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THE ORDNANCE SURVEY OF THE UNITED KINGDOM.

A lecture delivered at the S.M.E., Chatham, on 13th October, 1921, by Colonel Sir CHARLES CLOSE, K.B.E., C.B., F.R.S., Director-General O.S.

ACCORDING to the Oxford Dictionary the word *Ordnance* is a "syncopated variant" of Ordinance, which is itself derived from the old French "Ordenance," a regulation and an arraying in order. In the 17th century the word *Ordnance* came to be exclusively applied to artillery and engineer personnel and material, and the services relating to these.

"Headquarters of Engineers existed in the Tower of London before 1350, and a century later developed into the Office of Ordnance (afterwards the Board of Ordnance), whose duty it was to administer all matters connected with fortification, artillery and ordnance stores" (1). It is perhaps doubtful if the Office of Ordnance was formally founded in the 15th century, but it is probable that it developed during that century into something like the form which it substantially retained for centuries, in fact, until its abolition in 1854. In one form or another it had had a continuous history of some 500 years. The Master General and Board of Ordnance were a genuine power in the land, and the position and status of the Master General in those days differed considerably from those of the Officer who now bears the same title. The Master General was in some periods the King's principal military adviser. It was a post held by the great Duke of Wellington, and it was during his tenure of the Office that the first three Survey Companies were formed (in 1824-25).

The Tower of London remained the headquarters of the Ordnance Survey from its foundation, which may be dated 1791, to 1841. In the latter year the offices of the Survey in the Tower were destroyed by fire, and it is to this mere accident that the Department owes the transfer of its headquarters to Southampton, where there were some barracks, under the control of the Board of Ordnance, available at the time.

But before proceeding further with an outline of the history of the Survey it may be as well to glance at the previous development of cartography in this country.

There is in the Bodleian Library at Oxford an early map of Great Britain, dated about A.D. 1300. This map portrays the features of England, on the whole, well; the chief towns, rivers, castles and abbeys are given, and distances are marked along the roads, which are shown by red lines. This map is a genuine piece of map-making and is not based on tradition. In these respects it differs from contemporary maps, such as the *Mappa Mundi* of Hereford, which was produced about the same date. It is, perhaps, not stretching the imagination too much to assume that the Bodleian map was used by *Dominus Rex* in his journeys about the country, or by officials in his court.

This is not a treatise on old maps, so I will skip three centuries and mention the maps produced in the reign of Elizabeth, of which there are several. As an example, take this sheet of Kent dated 1596. It is engraved on copper, it is clear and easily legible ; the hills are shown in profile, as in the most ancient known maps—those of Egypt. But it is woefully inexact. Between Rochester Bridge and the North Foreland there is an error of many miles. It was no doubt constructed by compass and cyclometer or some such distance measurer, and is in fact a compilation of compass sketches.

Let us move on a century and a half and we come to our first elaborate official survey, *i.e.*, the Down Survey, so called because it was plotted " down " on paper ; at least that I believe is the usual explanation of the name, though it seems rather a weak one. This Survey was ordered by the Commonwealth in 1656. Its object was to lay down the boundaries of baronies, townlands, parishes, forfeited lands, etc., " after the late horrid rebellion." The contract price was 1d. an acre, or £2 13s. 4d. a square mile, and the work was carried out under the direction of Dr. William Petty, ancestor of Lord Lansdowne. Hills were shown in profile. The method of surveying was, I suppose, with chain and offset rod. Of course surveying was very fairly developed during the 16th and 17th centuries and there are many contemporary treatises on the subject.

We now come to what some consider the real germ and origin of the Ordnance Survey. In August 1745, Prince Charles, the young Pretender, grandson of James II., landed at Borradale on the West Highland coast and collected a small force of 2,000 men, MacDonalds, Camerons and others, and marched south. He entered Edinburgh unopposed on the 16th September and routed Cope at Prestonpans on the 26th. He then marched as far into England as Derby, but was obliged to retreat, and was defeated by Cumberland at Culloden on the 16th April 1746.

" The credit of originating and carrying into execution the first tangible project for a systematic topographical survey of part of the kingdom is to be divided between two Engineer Officers, both at the time holding distinguished positions on the Staff of the British Army " (2). The operations in the Highlands of 1746, and the subsequent pacification, brought forcibly to attention the need for a map of that region. Lieut.-General Watson, Deputy-Quarter-Master General to the Duke of Cumberland, commenced the mapping of the district round Fort Augustus with the aid of troops quartered there; William Roy, Assistant-Quarter-Master-General, assisted his Chief in the work. "It was General Watson," Roy says, "who first conceived the idea of making a map of the Highlands—which being undertaken under the auspices of the Duke of Cumberland, and meant at first to be confined to the Highlands only, was nevertheless at last extended to the Lowlands." The work was, in Roy's words, "rather to be considered as a magnificent military sketch than a very accurate map," and was interrupted by the breaking out, in 1755, of war with France and the work was never completed. But from 1747 onwards the idea of a military map, not of Scotland only, but of the whole kingdom, was never lost sight of by a small group of officers.

This original map by Watson and Roy is in the British Museum. The scale is the large one of 1,000 yards to one inch. I think that it deserves more study than has been given to it. It was no doubt executed by pacing and with compass. The hills are now no longer in profile but are represented by rough stump shading. And so ends the first chapter in the history of the endeavour to make a military map of Great Britain.

The next chapter in the history serves to show how two distinct motives contributed to the eventual establishment of the Survey. We have seen how military necessities originated the idea, but the next impulse came, not from war, but from science. "In October, 1783 the French Ambassador transmitted to Mr. Fox a memoir," by Cassini the astronomer, in which he advocated the carrying out a triangulation from London across the Straits of Dover to be connected with the existing French triangulation, the immediate purpose being to join the observatories of Paris and Greenwich and to ascertain their relative situations.

Roy, now a General, was put in charge of the work. It is an old story how a base was measured on Hounslow Heath, men from the 12th Regiment of Foot helping. The measurement was made by three different means, by steel chains, by glass rods and by wooden rods; and the King, the Master General of the Ordnance, and the President of the Royal Society visited the work whilst it was in progress. The terminal sites are still preserved and I gave an order only the other day for painting the railings round one of them. The interest in this base is, however, only historical and sentimental. The maps of the United Kingdom do not now depend upon it.

The triangulation extended from this and other bases was of a high degree of accuracy for the times, thanks to Ramsden the instrument maker, who built two 3-foot theodolites for the work, one for the Royal Society in 1784, and one for the Board of Ordnance in 1791. One of these is at Southampton and one at the Science Museum at South Kensington. The 3-foot theodolite at Southampton was lent a few weeks ago, for exhibition in a shop window of Messrs.

Selfridge in Oxford Street. I do not think that Roy and Ramsden would have objected to its thus being made use of, for Ordnance Survey purposes, 137 years after it was made. They would rather have rejoiced at its revived usefulness.

In the triangulation of the flatter parts of England a free use was made of church towers and spires; in the hillier regions this was, of course, unnecessary. The principal triangulation took the form of a net work covering the surface of the United Kingdom with triangles, of which the average length of the sides was thirty-five and a half miles. This work was completed in the field in 1852 and the reductions were carried out by the most distinguished geodesist who has ever served on the Survey, the late Colonel A. R. Clarke, F.R.S., R.E. The bases on which the triangulation depends are the Lough Foyle Base, measured in 1827, and the Salisbury Plain Base, remeasured in 1848.

We must now, for a moment, look back to the earlier days of the Survey to see how the practical work of map-making fared. And first it is to be noted that the formal establishment of the Ordnance Survey occurred on the 12th July 1791, by order of the Master General and Board of Ordnance, "an extra allowance" of 22/6 a day being paid to Major Williams and 7/6 to Lieut. Mudge "besides the usual allowance per mile for travelling from place to place." Both these Officers belonged to the Royal Artillery and "the party of Artillery who were to assist were to receive one shilling per day each while employed."

The first sheet of the 1-in. map was published in 1801, and, until 1824, the Survey had two objects only, the execution of the great triangulation and the production of the 1-in. map. These were the days of small things so far as establishment was concerned. In 1823 the establishment consisted of 7 Officers, 7 Surveyors, 8 Draughtsmen, 6 Engravers; a total of 28 all told.

But in 1824-25 the Duke of Wellington ordered the formation of 3 Survey Companies, the 13th 14th and 16th Companies R.E., and this was in consequence of the Government authorization of the execution of a 6-in. map of Ireland.

It may be asked,—if the great triangulation was not finished until 1852, how was it that the old 1-in. sheets were issued in earlier days? I have always assumed that the answer to this question is, that where the triangulation existed the 1-in. map was based on it, and where it did not exist, the work was carried out by compass alone. The early engraved sheets are beautiful productions and give an interesting picture of England a hundred years ago.

Contours were adopted by Colby for the 6-in. sheets of Ireland in 1839, but they did not appear on the 1-in. (which till then was only hachured), until 1892. The history of the invention of contouring appears to be the following. About the middle of the

18th century sea-bed contours were drawn on certain charts published by the French Government, but the first example of land contours, in this country at any rate, is due to a purely scientific investigation carried out by Dr. Charles Hutton, F.R.S., of the Royal Military Academy, Woolwich. Hutton was calculating the density of the earth by means of a determination of the attraction of the mountain Schiehallion in Perthshire, and he says that he "fell upon" the method of "connecting together by a faint line all the points (on the hill) which were of the same relative altitude." This was in 1778.

Here we have an excellent example of the favourable reaction of pure science upon practical affairs.

The mean date of the Great Triangulation is about 1820, and, as might be expected, its angular accuracy is not up to modern standards. This led several people, including myself, to suggest a remeasurement of those portions which form parts of the great European Arcs. But it occurred to me in 1908 that, instead of assuming the fact that a general remeasurement was desirable, it might be well to test a small portion of the old work remote from either of the two bases. Accordingly, on the advice of the British Association, a new base was measured at Lossiemouth by Major W. J. Johnston, R.E., in 1909, and a small net-work was extended from it.

Captain H. L. Winterbotham reduced this test triangulation and has written an excellent report on the subject. Broadly the investigation shows that the linear errors of the old net-work are in much the same terms as those to be expected in modern triangulation carried out in chains over similar areas. The error of any side is of the order of one inch to one mile. Or the matter might be put thus, if the 700 miles of meridional arc between the Straits of Dover and Saxavord, in the Shetland Isles, were measured with every modern refinement, it is not likely that the new measurement would differ from the old by much more than 25 yards. The influence on modern figures of the earth of any such remeasurement would be insignificant.

And here, perhaps, it is a good place to say that the pursuit of mean Figures of the Earth is, for the present at any rate, given up by modern geodesists. The mean figure is well enough known, what we must now examine are local figures, attractions and deviations.

