the German Army was traitorously stabbed in the back in 1918 by the moral collapse of the civil population. The lack of men and materials for the armies, the latter due to the blockade, the unfavourable strategic position of the armies, and economic collapse, were the real reasons which made it impossible for Germany to continue the struggle.

The Revision of the Regulations.—The article by "Lucius" is continued in the August issue, dealing with the increasing boldness and persistence of the Allied attacks, and Ludendorff's renewed instructions on, and modifications of, his defensive measures. The lessons to be deduced from the 1918 operations are enunciated.

In the October number begins a summary of the main lessons of the war in relation to post-war doctrines and the new regulations. First, open warfare demonstrates: (*a*) the preponderating importance of fire, and, to counteract its effects, the general use of field defences; full preparation before, and method in, the conduct of each operation are essential, the contradictory demands of method and rapidity must be reconciled as may be best; the adoption of less vulnerable formations, infantry extended to five paces as the probable limit, and well supplied with fire-arms of every nature; (*b*) The necessity for thorough intercommunication between the various arms, which must all act for the benefit of the principal arm, the infantry; (*c*) A large measure of initiative must be delegated to the actual combatants; (*d*) The encounter battle must still be expected on a greater or lesser scale at every stage of the operations. This leads to consideration of (1) reconnaissance and gaining touch with the enemy. Aeroplanes can give general information, cavalry can, perhaps, locate the actual line of fire and its flanks, but a body of infantry alone, with artillery support, can ascertain the strength of that line, and if this advanced guard or first line of battle is not to be cut up by superior forces the main body must be sufficiently close to support it, rally it after a check or accept battle in case of need.

The Shadow of a God.—In this article, in the August number, Captain de Gaulle points out how slowly military tradition dies, and the way in which the German general staff and Army Commanders in 1914 essayed to imitate the methods of the first von Moltke and his Army Commanders in 1866 and 1870. The parallel drawn is interesting, but owing to the more rapid means of intercommunication now in use the advisability of following such methods is decidedly questionable at the present day. In 1914 the result in the case of von Kluck's Command was unfortunate.

Reflections of an Artillery Officer (September number).—An editorial note mentions that this article is an extract from a book by General Rouguerol, *Après la Victoire,* published by Berger-Levrault. It describes the difficulties and powerlessness of thinking artillery officers before the great war in their attempts properly to organize the higher artillery commands and co-ordinate the various artillery echelons in battle. The General Staff, obsessed by its conception of all wars as those of movement, considered that the proper place for the senior artillery officers was at the base in the capacity of supply officers, receiving their orders through a junior officer on the Staff. As a result, France entered on the war with few artillery officers of high rank trained and with suitable staffs, without heavy field artillery and with insufficient ammunition for her field batteries. The demoralizing effect on the infantry of the impossibility of effectively replying to the German heavy guns was disastrous, the make-shifts at first resorted to did little to improve matters, and it was not until after the first two years of the war that the artillery organization and equipment could be placed upon a satisfactory footing.

(*November,* 1922.) *The First Army Corps at the Battle of the Marne, 6th to 13th September,* 1914.—A narrative account by General Deligny of the operations of his Corps. Without entering into great detail, the information and orders received and the action taken on them are shortly related with each day's events and progress.

The Revision of the Regulations.—A continuation of the article by "Lucius." After some further remarks on advanced guards, (2) the composition, employment and action of outposts are discussed. Secondly: The general lessons of position warfare, characterized by the long duration of the battles, are analysed. (*a*) The aims of open and position warfare are the same, but the procedure differs; the Army must therefore learn the tactics of both. (*b*) Since a defensive attitude is frequently imposed, the principles of defence should have a place in the regulations. (*c*) The consequences of the long duration of each battle and means for minimizing its inconveniences must be well understood, which leads to some discussion on the composition and employment of divisional and higher formations and their staffs. (*d*) Further remarks are made in regard to the antagonistic demands of method, and rapidity of execution; the conclusion arrived at is that the former must be practised until the position is reached, after which decentralization of command is necessary if the full fruits of the victory are to be reaped. (*e*) The rapid exhaustion of the infantry, and the parallel increase of material and mechanical means receives attention. (1) It is recommended that the fourth regiment be restored to the division; (2) the machine cannot replace the man, infantry is ultimately the supreme arbiter in the combat and, whatever saving of personnel may be possible in other arms, a reduction in the numbers of the infantry below a certain limit must involve grave risk. (*f*) The complications introduced into the conduct of a battle due to recent mechanical inventions are touched on.

Transatlantic Air Communications.—A short article by Colonel Defrasse, speculating on the possibility of instituting a service of airships across the Atlantic, with more special reference to services from Rome to New York and Buenos Aires which have been proposed in Italy.

Les Semeurs de Haine, by André-Fribourg (Berger-Levrault).—A review of this book says that its object is to prove that wars between nations have always been the result of the systematic working of "sowers of hate." The author has been tracing in Germany the organization of the patriotic and political propaganda which are driving Europe light-heartedly into a new cataclysm. Posters, pamphlets, songs, the theatres, the cinema, countless leagues and associations, university, government, the press, all are *semeurs de haine*, preaching the invincibility of the German Army, the denial of German culpability, the injustice and indignity of the Versailles treaty, the denial of German war crimes and the outrage to civilization caused by the presence of black troops on the Rhine.

(*December*, 1922.) *What is the Future of the Red Army?* By General T. Rostovtzeff.—After describing the qualities and limitations of officers and rank and file, and the organization, or want of it, in the Soviet army, the writer indulges in some speculations as to its future. Owing to want of money the government cannot maintain an adequate regular army and pay officers and men a living wage. An army of militia would be cheapest, but there are two great objections to it, (1) that transport is too disorganized to admit of mobilization in a reasonable time, and (2) the Bolshevist distrust of the peasant. Probably a "governmental force" will be formed for internal defence (and incidentally to keep the Soviet in power), the equipment for which may be maintainable in view of the comparative paucity of its numbers. It was for this reason, and not on humanitarian grounds, that Chicherin at Genoa pleaded for a reduction of armaments and the signature of pacts of non-aggression with the states bordering Russia.

The Revision of the Regulations.—The article by "Lucius" is continued. (*g*) Cavalry must be retained at all costs, and not converted into mounted infantry. In open warfare its use is as great as ever, and, even if it is seldom called upon in position warfare, nothing else can replace it. (*h*) The training of troops should not only develop the lessons of the last war, but should keep abreast of the times and include practice with newly-invented warlike processes, the true advantages of which are not always evident until they have been brought into actual use. (*i*) The lessons of position warfare are briefly summarized. (3) The present day conception of the offensive differs to some extent from pre-war notions. (*a*) The principle of superiority of force at the decisive point survives, but is modified by the necessity for prolonged effort, and for not exposing more than a minimum of troops at a time to the disastrous effects of modern fire-arms. It becomes more a matter of reserves of men and materials and superiority of fire. (*b*) Surprise must still be striven for by processes already described. (*c*) The problem of the development of the success was not satisfactorily solved during the war. It is fundamentally a matter of bringing up fresh reserves at the critical moment, which can only be satisfactorily accomplished by keeping infantry in cantonments 15 km. or so to the rear, and rushing them up by motor transport, while mounted troops can follow those already engaged. (*d*) Moral superiority is more than ever important and must be fostered by every possible means.

Nieuport, 1914-1918.—An extract from a forthcoming book of the same title, in which Commandant Robert Thys, of the Belgian Engineers, describes the flooding of the country in front of the Allied line in Belgium, the maintenance of the sluices, etc. The inundations secured the stability of that portion of the front during the whole course of the war, and, curiously enough, the possibility of making them was entirely overlooked by the Germans, in spite of historical records of their use in former campaigns. The book is said to be richly and profusely illustrated.

Chronicles of Foreign Armies.—The armies of the Baltic States are dealt with this month. A.R.R.

BULLETIN BELGE DES SCIENCES MILITAIRES, 1922.

(*Nos.* 6 *to* 12 *inclusive.*)

A series of articles dealing with the operations of the Belgian Army during the Great War, 1914-1918, has been appearing in the successive numbers of the *Bulletin* published during 1922. The authorship of the articles is anonymous; however, there is every evidence that the narrative is based on official records. The articles are illustrated by maps and plans upon which the defence works and positions of the troops are, in some cases, marked; the doings of the Belgian Army are given in considerable detail and will repay a careful study. The numbers of the *Bulletin* under notice deal in part with the defence of the southern sectors of the Fortress of Antwerp, which, as is well known, it was expected would play a very important rôle in any war in which

Belgium might be engaged; the idea being that, if the worst came to the worst, the Belgian Army could take refuge in the Fortress and withstand a prolonged siege within the limits of its defence works.

The very elaborate and complete preparations which the Great General Staff of the Kaiser's Army had made to batter down the permanent, as well as the field, defences standing on the line of advance of the German Armies into France (as also on their flank), and the intention rapidly to push through at any cost to their main objective, to a great extent upset the calculations of the Belgian Higher Command. It soon became evident that the Belgian Army would not be able to hold out in Antwerp for more than a few days. It has, in consequence, been argued that, in view of the great developments which have taken place in artillery, and the facility with which the heaviest armament can now be brought into the field, where railways exist, it is no longer worth while to spend large sums of money on permanent fortifications. The narrative relating to the defence of Antwerp contained in the numbers of the *Bulletin* under notice conclusively proves that permanent defences, even when antiquated, armed with pieces of inferior weight to those of the attackers and supported by an insufficient field army, cannot be put out of action as easily as is sometimes imagined. In the narrative, incident after incident is given showing that, although the antiquated permanent works forming the defences of the famous *place forte* were bombarded by guns and howitzers, ranging from 4 in. to 16·5 in. in calibre, and were seriously damaged by their fire, nevertheless, under resolute Commanders directing brave troops, the forts did hold up the Germans and prevented them from immediately breaking through the Belgian defensive lines into the heart of the city. The German troops sent forward to the assault on several occasions retired without reaching their objectives, and reported that the Belgian forts were not yet "sturmreif." Thus valuable time was gained by the defenders, very short of expectations though it may have been. It is not difficult to conjecture how very different the situation might have been, had the permanent defence works of Antwerp been more up-to-date and armed with weapons of a calibre equal to that of the attackers, and if, at the same time, an adequate field army had been available to deal with the invaders.

Some general lessons of value are to be learnt also from the narrative. Reading between the lines, there would seem to have been a failure on the part of the Belgian Staff to make the fullest use of the engineer arm and, further, to co-ordinate the work of the engineers in a manner best suited to meet the general needs of the situation. The arrangements made to enable the troops to pass from the south to the north bank of the Nèthe, and *vice versa*, do not appear to have been adequate: the requirements in this locality were not sufficiently carefully planned out in peace time, and, in consequence, there was a shortage of suitable bridging material on the spot when it was most wanted. The Engineers worked hard to improve access to the river and to construct rafts, but were handicapped owing to this shortage of material. The river is tidal, and, with the arrangements made, traffic across the stream at the temporary crossings had, during parts of the day, to be suspended. Again, in other cases, the Engineers blew up permanent bridges prematurely and hampered the movement of the Belgian troops. Now, experience teaches that no amount of hard work on the part of regimental officers and the troops will ever get over the results following upon bad staff work. In modern war, technical considerations are so very important, and yet they are so often overlooked that the question arises whether the time has not arrived generally to recast existing staff organizations and methods with a view to ensuring that in the planning of all operations due regard shall be paid to the highly technical aspects of all military problems so that the technical troops may be used and utilized to the fullest extent possible.