I must pass by, for want of time, the history of what is sometimes called the battle of the scales, which lasted from 1851 to 1858. In the result the Ordnance Survey standard scales became what they are now, namely, *the large scales* 1/2500, or about 25 in. to one mile, and the scale of 6 in. to one mile; and the *small scales* one inch, half-inch and quarter-inch to one mile, and the one-tenth-inch and the one to one million. The whole of the United Kingdom has been surveyed on the large scale of 1/2500, (excluding mountainous and waste areas), and there are about 80,000 plates of the map on this scale; the whole of the United Kingdom has been mapped on the scale of 6 in. to one mile and on the small scales. The latest part of the United Kingdom to be surveyed on the largest scale was Ireland. The 1/2500 survey of that country was begun in 1887 and was finished in 1914, having occupied 27 years. The expenditure was about £1,400,000, giving an average cost of £47 per square mile, or about 1/6 per acre. Now, there is a rule which is sometimes useful to surveyors, that in similar conditions, the cost varies approximately as the scale, so that to make a 1-inch map of Ireland, *de novo*, would have cost, at pre-war prices, about £1 17s. 0d a square mile. This may be compared with the actual pre-war cost, per square mile, of the Orange Free State half-inch survey, which was 8s. And from this we may judge that Ireland is at least twice as complicated a country as the Orange Free State.

The methods of survey adopted by our predecessors, and carried on until 1914, were well considered and could hardly be improved. A triangulation, primary, secondary, tertiary, the latter with sides averaging a little more than a mile long; a rigorous chain survey; then the plotting and examination in the field. And with regard to this examination the device was adopted of making intentional errors on the tracing sent to the field examiner. If the field examiner did not detect these errors he got into trouble.

There is a technicality, which affects the use of the large-scale maps, which I must mention briefly, namely, the fact that, owing to the curvature of the earth, it is not possible to plot the large-scale sheets on one projection for the whole country. Our predecessors were, however, a little timid in the matter and undoubtedly used too many independent meridians. Before the war we were engaged in reducing the numbers of these and we had already absorbed several when the war broke out. In these days of financial stringency, the reduction of the number of independent meridians is, for the time, suspended. But the expense is not very formidable, in spite of the report of a Committee that the work would cost hundreds of thousands of pounds. Committees and commissions are not infallible and I advise every one to read their reports with a free mind and not to be hypnotized by them. Anyway we successfully disregarded the opinion of the Committee in question.

Those old Officers of the Corps and of the sister Regiment were much to be envied who took part in the first Survey of the United Kingdom. They got to know with affection and exact knowledge the surface of this country. What experiences they had on the mountain tops of the Highlands and of Cumberland, Wales and Ireland! What journeys they took over the unspoilt countryside! What kindly help they received from all classes of their fellow countrymen! And how happily they carried out their labours and how successfully, until the Ordnance Survey became, without rival, the finest Survey in the world! There is a poem by Wordsworth, not perhaps very well known, written with a slate pencil on a stone, on the side of the mountain of Black Comb in Cumberland, and this poem gives a century-old glimpse into the everyday life of one of these old Officers of the Survey (3):—

"Stay, bold Adventurer; rest awhile thy limbs
On this commodious seat! for much remains
Of hard ascent before thou reach the top
Of this huge Eminence,—from blackness named,
And, to far travelled storms of sea and land,
A favourite spot of tournament and war!

. . . .

Know, if thou grudge not to prolong thy rest,
That on the summit whither thou art bound,
A geographic labourer pitched his tent,
With books supplied and instruments of art,
To measure height and distance; lonely task,
Week after week pursued! —To him was given
Full many a glimpse, (but sparingly bestowed
On timid man), of Nature's processes
Upon the exalted hills. He made report
That once while there he plied his studious work
Within that canvas dwelling, colours, lines,
And the whole surface of the outspread map,
Became invisible: for all around
Had darkness fallen—unthreatened, unproclaimed—
As if the golden day itself had been
Extinguished in a moment; total gloom,
In which he sate alone, with unclosed eyes,
Upon the blinded mountain's silent top!"

It is now time to turn to the existing constitution and work of the Survey. From the early days of the Survey civilian employees were added to the strength of the Department to assist in the prosecution of the work. These were known as first-class assistants, second-class assistants, and "men dragging the chain." The final adoption of the 25 in. scale for Great Britain in 1858, the speeding up of the maps on this scale in the 'eighties of the last century, and the commencement of the Irish 25-in. map in 1887, all resulted in the absorption of large numbers of civilian assistants and labourers. The civilian assistants can now, given good health and efficiency, all become pensionable, a very reasonable and proper regulation. Moreover, the Royal Engineer rank and file of the three Survey Companies, can, after serving 21 years in the Army, join the ranks of the pensionable civil assistants, and can continue to serve as civilians until they reach the age of 60.

The Ordnance Survey is thus, at the present time, a composite body, made up of officers, serving Royal Engineers of the Survey

Companies, ex-Royal Engineers who have become pensionable civil assistants, civil assistants, labourers, women, and boys under training. The total strength of the Survey in April 1914 was 2,077, but, owing to the necessity for economy, this strength has been brought down, and the Survey total is now (October 1921) 1,425, the programme of work being correspondingly reduced.

The authorized normal programme of work is, now, the following:—

(1) The revision, on the 25-in. scale, every 20 years, of those counties with an average population of 100 per square mile or over.
(2) The revision, on the same scale, of the other counties every 40 years.
(3) The publication of the revised 6-in. maps based on the 25-in.
(4) The revision of the small-scale maps every 15 years.

(It is probable that the surveys of Northern and Southern Ireland will be handed over to the Governments of those countries.)

To this programme should be added:—the training of military surveyors for service with the Army in the field, and the training of topographers for military surveys in peace time, and for boundary commissions; and the execution of such cartographic work as may be required by the War Office, Admiralty or other Government Departments.

Without doubt, the most important functions that the Survey fulfils, are those relating to the Army; and this fact can, perhaps, best be illustrated by a brief description of what was done in the Great War.

Before the war the Survey prepared for the War Office plates of the maps of the French Staff map on the scale of 1/80,000. These maps were printed and issued to the Expeditionary Force. The French 1/80,000 was not a first-class map, even for its scale, but it was nearly all there was available in France. The Belgian maps were on larger scales and were more accurate.

When the order to mobilize was received, in August 1914, I at once communicated with the War Office and enquired if any Survey Sections would be required for the Expeditionary Force. Now, our General Staff, in common with the other General Staffs, misconceived the probable character of the war, and I was informed that no military surveyors would be wanted. Then began the process of drafting many of the men of the Survey Companies to other units of the Corps. These men were, for the most part, retrieved and posted, later on, to the Field Survey units—but this is anticipating. It is, of course, easy to be wise after the event; but trouble would have been saved if the possibility of the use of Survey units had been allowed for.

Early in November 1914, Captain H. L. Winterbotham, R.E., and four non-commissioned officers were sent out to France to act as a Ranging Section; the idea being to determine the position of an aeroplane when this was vertically over a hostile target. The idea did not prove a success, but the Ranging Section did. For, in a very short time the Section was employed at its legitimate and necessary work. "The struggle on the Western Front early assumed the character of a siege. Intricate and extensive systems of entrenchment, strong and concealed battery positions, trench mortars and machine-guns, resulted in a corresponding growth of accurate and scientific gunnery. For this purpose, an accurate large-scale map was essential, and, as such a map of France did not exist, a new one had to be made. . . . In January 1915 this Survey was begun. The full magnitude of the task before the surveyor was naturally not fully appreciated at this time." (4).

To trace the history of the development of the Survey Sections on the Western Front from Sections to Companies, from Companies to Battalions, and the work they did, would require a lecture itself. All that can be said now is that, under the direction of Colonel E. M. Jack, R.E. (who had formerly served on the Ordnance Survey), and with the assistance of Lieut.-Colonel Winterbotham, R.E., Lieut.-Colonel McLeod, Lieut.-Colonel Reid, Lieut.-Colonel Legh, and other officers, the work expanded until it included surveying, battery fixing, sound-ranging and flash-spotting, so that when the Armistice was declared there were no fewer than 250 officers and over 4,000 other ranks serving in the Survey Battalions. The nucleus of the whole organization was provided by the personnel trained on the Ordnance Survey, but "much credit is also due to the temporary officers who joined the Survey Battalions and who were, perhaps, the pick of the rising young surveyors, scientists and engineers of the Empire." (4).

All this time the Ordnance Survey at home was devoting itself chiefly to war duties. The establishment at Southampton early became the principal source of supply for the maps required by the Armies on the Western Front. Under the directions of the War Office and G.H.Q. the maps drawn in France were sent by specially speedy routes to be reproduced at the Ordnance Survey Office. A good deal of work was also undertaken for the Admiralty. From the 4th August 1914 to the 31st March 1919, 32,872,000 maps, plans and diagrams, were supplied, mainly for the Western Front.

The half military, half civil, organization of the Survey responded without difficulty to the demands made upon it. Altogether out of a total male personnel of about 1900 between the ages of 18 and 60, on the strength of the Department, 961 either joined up or were already in the Army. In addition to these about 800 men were specially enlisted and drafted abroad.

As work developed the average dispatch from the Ordnance Survey Office, Southampton, to France, rose to 20,000 maps a day.

The maps were drawn and sent to us by the Field Survey Battalions, and the work of heliozincographing, printing, &c., was carried out at the Ordnance Survey Office and thousands of copies of the completed maps dispatched to G.H.Q. within two days of the arrival of the maps from France. But it eventually became necessary to establish an Overseas Branch of the Ordnance Survey, as it was found that altogether some six days were occupied from the time of the completion of the field work on the maps to the final delivery to G.H.Q. of the sheets required.

The Overseas Branch of the Ordnance Survey (O.B.O.S.) was located in the first instance, (March 1918), in a factory taken over at Wardrecques, near St. Omer, and fulfilled a very useful function. It was found, however, that this site was too close to the enemy and there was danger of the whole establishment being destroyed. It was therefore transferred to Wimereux, near Boulogne. On the 21st August the Wimereux establishment commenced work. The greatest total strength of O.B.O.S. was 181, including a detachment of 60 women of the Q.M.A.A.C. mostly recruited at Southampton. The whole was under the very efficient command of Lieut.-Colonel W. J. Johnston.

O.B.O.S. did admirable work, especially after the 21st March, 1918, when the German offensive on the Somme began. Two Field Survey Battalions were temporarily out of action and this led to very heavy demands being made on O.B.O.S., for the supply of maps to the two Armies affected. Again, on the 8th August 1918, the final British offensive began, and this entailed continuous work night and day for eleven days. O.B.O.S. fully justified its existence.

I must now pass briefly in review two other aspects of the work of the Survey, namely the scientific and artistic aspects; the scientific side of the work dividing itself into two parts, the physical and mathematical and the archæological. The chief modern undertaking on the physical and mathematical side is the execution of a revised primary level network. The field work of this new levelling of England and Wales was begun in 1912 and was finished in 1921. It has been carried out with every refinement of care. It will serve to give an idea of the accuracy of the work if it is stated that the probable error of the height of a point at Dunbar, as derived from Newlyn, some 650 miles distant, is 2 in. In connection with this levelling, three mean sea-level stations have been established, at Dunbar, Newlyn and Felixstowe, where automatic tide gauges are continuously at work. The results of this levelling will shortly be published; meanwhile it may be noted that a new form of fundamental bench mark has been devised and bench marks of this type are placed at intervals of about 30 miles all over the country. They are surrounded by railings and look rather like graves with small granite headstones.

The officers chiefly connected with this primary levelling are Major E. O. Henrici, Lieut.-Colonel A. J. Wolff, D.S.O., and Mr. Jolly, the Research Officer of the Survey. In addition to its immediate practical objects the levelling will serve as a sure reference net-work by which to test, in future years, vertical movements of land and sea. A hundred years hence—if our successors are careful to protect the marks—most interesting information will be derived from the net-work.