Nos. 4 and 10 of the *Bulletin* contain, in outline, an account, which is illustrated by sketch maps, of the operations in the Italian theatre during the Great War. In the former number, the narrative is brought down to and includes the story of the Battle of Caporetto, while in the latter number is given a brief description of the Battle of Piave. A useful summary of the German Field Service Regulations, issued on September 1st, 1921, which treat with the handling of the combined arms in battle, is contained in Nos. 4 to 12 (inclusive) of the *Bulletin*. A good deal of space is devoted to the Air Force, Cavalry and Artillery, but, as is often the case in publications of this kind, the functions of the engineer arm are to a great extent slurred over. This is unfortunate, as it is more than ever essential that the various arms of the service should be fully informed in regulations of this kind what are the functions and limitations of each and every arm. Unless it is fully set out and made clear what part each arm can, and must, play, whether in attack or defence, there is a danger that the fullest co-operation may not be secured in the field between the several component parts of formations, be they small or large. A series of articles, under the title, "What Have We to Fear from Germany?" appear in Nos. 7 to 9 of the *Bulletin*, wherein the question is discussed as to whether the manufacture by Germany of poison-gas can be prevented or limited. Germany still has, it is alleged, a monopoly in chemical manufactures, and the most logical solution of this difficult problem, it is suggested, consists in the destruction of the German monopoly and in an equal distribution among the various nations of Europe of the enterprises connected with the manufacture of chemicals. The suggested solution is not a practical one, unfortunately; accordingly, it behoves each nation that it should take a far-sighted view of the question, so that in the days of trial to come a surprise may not be sprung upon it as was the case in the Great War. The problem of *liaison* in the field receives attention in Nos. 7 and 8 of the *Bulletin*: the articles are based on the Belgian instructions on this subject issued on August 8th, 1918. The various means employed or available for transmitting verbal and written communications from point to point are summarized. It is pointed out that, although the organization of *liaison* is a matter pertaining to the domain of the General Staff, on the other hand, the physical transmission of messages and matters affecting the equipment required for the purpose, lies wholly in the technical domain and must be left altogether in the hands of the special troops to whom are entrusted the executive duties relating to the communication services.

The text of certain important communications addressed by von Hindenburg and by von Ludendorff to the German Chancellor and to the German War Minister during the Great War are republished under the title, " Battle Wears Out an Army. An Army Wears Out a Nation." These communications disclose, to some extent, the effect of the Great War on the resources of Germany, and indicate that modern war is as much a matter of destroying the economic structure and resources of a State as of killing and wounding its soldiers on the battlefield. In Nos. 11 and 12 of the *Bulletin* some account is given, with illustrations and sketch maps, of the Inundations carried out on the Belgian front during the Great War. Many interesting problems had to be dealt with. As soon as the decision was taken to inundate the region southward of Dixmude, a special branch of the Engineer Staff was created for the purpose of studying the complex questions involved. Later, in the spring of 1915, it was recognized that troops with a particular kind of experience would be required to look after the dikes and the special plant in use in the inundated region. Consequently, a Company of *Sapeurs-mariniers* was raised and took over the duties in connection with the maintenance, etc., of the hydraulic works in this region. Details relating to the inundations alongside the railway are given in the narrative, and that also east of the Yser between Dixmude and Fort Knocke. Some of the problems connected with the control of the waters in the Wateringue of Furnes and the management of the waters in the several sections of the inundated front are discussed. The measures taken to reclaim the inundated land for the purposes of the offensives from the British front in 1917 and in 1918 are touched upon.

Commandant Jacquet contributes an account, illustrated with sketch maps showing the disposition of the opposing troops, of the German offensive in Picardy (March 21st–April 4th, 1918). The reasons which prompted the German Higher Command to select the particular part of the line actually chosen for the delivery of the blow against the Entente front are gone into, and an account is given of the preparations made by the Germans, a large amount of which fell on the engineer arm. Apart from the fact that von Ludendorff aimed at the point of junction of the British and French Armies, in order to separate and get in between them, another of the main reasons why the blow was struck against the fronts of the British Third and First Armies lies in the fact that the Germans calculated that this part of the British front, which was of recent occupation, would not be as strongly fortified as the more northerly parts of the British front. Further, the Germans seem to have been fully aware of the fact that the trenches on the section of the line chosen for their offensive were lightly held.

The question as to whether Colonel Hentsch was actually responsible for the retreat of the German First and Second Armies from the Marne is closely examined in an article by Lieut. Fraeys published in No. 11 of the *Bulletin*. The evidence which is available (and some of it that is contemporaneous with the events under discussion is fortunately documentary) distinctly clears Colonel Hentsch from the imputation of having hastily interfered in the situation which he found existing on arrival at the battle-front, and of having in this way brought about disaster to the German arms on the Marne. On the contrary, the evidence tends to show that the German Higher Leadership was not equal to the demands made on it on this occasion.

The remaining articles in the numbers of the *Bulletin* deal with aviation, psychology, musketry, infantry and artillery tactics, etc., but are not of the same importance as those to which attention is called above.

W.A.J.O'M.

REVUE MILITAIRE SUISSE, 1922

(*Nos. 4 to 12 inclusive.*)

Attention is called, in No. 4 of the *Revue*, to the new edition of the *Règlement des pontonniers* to which the Swiss War Office gave its approval on December 21st, 1921; the contents of the volume differ materially from those of the edition of 1913. A summary, with illustrations, of the contents of the 1921 edition is contained in the original article. It is pointed out that the bridging material in the hands of the Swiss engineers was designed in the days prior to the introduction of heavy mobile artillery and of mechanical transport. The Regulations of 1913 provided for what was known as a "heavy bridge," suitable for carrying vehicles up to a maximum weight of 6,000 kg. (approx. 6 tons). The introduction of mechanically-driven vehicles necessitated provision being made for floating field bridges capable of carrying wagons weighing, when loaded, up to 10 tons or so. In the 1921 Regulations provision is made for a new "heavy bridge" which will carry vehicles having a maximum weight of 9,500 kg. (approx. 9½ tons). The Swiss engineers have solved the problem put up to them in such a way that the existing bridging equipment and stores can, with very slight modifications, still be utilized in the construction of the new heavy type of bridge, details relating to which are given in the original article. Before complete effect can be given to the 1921 Regulations, it will be necessary for the Federal Chamber to vote funds for the conversion of the bridging equipment and stores in the hands of the Swiss Army. Although the *Règlement des pontonniers* deals mainly with engineering details, the final Chapter is devoted to the discussion of the tactical problems connected with the passage of rivers in face of an enemy. Colonel Lecomte, the author of the original article, takes exception to the inclusion of a Chapter dealing with tactical problems in a volume dealing with a technical subject of a specialized kind. He argues that a volume of this kind is not likely to be consulted by the general body of Swiss officers; moreover, as the passage of a river in face of an enemy is an operation affecting the employment of all arms, he rightly points out that instructions on the subject should be issued not by a specialized arm of the service but by the General Staff. However, nothing in the nature of a Field Service Manual appears to have been issued in Switzerland; it may be the engineers have merely taken the initiative with a view to having the gap filled, and have probably consulted the proper authorities in order to make sure that the doctrines preached in their little volume do not offend tactical canons of the General Staff. Commandant Begou deals in Nos. 5 and 6 of the *Revue* with the tactical problem of the attack of a division: a trench warfare scheme is worked out on sketch maps, the rôle of the engineers being briefly touched upon. The *Training Manuals* published in recent times in France, Germany and Switzerland are brought under notice in Nos. 5 and 8 of the *Revue*. Colonel Poudret contributes notices relating to Colonel Grouard's *La conduite de la guerre jusqu'à la bataille de la Marne* and M. G. Hanotaux's *La bataille de la Marne* in Nos. 6 and 12 respectively. Colonel Grouard has taken up his pen in order to criticize what he deems to be the mistakes made during the operations with which he deals. He is impartial to the extent that he is as ready to point out what he considers to be the mistakes made by the French Higher Command, as well as those made by the German Higher Command and the British Commander-in-Chief. M. Hanotaux, on the other hand, has undertaken the task of defending Marshal Joffre and his Staff, and to explain the German movements in the light of the French strategy. Colonel Poudret presents a valuable analysis of the different points of view taken by the two authors on the principal matters in controversy in relation to the handling of the opposing forces during the critical days of the Great War. Colonel Feyler gives, in No. 9 of the *Revue*, an outline of the schemes worked out at the French G.H.Q., during the winters of 1915–1916, 1916–1917, and towards the end of 1917, in connection with a transfer by road of from 4 to 6 divisions to the Swiss frontier in the event of Germany launching an offensive *via* Switzerland against the right of the Entente front—the various hypotheses involved are clearly set out. A study of the problem in question led to the conclusion that, if the transport were held in readiness in anticipation of the moves, a covering force of the size mentioned could be conveyed to its destination within 11 days after the issue of the warning "Garde à vous"; otherwise, 16½ days would be required for the move. Outside Switzerland, the opinion held at the time was that, had Germany launched an offensive through Switzerland against the Entente right, it would have been unwise to rely on the resistance of the Swiss Army alone to keep back the Germans; this view is not comforting to the Swiss.

M. R. A. Jacques, an engineer, takes up the question of the Sixth Arm (Chemical Corps) in a series of articles contributed to Nos. 9, 10 and 11 of the *Revue*: he points out that the two outstanding features of the Great War were: (1) aviation, and (2) the wide use of chemicals. Problems connected with the limitation and control of armaments are discussed by him, and he points out that whereas a certain amount of supervision can relatively easily be exercised in peace time in relation to a force consisting of cavalry, artillery and infantry, on the other hand, difficulties of a serious kind are met with where it comes to the exercise of supervision in matters affecting the engineer arm. Again, in the case of the Fifth Arm (Aviation) and the Sixth Arm (Chemical Corps), although some small measure of control may be possible in peace time in the matter of regulating developments of a military kind in connection with aviation, it is altogether out of the question to attempt anything effective in relation to the chemical industry, which can, in peace time, be clandestinely built up as a powerful organization ready to be used for military purposes at a moment's notice. M. Jacques rightly lays it down that a nation which possesses a highly-developed chemical industry and an extensive commercial aviation service will at all times be an "armed nation," even should it most scrupulously respect the limitations of war material and the establishments of military personnel imposed upon it by international conventions. Brief notes are given concerning those chemicals which are largely used for agricultural and commercial purposes, and are, at the same time, of importance from a military point of view. In an article published in No. 11 of the *Revue*, Capt. Kunz examines the rôle played by the Fortress of Verdun in the Battle of the Marne. The narrative shows that at one time the instructions issued by the French G.H.Q., during the early phase of the Great War, were such that a literal compliance therewith would have involved a withdrawal of the French troops from the Fortress. Fortunately, the French Commander on the spot correctly appreciated the situation and managed to retain his hold on Verdun until the turn in the military tide on the banks of the Marne caused the Germans to desist in their attacks on the Fortress, which they had, by the way, approached with considerable caution, owing, no doubt, to some extent to their respect for the reputed strength of the French stronghold, but also because they do not seem to have learnt that the French troops in this region were numerically weak. The German V Army which was sent against Verdun was evidently hypnotized, and credited the defence works at Verdun to possess a greater resisting power than in fact was probably the case.

The remaining articles in the numbers of the *Revue* under notice deal, to a great extent, with subjects which are of more particular interest to Swiss readers.

W.A.J.O'M.

HEERESTECHNIK.

THE first number of the new magazine *Heerestechnik* has just appeared. It is a successor to the old *Technik und Wehrmacht* and is published by the "Offene Worte," Charlottenburg.