In the case of the archæological work of the Survey we are dealing with a subject which attracted the interest of many of the old officers of the Department, notably General Roy. Archæology is now a fully developed science, with its own methods and generalizations, and it is increasingly bringing out, into the open, matters affecting the study of humanity and everyday beliefs and standards of conduct. Now, maps play an important part in the matter, chiefly in the way of recording accurately what has been found on the surface, or dug up, and also, in presenting the plans of the discoveries and giving correct attributions. Until recently no special steps had been taken to ensure the mapping of archæological information or the correct description of archæological objects. Much information was, it is true, shown on the maps, but much was omitted, and the descriptions were not, in general satisfactory.

To remedy this, an Archæological Officer, Mr. O. G. S. Crawford, has been appointed to supervise the archæology of the printed maps. Mr. Crawford, who is an expert well known in the archæological world, takes every map into review as it is revised, undertakes, where necessary, inspections in the field and collates the evidence. He has recently discovered many "long barrows" in Gloucestershire which were not previously marked on the national maps, and has been able to show the scheme of distribution of long barrows in South-western England. (For those who have not studied the subject it may be explained that "long barrows" were constructed by a long-headed neolithic race, at least 4000 years ago.)

I do not think that any apology is needed for putting thoroughly into order the information relating to the past which appears on the national maps. Everything on the maps must be accurate, and the maps should be made serviceable to the greatest number of people and should appeal to the greatest number of tastes. And, with regard to the staff, the more interests the Survey deals with the better. A restricted routine sooner or later leads to want of vitality.

As to the artistic side of the Survey, this is shown not only in the maps themselves, but in the map covers and advertisements. We are fortunate in possessing in Mr. Ellis Martin an artist whose work has deservedly attracted a good deal of attention. Nowadays, not even a Government Department can act on the "take-it-or-leave-it" principle, and the Survey is becoming increasingly dependent on the support that it receives from the general public. The public, quite rightly, looks for all-round excellence—technical, scientific, artistic.

In concluding this brief sketch of the history and of the present activities of the Ordnance Survey, I should like to leave the impression, not of an isolated Department absorbed in its own methods and history, but of a Department fully in touch with geographical effort in the Empire and the World. No officer is more welcome to the Survey than one whose experience has carried him far afield, in India, in Africa, in the four quarters of the globe. No one amongst the rank and file is likely to do so well as the man who has helped to stake out distant frontiers or to survey our remoter dependencies. We are anxious not to limit our ideas or our practice to a narrow routine. The Ordnance Survey is itself the Headquarters of the International Map of the World; we are in touch with all the Surveys and we have all something to learn from each other. We benefit from the freshness of view that comes from variety of experience, of occupation and of idea; and the different aspects of the work put us in touch with the Army, the civil administration, the business world, and with the realms of physical science, art and archæology. And we strive to conduct our affairs in such a way that the national survey may be a legitimate source of pride to our fellow countrymen.

References to numbers in the text:

(1) *Encyclopædia Britannica*, 11th edition, Article "Engineer."

(2) *The Ordnance Survey of the United Kindgom*, by Lieut.-Colonel T. P. White R.E., 1886.

(3) *Memoirs of the Mudge Family*, a privately printed book, kindly lent to me by Major-General Sir R. Curtis, K.C.M.G., C.B. General Mudge, the second Director of the Survey, is the officer referred to by Wordsworth.

(4) *The Ordnance Survey and the War*, a compilation issued at Southampton, 1919.

JERUSALEM NEW WATER SUPPLY.

Compiled from a Report by Major F. W. STEPHEN, R.E., *dated 20th July,* 1918.

Existing Water Supply on British Occupation.—On the occupation of Jerusalem by the British forces in December, 1917, the water supply consisted of :—

(*a*) Water from previous year's rains stored in underground cisterns ; and

(*b*) A small aqueduct and 4-in. pipe-line from the Pools of Solomon and Urtas—length $10\frac{1}{2}$ miles, fall 66 ft.—delivering water to Jerusalem, *via* Bethlehem.

Capacity and Quality of these Sources of Supply.—The total storage capacity of the cisterns in Jerusalem, ranging from those of several million gallons' capacity under the Mosque of Omar, to the small domestic cisterns to be found under or near every house, was estimated at 360,000,000 gallons. Owing to neglect in repairs and cleaning, most of these cisterns were empty, or the water in them was quite unfit for drinking. They were mostly unprotected from mosquito breeding and were thus a serious menace to health.

The Pools of Solomon-Jerusalem piped supply was part of a very ancient system which by means of aqueducts had, probably at the time of the Roman occupation, supplied the city with as much as 1,000,000 gallons per day. All that now remained was the old aqueduct from the Pools of Solomon, leading to Bethlehem and Jerusalem, along which an earthenware pipe had been built into the once great ruins. This supply had been maintained by the Turks, and the delivery from the various springs was estimated to total 80,000 gallons per day, of which 40,000 gallons were drawn at Bethlehem and 40,000 gallons were delivered at Jerusalem. Here the water was supplied to :—

(*a*) The Birket el Sultan, an artificially dammed storage of foul water ; and

(*b*) To the cistern storage in the Haram Aria (Mosque of Omar), which was comparatively clean.

Reasons for Providing a New System.—After the British occupation the Army consumed the whole of the piped supply for drinking purposes, and large quantities of the cistern storage for animals. The civilian population, estimated at 50,000, was watered entirely from cistern water of doubtful quality, and the reserves, which would otherwise have been accumulating in the rainy season, were becoming rapidly depleted. The rainy season lasts from November to the middle of April, during which the average rainfall is 60 cm., ranging from 90 cm. maximum to 45 cm. minimum. It was evident that immediate steps had to be taken to ensure against a serious shortage during the coming summer.

The Chief Engineer, 20th Corps, whose area included Jerusalem, instructed his Field Engineers early in January to make immediate investigations for a new supply.

Preliminary Investigation for New Supply.—The probable sources to be tapped were well known, as, under the Turkish *régime*, scheme after scheme had been got out, only to die a natural death when it reached the stage of actual construction.

From north, east and west available supplies were ruled out owing to levels and the enormous pumping schemes consequently involved.

From the south the nearest supplies, those at Solomon's Pools, were already tapped. The next supply of any magnitude was in the Wadi Arrub on the Jerusalem-Hebron road, at 22 km. from Jerusalem.

In the Wadi Arrub the water appeared to flow from several spring-heads, and ran down the valley in an open stream, from which it was principally used to irrigate small patches of cultivation. Further investigation, however, showed that the so-called spring heads were connected by an ancient system of underground aqueducts, which finally led the water into a large reservoir or "Birket" lower down in the valley, about 1050 metres to the east of the main road. This old Birket was supposed to date back to the time of Herod, B.C. 4, and at that time formed part of the main supply of Jerusalem, feeding the Pools of Solomon by an aqueduct which had been long since disused and in some places had quite disappeared. The bottom of the Birket Arrub stood at 2723 ft. above sea-level and the Jaffa Gate of Jerusalem 2618.

In January the yield of these springs was gauged at 14,000 g.p.h., and was considered capable of increase by careful cleaning.

On the 14th February, 1918, the preliminary investigations had been completed; a line of levels had been run from the ancient Birket to Jerusalem and a scheme to deliver 250,000 gallons a day was submitted to the Engineer-in-Chief on 18th February. It was proposed to repair the Birket and to pump water from there into a new reservoir at the 19th kilometre on the Hebron road, at a level of 3,085 ft., from which it would run by gravity to a second new reservoir on the Jaffa road, outside Jerusalem, at 2,788 ft., whence it would be distributed as required.

Scheme as Finally Approved.—The scheme as finally approved was as follows and was governed chiefly by the machinery and piping available in the country:—

(*a*) To develop and collect the water from the springs and use the ancient aqueducts to convey the water to the ancient Birket, where 4,000,000 gallons' storage could be provided. This entailed the excavation, clearing, partly re-building and re-roofing of 1,100 metres of aqueduct and considerable repairs to the old Birket.

(*b*) To erect a three-throw ram pump of a capacity of 15 to 20 thousand gallons per hour against a head of 410 ft., with two 66 h.p. Hornsby engines in a pumping station adjacent to the Birket, so arranged that water could be pumped direct from the aqueduct leading from the springs, or from the Birket storage, as required. This latter provision was made so that, should the yield of the springs diminish during the dry season, all the output of the springs should be caught in the Birket during the time that the pumps were not actually running, thus not only having a 4,000,000 gallon storage in reserve but taking full advantage of the total yield of the sources of supply.

(*c*) To lay a twin 6-in. rising main from the pumping station to a reservoir situated at kilo 19, Hebron road, a distance of 3320 metres, with a difference of level of 351 ft. It was necessary to twin this main in order to shorten the hours of actual pumping to 12 to 16 hours per day. No larger diameter pipe was available.

(*d*) To build a reservoir of a capacity of 300,000 gallons on the natural watershed about kilo 19, Hebron road, in such a position that a natural gradient would be obtained, and water would be delivered to Jerusalem entirely by gravity. This reservoir to be of masonry, and to be built of two equal compartments, and completely enclosed.

(*e*) To lay a single 6-in. pipe from kilo 19 reservoir to a point in Jerusalem situated for position and level to feed the distribution system in Jerusalem by gravity. The length of the line is 20,350 metres.

(*f*) To build a reservoir of 200,000 gallons' capacity at Lifta, on the Jaffa road, Jerusalem, at an altitude of 2,788 ft., or 295 ft. below the level of the kilo 19 reservoir. This reservoir to be of the same type as the kilo 19 one and to be completely covered in.

(g) To lay the nucleus of the distribution system in Jerusalem, with a ring main capable of dealing with the maximum delivery of the gravity main in 12 hours. This system to include branches to all Army supply points, and a certain number of civilian watering points in districts where there was likely to be a shortage during the summer months. The total length of main on the original distribution system was 11,500 metres.

Instructions on the Laying of the Line.—The following instructions were issued on the laying of the line :—

(1) The line will be marked with iron kilo posts numbering from Jerusalem reservoir. Half-kilos to be marked with red-painted L.W.E. posts.

(2) Screwing parties will work from the half-kilos, and sections will be coupled up with expansion joints, so that each expansion joint will come at the kilo post.

(3) Scour valves will be placed at all the "dips," and will consist of 6-in. tee reducing to a 3-in. valve. The valves will be turned downwards and suitable pitched channels will be built under the valves.

(4) Air valves, $\frac{1}{4}$-in. piping tapped into the nearest socket, will be placed at each peak, and will afterwards be protected by locked chambers as heretofore.

(5) Sluice valves will be placed immediately adjacent to the expansion joints at kilos 4, 8, 12 and 16.

(6) A tee will be placed about kilo $3\frac{1}{2}$ (exact position to be given later). This tee will have one reflux valve immediately north of it. The object of this is to have an emergency fire service for the Main Supply Depôt.

(7) The line at kilo 3 to kilo $5\frac{1}{2}$ and kilo $8\frac{1}{2}$ to kilo $9\frac{1}{2}$ is subjected to very high pressure—about 600 ft.—and care should be taken in screwing the pipe at these points, and all pipes and fittings should be examined.

(8) Preliminary washing out will be done at expansion joints.