In his Introduction the editor states that the object of the magazine will be to give the professional soldier an insight into the technical and scientific processes of which he must avail himself in modern war. It would seem from this preface that such matters are regarded with dislike and indifference by the German professional soldier. Some of us will remember a famous saying in a captured German document which ran as follows:—"Alles was nach Wissenschaft schmeckt muss fern gehalten sein." One cannot but think, however, that the author's lament, though natural enough for a technical man to make, rather overstates the matter. A constant study of the art of war and perpetual training programmes are not conducive either to scientific reasoning or to technical polish, and the German officer is probably no exception to a general rule.

The magazine is to be divided into official and unofficial sections. It is presumed that the former section is kept for such articles as have official approval, whilst the latter are expressions of personal opinion. The whole reminds one, to a certain extent, of the modern story magazine in so far as every article in the first number ends abruptly with the promise of a continuation " in our next."

The official section opens with the first part of a study of the theoretical conditions affecting the life of barrels—gun, trench mortar, rifle and pistol—and the effect of their deterioration on fire control. In its continuation, no doubt, this article will become very technical. It starts, however, with another complaint as to the indifference of the professional soldier to this important matter. Apparently also our old friend, the " business man," is to be found in Germany, as elsewhere. He seems to have claimed that such matters as the construction of ordnance of all sorts would meet with no difficulty if it were placed in the hands of the " business man." The author of the article, however, maintains that the German business man combines a similar indifference to matters scientific with a profound ignorance of the fundamental principles of war.

The study of ballistics is one which is allied to many subjects in civil life. It has, therefore, received adequate treatment, but the problems of the construction and the life of barrels have no counterpart elsewhere and rest merely on rule of thumb. Explosions and indifferent shooting are taken as a matter of course, and not as a reason for more profound study of the underlying causes. The problem implies finding a proper balance between strength and weight on the one hand, and muzzle velocity and ease of handling on the other. In discussing the destructive forces to be investigated, the author mentions chemical, mechanical and merely thermal theories which have been advanced to account for the wear in the bore. He inclines to accept the latter. Apparently it has been customary in the German service to cast barrels as unfit for further use upon a rule founded on a loss of muzzle velocity. It is considered that this rule is not a wise one and that a loss of muzzle velocity may be noticeable in a barrel which will yet give a good pattern. Destructive forces are then classified, and that which acts upon the lands in consequence of the resistance of the projectile to taking up the rifling is discussed in some detail, in the middle of which the article breaks off.

The next article, of much more interest to the Corps, is one on coast fortification in sand dune country. The article opens with a geological discussion upon the formation of dunes, upon the effects of land and sea winds and a general idea of these matters is well explained by the aid of diagrams. It would seem that German permanent coast fortification has, in many cases, suffered from being masked by rising sand banks, and particularly in the case of such small works as machine-gun emplacements. Hedge and bush screens, partly to arrest the flow of the sand, and partly to break the force of the wind, are dealt with in the text and by diagram, and again the subject is broken with an abrupt reference to more " in our next."

The unofficial section begins with a study of the problem of the mass manufacture of arms, especially of small arms. Before the war such matters were in the hands of State factories, which had little, or no, touch with civil firms. In consequence of the war, these State factories have been closed down, and the workmen are largely lost to their subject. The problem which faces Germany is, therefore, to start the manufacture of arms in civil factories, and to ensure inter-changeability of parts and due regard to other military requirements. Permanence of type is, for example, emphasized as most important, and as an illustration of the value of this permanence, the German rifle ('98 model) now 24 years old, is quoted as having a long and useful life still before it. The difference between civil and military requirements is emphasized at considerable length and is illustrated by the difference between wheel construction for the ordinary agricultural vehicle and for military transport. Special military requirements are summed up, as ease of handling, durability, effective pattern, and reserve of power.

The next article is a continuation of one which appeared in the last number of *Technik und Wehrmacht* on the attacks on " Position de Nancy, Camp des Romains, Nowo Georgiewsk." In his opening article on this subject Lieut.-General Schwarte described the repulse of the III Bavarian Corps before Nancy. It was withdrawn to recover from severe losses during a period of rest at Metz, but was soon after allotted to General of Infantry Strautz, together with the V Prussian Army Corps, the 33rd Reserve Division (composed half of Prussian and half of Bavarian units) and certain siege formations, and given the task of breaking through the fortified line between Verdun and Toul. The XIV Army Corps and the Bavarian Cavalry Division were entrusted with the task of screening Toul. It would appear that the French were taken aback by this development and an unexpected attack on the 19th November drove them from their position on the heights overlooking the plain of the Woevre. This attack was conducted by the III Bavarian Corps, which was counter-attacked on the 22nd, 23rd and 24th by the French. The counter-attacks seem to have been pushed home with much vigour and were driven off with a good deal of difficulty and severe loss to the Bavarians. General Strautz's scheme now included a left wheel of the III Bavarian Corps, to facilitate which the 6th Division was ordered to take the Camp des Romains. The attack was to be prepared by :—

2 Battalions of Heavy Howitzers
2 ,, 21 cm. ,,
3 28-cm. coast defence mortars
2 30·5-cm. Austrian mortars
2 10-cm. batteries

This siege artillery opened fire at 10 a.m. on the 23rd. Good results were reported by mid-day, and early the next morning it was officially reported that the Camp des Romains and the batteries which were participating in its defence had been silenced, that the fort itself was breached, and that everything was now ready for the assault. Apparently this report lacked real foundation and was not dictated by the result of any reliable reconnaissance. Nevertheless, in view of the situation on the German right, where no success had been obtained, and of the danger of French counter-attacks from the South, it was decided to assault without delay. The 11th Bavarian Infantry Regiment and the 2nd Battalion of the Prussian Pioneer Regiment No. 16 were entrusted with the task. A rapid outline of the situation and of the measures to be taken was given to the troops. The author states that the officers of the 6th Bavarian Regiment had no idea of the proper way to conduct such siege operations and comments severely upon the indifference of pre-war German training to a subject, the importance of which had been frequently emphasized in official instructions. The officers seem to have thought the technical instructions delivered to them as so much "Spanish," and what is "Spanish" to a German officer is "Greek" to us. In spite of this lack of previous training, the attack was successful, though accompanied by very heavy losses, and at its most interesting stage we are told that it will be "continued in our next."

The last article is a report for 1902–21 on the doings of the German Survey. Before the War the German Survey was in military hands. Since the War it has become a Civil Department in Prussia and Saxony, while in Bavaria and Würtemberg it remains in the hands of the old military topographical authorities. Their principal task has been to maintain, revise and publish the German 1/100,000 map. The staff for Prussia and Saxony has been cut down to a total of 683, whereas in Austria, where the area to be mapped is less than a quarter, the staff remains relatively very much higher. It would seem that the activities of the Prussian Survey have not been largely curtailed. There is mention of much geodetic computation connected with the Berlin base and its extension by triangulation to Schubin. Observation in the field was carried out at 18 primary and 85 secondary stations. It is interesting to note that in 1914, in the neighbourhood of the fortress of Königsberg, most of the trigonometrical marks were deliberately removed or obliterated. These points are now being remarked, and no fewer than 1885 have been dealt with. A considerable amount of routine levelling has been carried out, and one or two survey publications of value have been issued.

H.St.J.L.W.

MILITÄR WOCHENBLATT.

(*September 23rd*, 1922.)—The leading article consists of a review of a highly technical work on Ballistics, by Dr. Theodor Vahlen, of value only to a limited number of specialists. It is interesting, however, to note that the critic bewails the small number of publications in Germany, dealing with ballistics and similar technical artillery questions, while drawing attention to the wealth of literature that is appearing in other countries, both enemy and neutral. "With a fortunate issue to the war, it was to be hoped that ballistic literature would evince considerable productiveness—unfortunately it has turned out differently."

Considerable prominence is given to a notice of a publication entitled "Five Years of the Independent Social Democratic Party of Dresden," which the critic considers a remarkable contribution on the revolutionary movement. He draws attention to the pacifist activities of certain Social Democrats in Dresden, some of whom bound themselves together as early as January 4th, 1915, to work for peace; their work in the early part of the war was necessarily clandestine, but the split in the Social Democratic party which it produced became the more pronounced as the war continued. In this struggle within the party recourse was had with great effect to pamphleteering, two strident examples of which are quoted. The first, bearing the date May 1st, 1915, begins " For nine months the world-war has now lasted ! Horrors without end has it brought upon mankind . . . " and proceeds to urge a general cry for peace. The second, issued in 1916, also on the 1st May, includes the following " . . . On May 1st we stretched the hand of brotherhood across frontiers and battlefields to the people in France, Belgium, Russia, Serbia and the whole world." England presumably is not specified, as the 1st May means so little to us ; but further on the pamphlet exclaims that the enemy is not the French, Russian or English people, but the German " Junker," the German capitalists, and the German Government. How far these effusions had any real effect in lowering German morale is not alluded to, but they come in useful as pegs on which to hang the argument that the war was not lost by Germany in the field, but at home.

In an article on " The Threatened Rhineland," the writer bewails the lack of attention that is given to the French propaganda campaign, which is said to be laying great stress on the much higher morale of France as compared to the debased " Kultur " of Germany, as evidenced by the war crimes of the " Huns." This campaign is conducted with such cleverness and insistence that even many a good German is perplexed and is inclined to perceive some grain of truth in this " French babble." To counter the French propaganda, the writer urges the evidence of the German " counter-list " (of war criminals on the Entente side) and the results of the Leipzig trials. Unfortunately, the former, though promised by the German Government in May of the year before last, still awaits publication. As regards the Leipzig trials, he only admits their humiliating result because they took place at the bidding of the Entente, and while only Germany is forced to this " the far worse war crimes of the Entente remain unatoned ! " He stresses the fact that the great majority of those arraigned by French and Belgium were acquitted, and says the charges were based on intentional slanders and distortion of facts, with the one and only object of pillorying Germany. The result, he claims, in neutral countries and in America was thus not unfavourable to Germany. The fact that discussion of the question of war guilt has been forbidden in the occupied territory is labelled an unmistakable sign of a guilty conscience, and the writer ends with " Truth Will Out. . . ." This wish will be echoed by those whose *propaganda* he is attacking.

(*October 1st*, 1922.) In an article entitled " Thoughts on Artillery Tactics in the War of the Future," Colonel Freiherr von Weitershaufen first bewails the fact that all practical experiments in this direction are as good as prohibited to the Germans, and that he must rely on inspirations gathered from personal experience and the study of military literature. After some platitudes on artillery control, he states that the World War produced the centralized control of all batteries under one divisional artillery commander, while the higher formations only retained control of the heaviest calibres. He then proceeds to state that in the late war two new weapons were developed, which will influence also artillery tactics in the next war, namely bombing squadrons and tank artillery. In his opinion bombing squadrons are indicated as suitable to take the place of heavy artillery, particularly for attacking rear areas. The question, therefore, requires particular study whether the construction of heavy artillery is worth while and whether bombing aircraft may not perhaps produce more devastating results. But if bombing squadrons are called on to undertake to a great extent the rôle of the heavy and heaviest calibres, then their employment must be taken into consideration in the problem of artillery fire direction. On the other hand, the increasing importance of fighting in the air implies stronger defence by anti-aircraft guns. Every division will have its own anti-aircraft artillery under a single A.A. artillery commander, since the tasks of this arm have nothing in common with those of the other guns.

Arguing thus, the writer deduces that artillery of the future will consist only of medium and light calibres for support of the infantry fight, calibres that suffice for gas attacks, a form of fighting which in his opinion is destined to play a great, if not a decisive rôle. As small calibres he includes guns up to 10-cm. inclusive, and as medium up to 18-cm. inclusive. He advocates batteries of only 3 pieces, in order that full advantage may be taken of the ground, or batteries of 6 pieces divisible into two completely independent half-batteries.