(9) The preliminary covering will be 1 ft. deep ; final covering 2 ft. deep. Where banks and cuttings will permit, the pipe should be kept to one side, preferably the side furthest from the Bethlehem road, to allow of a foot patrol.

(10) The pipe is all American except $5\frac{1}{2}$ kilos, which are English. The English pipe will be laid where pressure is lightest, *viz.*, kilo 15 to kilo $20\frac{1}{2}$.

Carrying Out the Work.—Owing to severe weather and shortage of labour and transport the work did not commence until 12th April in Jerusalem and 15th April at Birket Arrub. Water was delivered into Jerusalem on 18th June.

The work was carried out by the following method :—One party of Sappers and local labour was employed on setting out the main pipe line and building profiles. After careful reconnaissance the final line was set out and profiles were built or dug at 20 metre intervals. This occupied 15 days. Starting ten days later, two parties, one of Egyptian Labour Corps and the other of contract labour, carried out the formation of the pipe-line, building culverts, etc., one party doing the first 15 kilos and the other $8\frac{3}{4}$ kilos. The formation was 2 m. wide on top, slopes $1\frac{1}{2}$ to 1, and drainage culverts placed where necessary. This work occupied 34 days.

Starting five days after these a party of E.L.C. and local labour laid the following distribution mains in Jerusalem :—

$2\frac{1}{2}$ kilos	6-in. main
$2\frac{1}{2}$,, ...	4-in. ,,
$6\frac{1}{2}$,, ...	3-in. ,,

The laying was difficult owing to traffic and rock excavation where it was not possible to use explosives, and the work occupied 58 days.

The work of clearing and repairing the feeder aqueduct, building the first half of the kilo 19 reservoir, the engine-house and suction-sump was begun on 15th April by E.L.C. and local labour and finished on 13th June. The investigations and clearing of the old system of aqueduct had to be undertaken with great care. All the aqueducts were partially cleared, but about one-third of the work of excavating and recovering them still remained to be done. The reservoir was built in lime mortar. The suction sump enabled the pumping to be commenced before the ancient Birket was restored.

The first half of the Jaffa road reservoir was begun on the 5th May by E.L.C. and local labour and completed on 14th June. A considerable amount of rock excavation was done in the foundation of this reservoir. Stone was quarried on the site and the masonry was built in 6 to 1 cement mortar.

On the 1st May commenced the tractor distribution of the 6" pipes, of which there were 5,000, weighing 750 tons. Twelve tractors were employed and the work was finished on the last day of the month. Originally it was estimated that five tractors would do the work in 30 days, but as they had to travel over metalled roads a further seven were allotted.

On the 14th May parties of E.L.C. began placing the pipes on formation, screwing and preliminary covering of the 6-in. mains. In some cases carries of as much as 3 kilos by the E.L.C. were necessary, chiefly owing to the line following the Wadi Biar a considerable distance from the metalled road. The work was completed by 10th June.

On the 15th May the erection of the 3-throw pump and two 66 h.p. Hornsby engines was begun by Sapper labour and was completed by 13th June. The pump was requisitioned in Cairo. Certain structural alterations were necessary and were completed before delivery at the site. The 66 h.p. engines came from the original pumping station at Mazar.

The 17th June was employed in washing out and coupling up, and water was delivered into the Jaffa road reservoir at 18.45 on the 18th June.

Tests.—The pump delivered 15,000 g.p.h. against a head of 400 ft. The reservoirs were satisfactory and no leak occurred. The gravity main delivered 12,500 g.p.h. to the Jaffa road reservoir, or 25 % in excess of the calculated discharge.

The distribution system at every point was up to the calculated discharge and was being rapidly extended at the date of the report.

Instructions for Completion and Maintenance.—The following further instructions were issued :—

(1) *Covering.* The final covering will be completed to a depth of 2 ft. over pipe ; 2 ft. wide at top, and $1\frac{1}{2}$ to 1 slopes, stone pitched where necessary.

(2) *Anchorage.* Anchorages built in masonry will be placed on all slopes over one in ten, two in each slope, *viz.*:

kilo $2\frac{1}{4}$ to $2\frac{1}{2}$, two ; kilo $13\frac{1}{2}$ to $13\frac{3}{4}$, two ; kilo $14\frac{1}{4}$ to $14\frac{1}{2}$, two ;
kilo $2\frac{1}{2}$ to $2\frac{3}{4}$, two ; kilo $13\frac{3}{4}$ to $14\frac{1}{4}$, two ; kilo $14\frac{1}{2}$ to $14\frac{3}{4}$, two.

Ten of these were made in workshops, the two others were indented for.

(3) *Road Crossings.* All road crossings will be banked to 2 ft. over pipe and ramped to 1 in 20 either side of pipe line, stone pitched where necessary.

(4) *Protection of formation.* Where natives are found to use the formation as a track, stone walls will be built over the covering at intervals, as obstacles.

(5) *Drainage.* Where the drainage is considered to be insufficient, such as between kilo $1\frac{1}{2}$ and kilo $2\frac{1}{2}$, additional culverts will be built before the rains.

(6) *Kilo Posts.* Kilo posts will be built in dry stone with number stone let in in face indicating kilos and half-kilos.

(7) *Expansion Joint Chambers.* With the exception of those in rising main kilo $20\frac{1}{2}$ to kilo $23\frac{3}{4}$, these will be built in dry stone, roofed with flat stones of suitable size.

(8) *Scour Valve Chambers.* When all scour valves are fixed they will be enclosed in locked chambers as shown in drawings.

(9) *Air Valve and Line Valve Chambers.* When fixed, these will be built in vertical chambers with a standard 2-ft. manhole cover and locked.

(10) *Kiloage of Valves, etc.* Kiloage of all valves and expansion joints to be measured and clearly indicated on the plan and section.

(11) *Repair and Patrol Stations.* These will be established :—

(i) At Jerusalem.
(ii) Solomon's Pools.
(iii) Birket Arrub Reservoir.

Repair sets to standard list (Appendix A) will be kept at these stations. Patrols consisting of one E.L.C. pipefitter and two E.L.C. natives will traverse the section daily, outwards before 1200 and back after 1200. They will carry keys of valve chambers, caulking tools and materials, spanners, picks and shovels.

(12) *Reports.* Reports will be sent to Works Office as to "all clear" or otherwise, each night, from Jerusalem and Birket Arrub stations, and within 24 hours from centre station. Weekly reports on condition of line, and list of station equipment, to this office on Wednesday evenings.

Appendix A.

Equipment of Patrol Stations.

Pipe wrenches, 6 in.	5
Pipe cutters, wheels, 6 in.	2
Expansion joints, complete with packing	2
Chisels, hand flat	6
Chisels, hand	6
Hammers, hand	4
Caulking tools	6
Spanners, adjustable	4
Lead wool	50 lbs.
Red lead	50 lbs.
Picks	10
Shovels	10
Fosses	10
Baskets	20

Appendix B.

Personnel of Patrol Stations.

Sappers, 3; E.L.C. pipefitters, 3; E.L.C. labourers (minimum), 6.

Appendix C.

Procedure in Case of a Complete Pull-out or Burst Pipe.

(1) Runner to be dispatched to kilo "0" Reservoir with report.

(2) Line valves both sides to be closed.

(3) In case of (*a*) Pull-out—

Pipe socket to be cut off or pipe cut close to socket and expansion joint fixed.

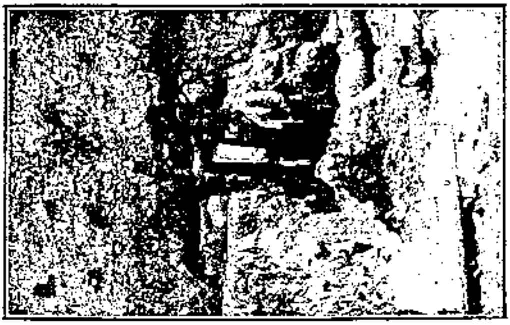
In case of (*b*) Burst pipe to be replaced—

New pipes cut to give three inches clearance between pipe ends, and expansion joint fixed.

(4) Open line valves.

(5) Dispatch runner to kilo "0" Reservoir to report "all clear" and return with message that supply has been resumed.

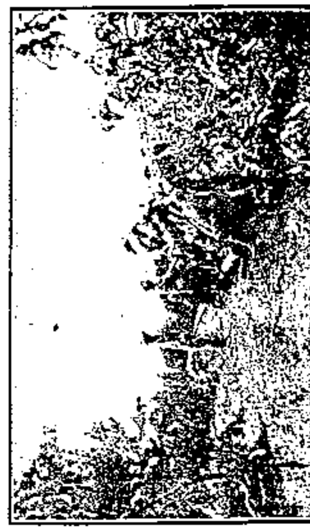
JERUSALEM NEW WATER SUPPLY.



Old Sluice Gate Birket.

Uncovering the Old Aqueduct.

Main Spring Head.



E.L.C. Screwing Party K10½

S.E. Corner of Birket.

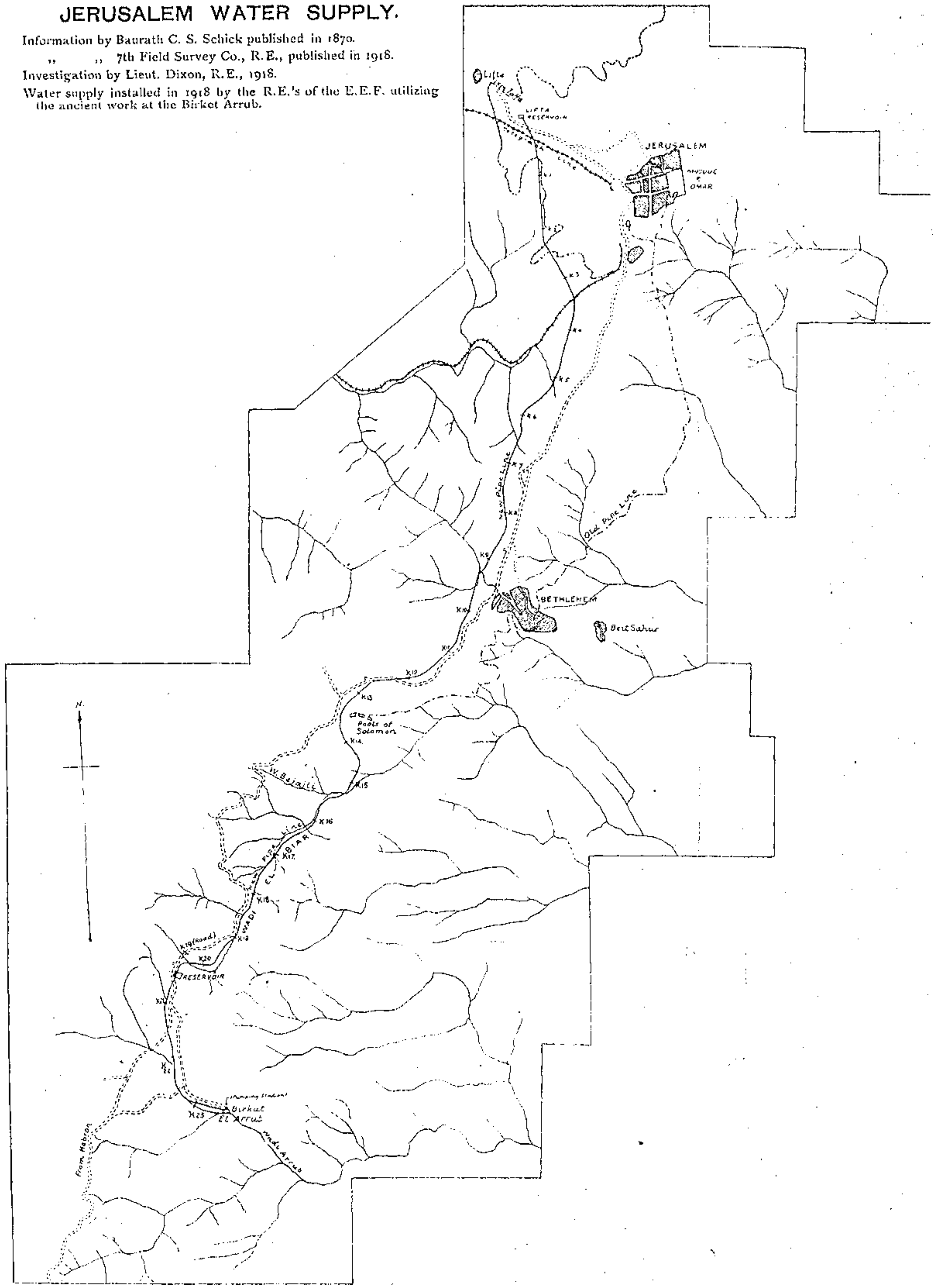
JERUSALEM WATER SUPPLY.

Information by Baurath C. S. Schick published in 1870.

" " 7th Field Survey Co., R.E., published in 1918.

Investigation by Lieut. Dixon, R.E., 1918.

Water supply installed in 1918 by the R.E.'s of the E.E.F. utilizing the ancient work at the Birket Arrub.

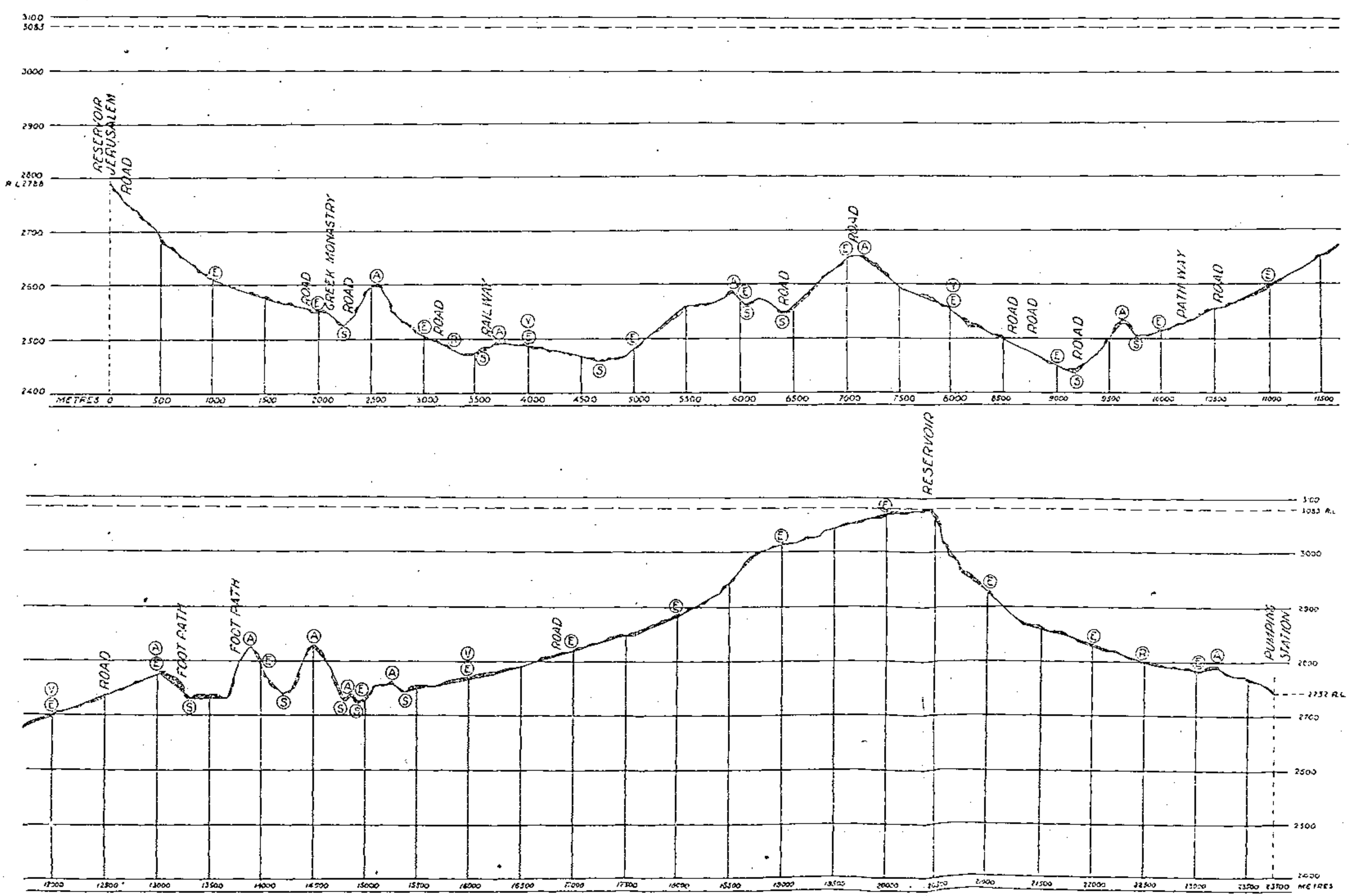


JERUSALEM WATER SUPPLY.

SECTION FROM JERUSALEM RESERVOIR TO PUMPING STATION.

SCALE – VERTICAL – 1 INCH · 100 FEET
HORIZONTAL – 1 INCH · 500 METRES.

(A) DENOTES AIR VALVES.
(S) " SCOUR VALVES.
(E) " EXPANSION JOINTS.
(V) " SLUICE VALVE.
(R) " REFLUX VALVE.



THE EVOLUTION OF INTERCOMMUNICATION IN FRANCE, 1914–1918.

By Major R. E. PRIESTLEY, M.C., Royal Corps of Signals (R. of O.).

THE evolution of Signal Service policy, organization and practice in France during the fateful years 1914 to 1918 was undoubtedly on a par with that of any other branch of the army of first importance. The intercommunication system of an Army is equivalent to the nervous system of an organism and is just as vitally important. Paralysis of an Expeditionary Force of modern dimensions will follow just as surely on signal inefficiency or disaster as will paralysis of the human body when the main trunks of the nervous system have become diseased or have been severed. An equal similarity exists between the relative simplicity of the nervous system of a generalized organism low down in the genealogical tree of life and the signal system of an army of mediæval times, while the complexity of the nervous system of the higher vertebrates is paralleled by that of the intercommunication service of the highly specialized army of a civilized nation of the twentieth century. An observer, ignorant of the facts of 1914–1918, confronted with the signal system of an army of six divisions in the former and in the latter year, might well be excused for wondering at the multiplication of men, methods, and instruments included in the establishments of the latter.

In 1914, the Expeditionary Force was served by a relatively simple system of field telegraph and dispatch riders. The telephone was almost unused for speech forward of G.H.Q.; wireless telegraphy was completely reserved for the maintenance of intercommunication between G.H.Q. and the independent cavalry and between the major formations of the latter. The spark wireless stations in use were of an elementary type much subject to engine trouble and, as the sequel proved, much too powerful for the ranges to which their employment was to be restricted throughout the war on the French front. Continuous wave wireless—in 1919 the backbone of the intercommunication system of the Army of the Rhine—was not within measurable distance of being applied to army purposes at all.

During the mobile warfare of the autumn of 1914, this skeleton organization, eked out by *liaison* officers either mounted or travelling in cars and reinforced by visual near the fighting line, proved sufficient to meet the essential needs of a highly trained Corps of Officers. Superfluities of intercommunication naturally had to be dispensed with, but this was only in accordance with the intentions of the General Staff. During the retreat from Mons, the advance to the Aisne, and through the First Battle of Ypres, dispatch riders by day and telegraph by night successfully ensured a necessary minimum of signal touch throughout the higher formations.

The inception of position warfare, however, with the rapid development of intensive artillery action and consequent perfection of defences to withstand the impact of shells, almost completely robbed the situation of the features to which the pre-war signal establishments had been quite well adapted.

The essential difference as affecting "Signals" was the slowing down of the action of battle until months of preparation and fighting were required to achieve the amount of movement which in previous wars, and in the early days of this war, had been the result of a day or of two or three days at most. Armies became pinned to fixed lines of defences ever increasing in complexity and impregnability. Gunners had time to pay particular attention to communications of all types. Staffs had leisure to think out elaborate combinations requiring a multiplicity of orders, situation reports and returns. Hand in hand with this increase in complexity, marched an increase in size of the forces engaged, as the conflict changed from the business of a professional army to the main object of existence of the manhood of the nation. To officer such monstrous armies as were slowly but surely coming into action overtaxed the resources of the Regular Army. The consequent falling off in the efficiency of Staff and regimental officers was reflected in a multiplication of orders. Especially was this seen in the necessity both for means of more personal intercommunication (the telephone) permitting of detailed explanation, and of safer means of transmitting written messages even to the most forward executive officers in or near the trench lines.

It is to this change from mobile to stationary warfare that almost all the technical evolution of the Signal Service must be attributed. A short sharp campaign might have left the intercommunication system much as before the war. Indeed, it is difficult to imagine how any great change in technique could have been brought about without the intervention of the adequate time element provided by the deadlock which was the feature of the war on the Western front between December 1914 and June 1918.

In a short summary like the present it is, of course, impossible to treat in detail the changes which had such an immense cumulative effect. Considered broadly, however, three separate but interdependent lines of evolution can be detected which brought about respectively the present organization, the present practice, and the present policy, of the Corps of Signals.

Of these three, the first two belong essentially to the period of Position Warfare; the last was worked out in theory during the more extended of the offensives of 1916 and 1917, but was naturally not finally sealed until its wisdom had been proved in the mobile warfare of 1918. Decisive warfare is necessarily mobile warfare. It is to the fact that the Directors of the Signal Service bore this in mind throughout the long-drawn-out stationary phase of the conflict, that much of the permanent value of the dispositions and changes then made is due. A rigid, crystallized, unadapted intercommunication service could not have coped successfully with the advance of the autumn of 1918. It certainly could not be expected to conform rapidly and efficiently to the environmental conditions of such a campaign as the advance through Palestine, nor to the normal course of warfare on the frontiers of Empire which is the "peace-time" avocation of the Regular Army.

The outstanding features of the evolution of signal organization during the war may be summarized as follows.* The attention of the signal higher command was first directed towards the removal of a certain looseness of organization which had been a distinct drawback to the pre-war Signal Service as seen working during the first few months of the war. The creation of a chain of command within the Service itself was a *sine qua non* if efficiency was to be obtained. Good end in itself though this was, a far-sighted policy soon combined it with the attempt—successful in 1916—to convert the senior signal officer of each of the higher formations from an executive officer at the orders of a Staff who could not be expected to understand fully the possibilities and limitations of a complicated signal technique, into a true Signal Adviser to his General, with the status of a Staff Officer of high rank. The creation of the positions, D.D. Signals, Army, and A.D. Signals, Corps, with the rank of full Colonel and Lieut.-Colonel respectively, was undoubtedly a victory fraught with more good to the Signal Service than any other single reform carried out during this critical period. It was this preliminary step which largely made possible the alteration in signal establishments which was the other outstanding feature of signal re-organization in this year.