He then lays stress on the necessity for observation personnel, allotting 20-30 men for this to each half-battery. For the artillery commander in modern war all the aids possible are demanded to ensure efficient artillery direction, including detachments for flash-spotting, sound-ranging, mapping, meteorological observation, aircraft and balloons ! Some light-armoured caterpillars, for ammunition supply to critical points of the battle which are subjected to particularly heavy fire, come also into his category of artillery necessaries.

He then proceeds to discuss tanks as the form of artillery which will actually accompany the infantry in the fight. Tanks will only be capable of giving adequate support to the infantry in the assault when the latter have gone beyond the reach of their " battle artillery," and the latter have, by changing position, only been able to bring a portion to their support. Tanks, being destined for the destruction of machine-gun nests and other positions that are offering stubborn resistance, can only carry out this rôle satisfactorily if they form part of the attacking infantry and under one united command. In this way he allots tank squadrons, together with light trench mortars, " etc.," under the commander of the infantry regiment.

Summarizing, of the four groups he has indicated, he insists that the " battle artillery " and bombing squadrons must work closely together, under the single direction of the artillery commander ; A.A. artillery works independently and tank artillery in close co-operation with the infantry.

He concludes by referring to the lessons of the fighting on the Loire, in 1870–71, and of the late war to point the moral of the main principle of artillery tactics, viz., to pave the way for the infantry to victory. He foresees that in the war of the future the infantry will, only after the war has gone on some time and they have sustained heavy losses, realize that their success depends on the protection of their own guns.

The subject of the war criminals is brought up again in this number in an article attacking the *Indépendance Belge*. The latter has aroused the writer's wrath by criticizing the inadequacy of the sentences on certain war criminals such as Neumann, Dithmar, Boldt, etc., and by commenting strongly on the German attitude towards these criminals, whose conduct won the applause of the reactionary and chauvinistic elements of the German nation. After summarizing shortly, and in his own way, the evidence and sentences in certain of the cases, the writer proceeds to accuse the Belgian paper of bringing forward a heap of lies in connection with an important international question, and then drags in " the mendacious foundation of the whole Versailles Treaty."

He concludes by saying that to combat this before the whole world with all means at their disposal is one of the most important questions of the present which confront the German nation for the sake of its future.

(*October 11th*, 1922.) In a notice of the ex-Crown Prince's book of reminiscences of the war, Major-General von Borries first points out that there is no doubt that the book is the result of the ex-Crown Prince's own pen, and that the writer, Karl Rosner, has only been called in at a few points in the book. After some eulogistic preliminaries and references to the " incomparable German army of 1914," as well as to the " tired, but unbroken heroes " of the retreat at the end, the critic describes how the ex-Emperor admonished the ex-Crown Prince, on his promotion to the command of the 5th Army at the beginning of the war, saying that " what his chief of staff advised, that he must do." Von Moltke apparently then had his say, praising his military perception, but adding that he must bear the responsibility even though he carried out the advice of his chief staff officers. The writer then remarks that the ex-Crown Prince's military education and training had furnished him with insufficient grounding for the leading of an army, and so it is to be assumed, and is also brought out by the book itself, that in the early part of the war he depended on his capable chief staff officer, who, besides, had been his instructor in the General Staff up to the war. The book also shows that by degrees the ex-Crown Prince developed his own independent opinions so that at last, in the course of the " unsatisfactory " operations before Verdun in 1916, he came into sharp opposition with and broke with his Chief-of-Staff. He seems to have been able to hit it off better with Colonel Count von der Schulensberg, who was his right-hand man later. He seems to have hit it off with the Hindenburg-Ludendorff combination at German G.H.Q., who, as the writer rather naïvely remarks, gave heed to the fact that they were dealing, not only with an Army Commander, but also with the heir to the Throne. It is evident that the book has been based on a careful and comprehensive diary with due regard to the war literature which had already appeared both in Germany and elsewhere. The critic gives the ex-Crown Prince credit for being able to keep distinct the appreciation which guided him in the actual stages of the fighting and the judgments at which he has arrived since. Naturally Verdun occupies the greater part of the book; after referring to the severe criticisms of the ex-Crown Prince on the part played in that phase by the German G.H.Q., and its dire results, the critic remarks that another question arises, why the Crown Prince, who perceived the futility of that struggle earlier than his Chief-of-Staff and the German G.H.Q., did not use his influence and position to bring the Verdun operations to an end.

A page and a half of this issue are devoted to two articles of no military interest, both of the style of abuse of all things French to which one is getting used. The first attacks the French Government, saying that it is hindering the reconstruction of the devastated areas, and that all sorts of swindles are being perpetrated, on the principle that nothing matters as "the Boche must pay for it all." The other article is a further diatribe on the Leipzig trials, ending up with a reference to the "early issue of the official German counter-list" which is to give the right information on the true war criminals!

E.G.W.

THE MILITARY ENGINEER.

THE *Military Engineer* for January–February, 1923, publishes an address delivered by General Lansing H. Beach, before the Second Annual Convention of the United States Highway Education Board on the "Rôle of Highways in National Defence." General Beach points out that national defence does not involve solely protection against an invader, but includes the "preservation of our social and economic life from internal disorders." For defence against an invader the coast line is divided into sectors, in each of which there would be mobilized, in case of emergency, a force varying in strength with the importance of the sector. Acting from a suitable centre, the force demands good roads, and for the passage of tanks and mobile artillery the bridges must be capable of supporting weights of 20 to 30 tons. For protection from internal disorders the General considers the case in which the rail-roads might fall into the hands of elements of disorder. Careful schemes for the mobilization of motor transport have been prepared, but these would be of little avail if the roads which are required are either non-existent or in such condition that they are not serviceable. The War Department has prepared for the Bureau of Public Roads an outline of a system of roads covering the entire country which it believes should be developed for military purposes.

VOINA I MIR.