Until after the Battle of the Somme (1916) various considerations —for instance, the scanty supply of trained reinforcements, the rapid development in signal technique which characterized position warfare, and, especially, the pressure of the war itself—prevented any

* For detailed information as to the work and evolution of the British Signal Service in France from 1914 to 1918 the reader is referred to the volume "History of the Signal Service in the European War (France)" now published under the auspices of the Institution of Royal Engineers and the Publications Committee of the Signal Service Association. It is hoped that circumstances will later permit of the publication of a companion volume, already partly prepared, which will deal with other fronts.

more than temporary adjustments of signal establishments to meet the new conditions. In the winter of 1916–1917, however, all these sources of inertia were overcome and the position warfare signal service was officially approved, the new establishments being made up to strength in time for the spring offensive of 1917. The features of the reorganization were, the additional of personnel for local regional maintenance ("area" personnel), great increases to artillery signal units (the Signal Service was now entirely responsible for the intercommunication of artillery formations), and the creation of several technical trades not formerly existent. Here are seen the direct reactions to (1) relative immobility, (2) artillery domination of the situation, and (3) an advanced signal technique which will be referred to later. The forward movement of technical qualifications towards the lesser units in the immediate battle line was throughout a feature of signal development during the war.

Perhaps more important even than the changes which did take place in this "First Great Reorganization" were those that were left undone. The Signal Directorate set its face steadily now and hereafter—in the face of many obstacles—against any decrease in the mobility of the essential intercommunication units of Armies, Corps and Divisions. The wisdom of this policy was to be seen in the success of the remodelled Signal Service in the comparatively mobile warfare of 1918.

Intimately interlocked with this question of reorganization was that of changes in signal practice. Position warfare, while it made complicated intercommunication schemes desirable and possible, made all intercommunication difficult, costly of life and material, and, at times, extremely unreliable. The barrage was as efficient at destroying forward lines as advancing infantry. High explosive long-range fire battered to pieces not only the signal routes, but the nodal points of the ganglia of the human nervous complex. Reaction to these stimuli took many forms. The two most important were perhaps, (*a*) the multiplication of means of forward signalling and (*b*) protection of forward line routes. From the latter, again, sprang the policy of concentration of signal responsibilities along definite main channels which was another great step forward in the evolution of a definite signal policy.

The first great reaction between the means of signalling employed and the position warfare environment was the wholesale introduction of the magneto telephone for forward signal work. This took place in 1915 and was the direct result of the cessation of movement. From it was to spring the overhearing menace which in itself gave rise to a special department of Intelligence, to special highly technical instruments, to distinct new means of signalling involving earth telegraphy, and which finally stultified the forward telephone system.

The first main effect of the increase of forward telephone communication was, however, the multiplication of lines at the time of all others when they were likely to cause most trouble to all concerned. A welter of lines of every description, running in all directions, many of them laid, cut, and abandoned in a few hours, threatened to bring an overburdened Signal Service into lasting disrepute. This unfortunate consummation was only avoided by the evolution, first of the shallow bury, and later of the deep 5·9-proof bury. Before the end of 1916, the latter had brought about the replacement of an insecure network of field and trench cable by a more or less orderly "grid" of safe main-line route from the front line to the rear limit of the "zone of frequent shelling."

Before this result had been achieved, however, the unsafeness of the line system had been emphasized in a manner not likely to be forgotten. The immediate result was the rehabilitation of Visual and its rejuvenation through the invention of improved and less easily "overseen" instruments. The transference of an efficient Pigeon Service from the Intelligence Branch of the General Staff to the Signal Service and its development to a size undreamt of by its originators followed. Finally yet other alternative means of intercommunication were perfected by the evolution of wireless telegraphy and its adaption to trench warfare and by the training and organization of runners on a larger scale than ever before.

Later came the Power Buzzer and Amplifier as the results of experiments on overhearing, while the Fullerphone, developed as a counter-measure to the same menace, gradually (in 1917 and 1918) ousted the forward buzzer and telephone from their former monopoly.

Comparatively early in the war, the clumsy vibrator of 1914 days had been replaced at all Formation Headquarters by the more efficient and less nerve-racking Sounder.

From 1916 on, when the various alternative means of signalling had become practicable rather than experimental, the great tussle began between "line" signalling and other methods not dependent for their efficiency upon the continuity of a metallic conductor, between Headquarters in the Battle Zone. Safe buried line routes were always the backbone of a stationary warfare system. In attack and retreat, on the other hand, the Lucas lamp from heavily protected emplacements; the wireless set with inconspicuous aerials; the Power Buzzer with short earths buried in tunnels or in deep trenches and instruments hidden in impregnable dug-outs; the pigeon with its straight flight through untainted air; survived where lines were often blown to pieces, impossible to maintain, or even, sometimes, to lay. The successful signal officer was he who best disposed his men so as to make full use of alternative chains of at least two or three of the above means. Signals in position warfare became more and more a matter of organization. The forward signal officer reduced to the employment of runners as his sole means of intercommunication had to admit that, for the time being, he was a rather costly failure, though under certain sets of circumstances such a temporary failure was unavoidable.

While 1915 was the year marked by the evolution of these alternative methods, 1916 saw their combined employment in somewhat haphazard schemes whose main fault was perhaps the overtaxing of the available personnel by the utilization of too many means along too many routes from front to rear. Yet these schemes were oftentimes successful and carried within them the germ from which the future policy of the Service was to be evolved. The experience of this year was not lost. In 1917 came the standardization of forward signals along a single route in each fighting formation. The publication of the two Staff Manuals for Intercommunication in Battle gave the signal officer an authoritative backing which proved to be of incalculable value. The publication of S.S. 191, in particular, crystallized, and brought within the reach of everyone concerned, the greater portion of the knowledge about intercommunication which had been gained both by the Signal Service and by the General Staff during three years of intensive warfare. Changes in details of organization, practice and policy still took place, but the main lessons had been learnt and no essential alterations were made.

Enemy long-range bombing and shelling in the autumn of 1917 to some extent forced a return to lighter and more scattered routes in the rear areas. Routes of 12 to 20 wires replaced the heavy permanent routes of 28 wires and upwards which had become more and more a feature of the countryside in rear of the buried cable "grid." This and the burying of leads in and the diversion of routes round towns and camps, added another strain to a rear intercommunication service which had grown steadily with the increase in size of the Expeditionary Force. L. of C. and G.H.Q. Signal Companies on August 4th, 1914 totalled 10 officers and 354 men. At the time of the Armistice "L" Signal Battalion, which had absorbed G.H.Q. Signal Company, had reached the startling figures of 110 officers and 4,102 men. In addition, from the beginning of the war, Signal Depôt and Signal Parks, highly organized and extensive in size, had catered successfully for the supply of technical reinforcements and stores.

Such are the broad outlines of Signal Service evolution up to the time when the mobile warfare of the spring and autumn of 1918 brought about in some degree a reversion to type. All the new signal units considered essential to a mobile system possessed the necessary meed of transport of which motor transport was an important constituent in all the higher formations. The March retreat was a severe test of signal organization and discipline, but formations retreating according to plan were accommodated on the rear line system or an improvised cable "grid." Even formations which were hardly pressed and sometimes lost their directions were not without means of keeping touch. The great development of wireless and visual, notably the spark and continuous wave short-range sets and the Lucas lamp, sufficed usually to meet both such extreme cases and the more normal, but, under these conditions, doubly essential, lateral intercommunication.

In the advance again, a central cable or airline route was the main stand-by of the advancing Divisions, Corps and Armies. When the rate of construction of such routes lagged behind the speed of advance, as was sometimes inevitable, wireless was again invaluable while forward of Brigade Headquarters two-way visual on an unprecented scale helped out the runners of the infantry and the mounted orderlies of the cavalry screen. Nor was the aid of aeroplane scouts uncatered for. In 1916 and 1917 these auxiliaries had been of great value to the intercommunication service. In 1918 their employment for conveying situation reports was assisted by the systematic establishment of Aeroplane Dropping Grounds at all Report Centres and Headquarters.

The adoption of a predetermined route of advance was an incalculable boon to signal officers forced to adopt rapid leap-frog tactics to keep visual, wireless and cable offices abreast of the leading battalions and Brigades. Isolated cases occurred of signal offices being set up by Divisional Signal Companies in villages yet technically in the possession of the enemy. By its marked success in this last and greatest test the Signal Service proved decisively that the correct lessons had been drawn from those essays in semi-mobile warfare which had from time to time relieved the monotony of the stationary warfare of the previous three years. The tribute paid to the intercommunication personnel in the Commander-in-Chief's last dispatch was perhaps no more significant in this respect than the fact that everywhere the relations between the General Staff and their signal officers were cordial in the extreme. An inefficient intercommunication service might undoubtedly have proved the limiting factor to the advance. That this never was the case, never even nearly the case, is positive proof that signal evolution proceeded throughout the war on the right lines and at the right speed.

THE "LEWIS" MEDAL.

At the Corps Meeting held on the 14th June, 1919, a very generous offer of Mrs. Lewis for the establishment of a silver medal in memory of her husband, the late Colonel J. F. Lewis, R.E., was put before the meeting and unanimously accepted. It was further decided that the conditions of award should be as follows:—

"That the medal be presented to the young officer of each batch passing through the School of Military Engineering, on the recommendation of the Commandant, for proficiency in fortification and field engineering."

Colonel Lewis was an expert in fortification, and it is, therefore, natural that the medal should be awarded for proficiency in that subject.

Owing to the exigencies of the service, the first full course of training, qualifying for the award, has only recently been completed, and the first "Lewis" medal was presented to Lieut. Ernest Bader, R.E., on 8th October, 1921.

The medal, the design of which is shown in the accompanying photographs, is the work of Mr. Frank Borscher, and was struck by Mr. John Pinches. On the obverse, it gives an excellent portrait of Colonel Lewis wearing the old R.E. frock coat, as worn in the last half of the nineteenth century by all officers of the Corps and later restricted to Field Officers only, until soon after the South African War, when the plain frock coat became regulation for all branches of the service; and over it is the R.E. cross-belt, as still worn. On the reverse is shown the Rock of Gibraltar, from the Rock Gun to Europa Light, chosen as emblematic of British fortification and also because Colonel Lewis held the appointment of Commanding Royal Engineer (now Chief Engineer), Gibraltar; it was his last station and he retired from it owing to age, in 1903.

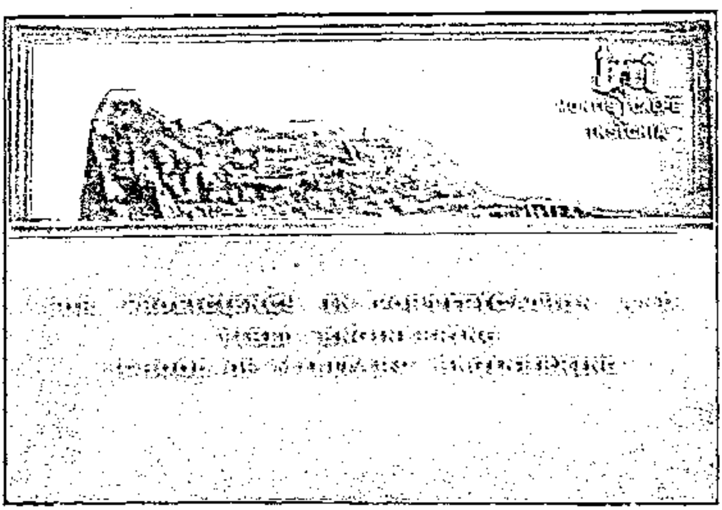
The following brief sketch of Colonel Lewis' career is taken from the memoir published in the *R.E. Journal* of June, 1918:—

Born near Exeter, on the 14th May, 1846, Colonel Lewis passed into the R.M.A., Woolwich, in 1864, obtaining his commission in the R.E. on the 15th January, 1867; was promoted Captain on the 13th September, 1879; Major on the 15th January, 1887; Lieut.-Colonel on the 22nd May, 1893; Colonel on the 22nd December, 1898; and retired, under the age clause, on 14th May, 1903.

He re-wrote the Text Book of Fortification, *Permanent Fortification for English Engineers*, published by the R.E. Institute in September,

THE "LEWIS" MEDAL.

OBVERSE.



REVERSE.

1890; reported on the fortifications of the Island of Ascension, for the Admiralty, in 1896; and that of the Falkland Islands, also for the Admiralty, in 1896-7; and on the Defences of Wei-hai-wei, in 1898.

After his retirement he was specially appointed to go into the land question at Hong Kong, in 1905, the resulting "Lewis Agreement" being still consulted. Thence he went to Port Arthur, to report on the defences after the Russo-Japanese War.

He offered his services to the W.D. when war broke out in 1914, but, owing to his age, his offer was not accepted. He passed away on the 7th February, 1918, at his house, at Winchester.

"He was of a strongly religious character and, as was said recently of an officer who fell in France: 'He was a real noble and Christian English gentleman, than which no more can be said of any one.'"

PROFESSIONAL NOTE.

AMERICAN PONTOON EQUIPMENT.

THE DEVELOPMENT OF HEAVY PONTOON EQUIPAGE FOR INCREASED ARMY LOADS OF THE FUTURE.

[CONTRIBUTED BY THE R.E. BOARD.]

THE following is a *résumé* of an article under the above heading, by Captain Theodore Wyman, junr., Corps of Engineers, which appeared in the September-October number of *The Military Engineer, the Journal of the Society of American Military Engineers*, and the discussion which followed it.

REQUIREMENTS OF FUTURE PONTOON BRIDGES.

The adoption for the mobile army of recently developed heavy mobile cannon, self-propelled or tractor-drawn, heavy tanks and heavy truck transportation, has necessitated the development of heavy pontoon bridge equipage, of greater capacity than the present standard equipage. Heavy pontoon bridge equipage of construction along the lines of the standard equipage, of minimum weight, and adapted to being transported readily on vehicles subject to being animal-drawn, truck-drawn or tractor-drawn, must carry safely the heaviest loads which accompany the Corps, namely, the loaded 5½-ton Mack truck, which, when loaded to capacity, has a maximum concentrated axle-load of 13,500 lbs. on the rear axle and 7,800 lbs. on the front axle, the distance between axles, centre to centre, being 13 ft. 4 in. There must also be developed a reinforced type of pontoon bridge, using the new equipage, supplemented by special materials deemed necessary to carry safely the loads which accompany the army, which recent developments of Ordnance materials indicate may include the new Christie Self-propelled Mount for a 6-in. gun, weighing 19 tons, and the Christie Medium Tank, weighing 18 tons. Extensive studies of all available records showed that the allowable weights for a pontoon equipage, readily transportable, would limit the capacity of the pontoon boat to a supporting power of 20,000 lbs. with a 9-in. free-board, and the length of the normal bay to 16 ft., which would require a superstructure consisting of seven or eight baulks of weights easily handled by two men, rigidly connected to two side-rails—also road-bearers—by transverse baulks and baulk-collars, and a double thickness of 2-in. chesses.

Pontoon Boats.

Three types of experimental boats, *viz.*, wooden, steel and aluminium boats, were designed, manufactured and tested.

The wooden boat was of the scow type, similar to the existing standard pontoon. Its dimensions were:—length, 32 ft., beam 5 ft. 8 in., depth 3 ft. 1 in., and it weighed 2,225 lbs. It was constructed entirely of wood with an oak frame and ⅞ in. white pine skin.

The steel pontoon was of the boat type, of galvanized steel construction throughout, and its dimensions were:—length 32ft. 6 in., beam 5 ft. 8 in., depth 3 ft. 1 in., and it weighed 1,765 lbs. It was constructed of galvanized sheet steel, riveted to an angle-iron frame and channel-iron gunwales and was divided into four watertight compartments by transverse bulkheads, which materially strengthened the boat and increased its flotation, as it was necessary to pierce at least two compartments in order to sink the pontoon when in its position in bridge.

The aluminium pontoon was of the boat type and was constructed of aluminium skin mounted on an oak frame, of sufficient flotation to prevent the pontoon from sinking when filled with water. Its length was 31 ft. 6 in., beam 5 ft. 8 in., depth 3 ft. 1 in., and it weighed 1,635 lbs. This boat was also provided with four separate watertight compartments by means of transverse bulkheads, in order to increase its strength and carrying capacity when one or two of the compartments were punctured by gunfire or otherwise.

These boats had sufficient displacement to carry super-imposed loads as follows and allow for a 9-in. free-board:—

Wooden boat, 20,000 lbs.; steel boat, 22,000 lbs.; aluminium boat, 23,000 lbs.

Tests.

The tests were carried out between 3rd April and 2nd June, 1921, at Camp A.A. Humphreys, Va. In order to be as thorough as it was possible to make them within a limited space of time, they included the following general points:—Boat Tests; Tests of the Material in a Grounded Pontoon Bridge; Tests of the Material in the Pontoon Bridge; and Transportation Tests.

Boat Tests.

All the boats functioned equally satisfactorily in a pontoon bridge constructed in water, and carried successfully axle-loads ranging up to and including 17,900 lbs. The Mack truck and the 10-ton Holt tractor were passed over the bridge without incident, and later both were passed over together, spaced so that the centres of the loads were located over adjacent pontoon boats. A Mack truck was loaded until its gross weight was 27,800 lbs.; divided approximately with 9,380 lbs. on the front axle, and 17,900 lbs. on the rear axle, and then passed over the bridge. Under this load the saddle boat—the pontoon next to the trestle—was immersed until it had only 4-in. free-board, while under the same load the second boat in the bridge from the shore had 9-in. free-board. This indicated that the capacity of the saddle boat determined the maximum load which could be passed over the bridge.

This was due to the fact that the span between the trestle and the saddle boat was longer than the normal span and also because only a small part of the load was transmitted to the adjacent pontoons. The pontoons are gunwale loaded.

A pontoon bridge of five bays was built on land with the pontoons resting on a bed of river gravel simulating the bottom of a stream. All of the experimental pontoon equipage carried axle-loads up to and including 17,000 lbs. without incident. Under a 30,000-lbs. axle-load both the aluminium boat and the steel boat commenced to fail by buckling of the gunwales. Under a 40,000-lbs. axle-load the gunwales of the metal pontoons were so badly crushed that they had to be removed. Both failed to the extent to make repair difficult. An axle-load of 46,000 lbs. was successfully carried by the wooden boat without showing any signs of failure. These tests showed conclusively that the wooden boat was superior in a grounded bridge. In view of the wide tidal fluctuations of the coastal streams of the United States, it is believed essential for pontoon boats to carry successfully the increased army axle-loads when the boats are grounded on the bottom of a river.

All three boats were readily loaded and unloaded, and none presented any difficulties when handled by a detail of 18 to 20 men. The differences in the weights of the boats made no material differences in the tractor-drawn and motor-drawn transportation tests. In a horse-drawn test all were easily hauled. All boats were easily handled in the water by crews of four rowers and a steersman, and the higher free-board presented no real difficulties in rowing. A load of sixty soldiers with heavy marching packs was readily transported in each type of boat. Under rifle fire at a range of 125 yards five shots were sufficient to put the steel boat in danger of sinking. In each case the bullet made a clean entrance hole through the near side and from two to six ragged holes through the far side. Another account says that bullets striking above the waterline made round holes much larger than the bullet, nearly $\frac{5}{8}$ in. in diameter, and bullets striking at or below the water-line tore jagged irregular holes from two to three inches across, because of the striking effect of the water itself upon the brittle steel of which the pontoon was made. Eleven shots were sufficient to flood the aluminium boat. In each case the holes through the aluminium skin, in and out, were clean and no bullet caused more than two holes. One hundred and twenty-five rounds were fired at the wooden boat without stopping to do any patching. Holes were generally clean and the water entered very slowly. The results of the rifle tests were decisively in favour of the wooden boat. However, it must be remembered that the range was only 125 yards and that at a greater range difficulties might be encountered in penetrating sufficient compartments below the water-line of the steel and aluminium boats to flood them with water. Furthermore, a pontoon bridge constructed of boats subject to being readily sunk might prove extremely advantageous during a retreat, when, due to lack of time to remove it, the destruction of the bridge might be highly desirable. A few hand grenades properly applied to the steel pontoon boat could easily accomplish this result. The bullet holes in both metal boats were readily plugged before the boats were filled with water, by a rubber gasket patch which consisted of a rubber washer on a wide-headed bolt provided with a wing nut. Several other types of patches were tested but did not prove adaptable to patching ragged holes in the skins of the boats.

All of the boats were equipped with four skids which proved a decided improvement and aided materially when moving boats on land and handling them in the water. All boats were equipped with a windlass located in both bow and stern, similar to that used in the German pontoons, but under tests this equipment did not present any great advantages over the mooring post now in use.

The principal argument in favour of metal boats is their resistance to time and the elements while in storage in a hot arid climate and their immediate availability for service at all times after construction. So far as availability of materials for construction and rapidity of construction are concerned, experience in the manufacture of boats indicated that the steel boat should rank first, the wooden boat second and the aluminium boat third. In general the performances of the aluminium boat under tests were superior to those of the steel boat, and the officers conducting the tests recommended to the Chief of Engineers that sufficient aluminium boats for an experimental pontoon division be procured and subjected to field tests over a long period of time. This recommendation was explained in the Discussion as follows:—It was thought that little more could be learned with respect to the wooden boat, but it was felt that the many advocates of metal would hardly be satisfied by tests so short in duration, and which could not, in fact, be called complete. Additional experiments with the metal boat were, therefore, urged to give it a better chance to recommend itself as a type, or, failing that, to hush the clamour of its champions.

Baulks.

Due to results of tests conducted by the Bureau of Standards and the Forest Products Laboratories of timbers which may be secured in large quantities, Douglas fir was selected as the material most suitable for baulk construction. Tests of baulks constructed of Douglas fir reinforced by steel plates and ½-in. twisted steel rods, indicated the impracticability of reinforcing wooden baulks with metal. Studies indicated the impracticability of using steel I-beams for baulks due to excessive weight.