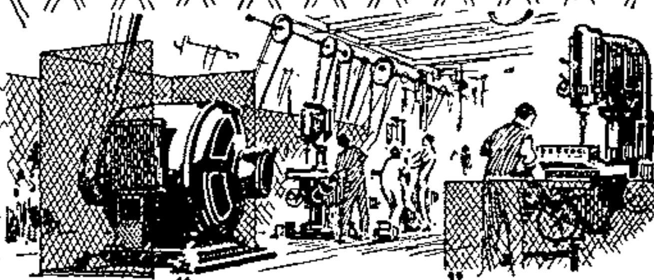
The Institution has recently received the 4th number of *Voina i mir* (War and Peace), a Russian military magazine published in Berlin, by the "Phalanx"-Verlag. The editor is Lieut.-General (of the General Staff) Professor A. K. Kelchevski, and he is assisted by Lieut.-General Borisov, Colonel Kolossovski, Major-General Noskov and others. The magazine consists of 240 pages, is exceptionally well bound, well printed and well illustrated. In an opening address the Professor appeals to Russian officers and soldiers to study military science and the art of war. In the great war his countrymen, and especially their senior commanders, were found wanting. Millions of sacred graves in the labyrinths of East Prussia, in the low-lying marshes of Poland and Galicia, in the wooded Carpathians, the solitary heights of Armenia and Turkey, the vine-clad fields of Champagne and the fever-stricken lands of the Salonica front cry out to them to blot out the faults of ignorance. The journal is unpolitical, its pages are open to all branches of military knowledge, but no politics.

In an article entitled "Dangerous Opinions," Professor Kelchevski attacks General Borisov for opinions published in a recent number of the *Voennii Sbornik*, that two fundamental modifications in the theory of the art of war, revealed by the experience of the war of 1914–18, are (i) that due to the increase in the power of resistance of small forces, and (ii) the influence of economic localities as objectives on plans of campaign—the first a tactical change, but one which must also strongly influence strategy, the second more nearly a purely strategic one. As regards the first it is claimed that "the increased power of resistance, even of very small forces, led to the lengthening of the active fronts." "It was not the want of munitions which led the belligerent armies into the so-called *position* warfare, but the extraordinary increase—even to the extent of a machine-gun replacing a company—in the power of resistance of the troops." It appears that, during the war, General Borisov served in the strategic branch of the Chief of the Staff of the Russian armies, and on this discovery, of the increased power of resistance of the troops, the Professor lays the blame for a policy which extended the Russian forces along wide lines of continuous trenches, a two-battalion regiment holding a front of 6 versts, and a division from 15 to 20 versts. His own regiment, the 2nd Finland Rifle Regiment, of two battalions, on a 6-verst front, beat off a nine days' attack by the Germans in December, 1914, when their losses were 60 per cent. of their strength, and later they held a similar front for 95 days without relief. No wonder that such experiences kindled among the soldiers a distrust in the capability of their leaders, a distrust which in the revolution led to bewilderment and cries for peace. In June, 1915, the General went to France and found the 70th French Infantry Division, near Arras, occupying a front of 1½ km., the men getting only four days out of 24 in the front trenches, and an English Corps with divisions occupying 2 km. sections, with the men in the trenches for only three days in 30. These arrangements were sound and the others unsound, for, however much the power of weapons may have increased, it is the man that matters in the long run, the man whose physical and moral forces have their limits, which fall rather than rise with the increase in the volume of fire. Our author ridicules the idea of the machine-gun replacing the company, for then might France reduce her army to four divisions and devote the savings in her budget to premiums for the improvement of the birth-rate. The widely extended weak formations in the unimportant sectors resulted in inadequate forces in the decisive sectors, and the cries for assistance from the former led to a further weakening of the latter, so that in the whole war not once was a result obtained which could be called decisive. In future wars, we must contemplate, not long defensive lines, but how to develop to the full the resources of the country for the delivery of lightning-like strokes and the reinforcement with fresh forces, not where we are weakest, but where things are going well. The present-day fight rapidly wears out the moral and physical strength of the combatants, and the writer considers that those organizing an attack should provide for it double or even treble the numbers required by calculation for a successful operation. Overwhelming success in the more important sectors is the best support which can be given to sectors of secondary importance. But the troops assigned to these latter sectors must not be unduly extended and must be so well supported by reserves that they can change rounds, if possible, every three or four days. General Borisov's second discovery is that the war showed that the increased power of resistance of an enemy requires now, not only the capture of his capital and the destruction of his active forces, but also the fullest and most rapid destruction of his means of equipping and feeding these active forces. " What hindered us," he writes " at the very beginning of the war, instead of the fruitless and expensive invasion of East Prussia, from making a surprise attack upon the mining district of Silesia? Nothing. Our geometrical strategy and our ignorance of the economic section of the Art of War." General Kelchevski allows that a well-organized air force may now destroy an enemy's industrial centres on the very first day of war. But for a plan of campaign, as contemplated by General Borisov, the objective must ever remain the destruction of the active forces of the enemy. He ridicules the idea of an invasion of Silesia, which could have led only to disaster. General Borisov considers himself a connoisseur of the Napoleonic epoch and yet he forgets Napoleon's dictum " Never uncover your line of communications—this is the A,B,C of military science." This number contains well-illustrated articles on " The German Signal Service in Wartime," " Gliding," and " Tanks," and over 12 pages are devoted to a review of Major Victor Lefebure's book on chemical strategy in war and peace, *The Enigma of the Rhine.*

VOINNA-INJENERNA BIBLIOTEKA.

ANOTHER new publication of considerable interest to Military Engineers is the Bulgarian *Voinna-Injenerna Biblioteka* (The Military Engineering Library) of which we have received the first three numbers. Articles are published on the following subjects :—" The Engineers During the War," " The Influence of Technical Equipment upon Strategy," " Mutual Induction and the Means of Removing It," " The Principles of Fortification in Trench Warfare," " The Technical Instruction of Engineer Officers," " Concrete and Ferro-Concrete in Fortification," " The Action of the Troops in the Crossing of Large Rivers," " Removable Girder Bridges." Many of the articles, and especially that last mentioned, are liberally illustrated.

F.E.G.S.



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