The following table shows the types of baulks constructed, dimensions and weights of same, and the loads carried by bays constructed of same. In each case seven baulks plus two side rails were used per bay.

Type.	*Size.*	*Weight.*	*Type of Bay.*	*Axle-load under which Bay failed.*
1-Piece wooden baulk of Douglas fir, rectangular cross section	$4\frac{1}{4}$ in. × $6\frac{3}{8}$ in. × 23 ft.	166 lbs.	Boat-to-boat span 16 ft. Transverse baulk used.	This bay carried 46,000 lbs. without failure.
Do.	do.	do.	Boat-to-boat span. No transverse baulk.	Failed under 44,500 lbs.
Do.	do.	do.	Boat-to-trestle span 18 ft. 10-in. Transverse baulk used.	Bay failed under 36,000 lbs.
2-Piece wooden baulk. Two pieces of Douglas fir bolted together. Rectangular cross section	$4\frac{1}{2}$ in. × $6\frac{3}{8}$ in. × 23 ft.	155 lbs.	Boat-to-boat span 16 ft. Transverse baulk used.	Bay failed under 42,000 lbs.
1-Piece wooden baulk of Douglas fir, I-beam cross section	$4\frac{3}{4}$ in. × $6\frac{3}{8}$ in. × 23 ft.	146 lbs.	Boat-to-boat span 16 ft. No transverse baulk.	Bay failed under 40,000 lbs.
Do.	do.	do.	Trestle-to-trestle span 20 ft. Transverse baulk used.	Bay failed under 19,000 lbs.
Steel I-beam baulk	5 in. × $9\frac{3}{4}$ lbs. × $15\frac{1}{2}$ ft.	155 lbs.	Trestle-to-trestle span $13\frac{1}{2}$ ft. No transverse baulk.	Bay failed violently under 40,000 lbs.

From the foregoing figures it is obvious that the one-piece baulk, constructed of Douglas fir of rectangular cross section, $4\frac{1}{4}$ in. × $6\frac{3}{8}$ in., is the strongest type of baulk. However, all bays made up of the various types of baulk carried successfully a loaded $5\frac{1}{2}$-ton Mack truck, a 10-ton Holt tractor, and axle-loads up to and including 17,000 lbs., without incident or excessive deflection. The figures also indicate clearly the advantages obtained from the use of the transverse baulk for partially transmitting the load to the side rails. The transverse baulk was constructed of Douglas fir, $4\frac{1}{4}$ in. × $6\frac{3}{8}$ in. × 12 ft., and was equipped with spacing cleats which engaged the longitudinal baulks. It was rigidly connected to the side rails by means of baulk collars constructed of steel. These collars consisted of two pairs of lazy tongs which opened to receive the transverse baulk and supported it when closed, and which were flexibly connected to a saddle provided with a jack-screw that rested upon and across the side rail baulk. The baulk collars tested were equipped with a cam to open and close the tongs. This refinement proved unnecessary and it is believed that a simplified design will provide a strong and flexible means of lashing the side rails, chesses, longitudinal and transverse baulks firmly together. The baulk collars may be quickly installed from the bridge floor.

All of the baulks tested were equipped with steel pins which engaged in baulk-pin sockets on the pontoons, thereby providing a positive though flexible connection between baulks and boats and also eliminating the temporary lashing now made when laying baulks in place. The retention of the baulk-pin is favoured. It did not present any difficulties when stacking the baulks in piles or transporting them on wagons. In addition to the baulk pin connection, the baulks were lashed to the boats by means of the standard $\frac{1}{2}$-in. lashing, to prevent movement in the vertical plane only. Numerous studies were made of designs for mechanical lashings which in most cases were a mechanical contrivance located on the baulk, thereby precluding an adjustable length of bay. The aluminium boats were equipped with a mechanical lashing consisting of a strap constructed of brake-lining material, one end directly connected to the gunwales and the other end adjustably connected by means of a ratchet device and adaptable to lashing the baulk to the boat at any point along its length. However, under test they proved cumbersome and unreliable and presented no advantages over the rope lashing now in use.

The boats were provided with lashing hooks. However, it is believed that a waling piece fastened to the inner sides of the ribs of the boat, about 6 in. below the gunwales, would provide a more suitable means for lashing baulks at any location throughout the width of the roadway.

In order to make all pontoon boats identical as to the lay-out and location of the baulk-pin sockets, it is necessary to lay the baulks with a slight slant, or at an angle whose offset from the centre line of the bridge equals the width of the baulk. It would be impossible to lay the baulks parallel to the centre line of the bridge unless three alternate baulk-pin sockets are provided for each baulk location. Another advantage gained by the angular method of laying baulks applies to the side rails of the bridge. When the side rails are laid in this manner, the inside roadway end of the baulks pointing towards the far shore on the right-hand side, no projecting baulk ends are in a position to be struck by, or to interfere with, traffic which bears to the right in the usual manner.

CHESSES.

The chesses were constructed of white pine on account of its lightness, $1\frac{1}{16}$ in. thick, by 12 in. wide, by 12 ft. long. A length of 23 in. at each end was reduced to a width of $10\frac{1}{2}$ in. and reinforcing rivets of $\frac{1}{4}$-in. steel were riveted through the chess $1\frac{1}{2}$ in. and $21\frac{1}{2}$ in. from each end to prevent the chess from splitting. Its weight was 43 lbs. A double thickness of chesses was used on the bridge tested and proved to be the weakest element. The white pine was badly crushed under the wheels of the heavy loads and in many cases the loads cut through the double layer of chesses when the wheels were not located directly over a baulk. These tests indicated that white pine is no longer adaptable for the construction of chesses intended to carry the increased loads, and studies of the possibilities of longleaf Georgia yellow pine, maple and oak, for use as chesses, are being made. The width of the roadway of the bridge tested was 9 ft. 6 in., but later developments proved the necessity for a bridge with a 10 ft. 6 in. clear roadway. This increase will undoubtedly require eight baulks per bay in order to decrease the chess span between baulks to a minimum.

TRESTLES.

Two types of trestles were designed, manufactured and tested. Type No. 1 trestle was constructed entirely of structural steel and Shelby cold-drawn tubing. It consisted of two threaded steel columns that adjustably supported, by means of capstan nuts, housing and clamp members, a 9-in., 21-lbs. I-beam transom, together with its reinforcing members. The entire transom unit could be raised, lowered and clamped in place from the roadway of the bridge by two men. The trestle consisted of seven separable units, the transom, two struts, two columns and two trestle shoes, and weighed complete 1,090 lbs. In order to strengthen the transom, its unsupported span of 12 ft. was reduced to 8 ft. by the use of two struts of 3-in., $5\frac{1}{2}$-lbs. I-beams, 2 ft. 8 in. long, used as diagonal braces. When the transom and its struts were placed in their respective housings and the suspension members and cross-guide rods were tightened to their home positions, the entire assembly became a complete bridge panel, adapted to be supported by its two side columns and trestle shoes. The trestle shoes had approximately 4 sq. ft. of area and were constructed of wood, reinforced with angle-iron around the bottom edge and across the bottom face, and equipped with steel teeth projecting downwards to prevent side-slipping. The connections between the shoes and the columns allowed the shoes to accommodate their positions to inequalities of the foundations without disturbing the vertical position of the side columns.

Type No. 2 trestle consisted of a lattice angle iron transom slidingly adjustable along its two end supporting steel columns by means of chain hoists supported by the upper ends of the side columns. The transom was supported in place by pins that passed through the end plates of the transom and corresponding holes in the columns. The trestle consisted of seven separable parts, transom, two columns, two chain hoists, and two trestle shoes, and weighed approximately 1,300 lbs. The transom was 12 ft. 6 in. span, 18 in. deep and 9 in. wide. It was built up of two lattice transoms, 2 in. by 18 in. by 12 ft. 6 in., set back to back, the ends of the transoms being riveted to the transom column housing and the intermediate portions of the separate transom members connected together by splice plates. The shoes consisted of flat steel plates reinforced with teeth at the corners to prevent side slipping. Their construction was such that the shoes could rest firmly on their foundations, and at the same time allow the side columns to stand in vertical positions.

Both types of trestles functioned equally satisfactorily under tests and successfully carried axle-loads up to and including 46,000 lbs. without excessive deflection or incident. The second type described is favoured because of its simplicity and relative ease of assembly. It is well to note here that a standard wooden trestle was used in the pontoon bridge constructed on land until it failed under an axle load of 13,500 lbs. The wooden shoe failed by splitting, allowing the unsupported leg to enter the ground a distance of 16 in., which in turn allowed the wooden cap to strike the ground with such force that the cap and three baulks were completely fractured. The incident showed the relative weakness of the standard wooden trestle.

Saddle Boat Support.

The tests indicated that the weakest bays are those adjacent to the saddle boat and trestles. An effort was made to eliminate the standard saddle and to adapt the long baulks for use in the bays adjacent to the saddle boat. The saddle boat was equipped with seven saddle transoms designed to secure a long firm bearing over the centre of the supporting boat, independent of any rise or fall in the water level resulting from rain or tides. Each saddle consisted of two wooden rockers constructed of oak, lying side by side and free to move independent of one another. The rockers supported their respective baulks across the entire width of the pontoon boat, the baulks being held in position by baulk-pins that engaged in baulk-pin sockets in their respective rockers. The rockers were housed in a steel cradle that extended across the gunwales of the boat. Under tests these saddle transoms did not function as expected, due to the fact that the saddle boat turned on its side in the water before the wooden rockers adjusted themselves to the gradient of the roadway. In view of the fact that the tests showed that an axle-load which could not develop the full capacity of adjacent boats would immerse the saddle boat to a 4-in. free-board, it appears advisable to construct the saddle support of two boats fastened together by lashings, with transom members lashed to the gunwales of both boats supporting a sill of the standard type now in use to carry the superstructure. It would also be advisable to reduce the length of the spans adjacent to the saddle boat.

MISCELLANEOUS EQUIPMENT.

An abutment sill—shore transom—similar to the standard type and equipped with baulk pin sockets to engage the trestle baulks, 14 ft. hickory oars reinforced with special aluminium tips to prevent splitting, rowlocks adaptable to the higher free-board of the pontoons, and pickets constructed of standard galvanized wrought-iron pipe, were tested and found suitable for use with the new pontoon equipage.

TRANSPORTATION.

Studies of the requirements of modern armies in the field showed the desirability of having pontoon vehicles subject to being animal-drawn, truck-drawn or tractor-drawn.

The following extract from the historical record of the 464th Engineer Ponton Train indicates clearly the necessity of having pontoon vehicles constructed along automobile lines and capable of being truck-drawn :—

" On Oct. 29th we received an order to prepare to move overland to Bethelainville. Twenty trucks were provided to complete the movement overland of 67 vehicles, movement to be completed in one haul. As this was a physical impossibility we decided to comply with the order to the best of our ability. On Oct. 30th 19 motor trucks arrived and departed at 9.30 a.m. with 38 vehicles, each truck towing two vehicles. We were obliged to borrow 100 horses to bring the equipment from the Island to the main road, this work being done during the night of Oct. 29th under a bombing attack aimed at the adjacent steel plant. At 10 p.m., Oct. 31st, this convoy completed the movement to Bethelainville and at 4 p.m., Nov. 1st, the equipment was hidden in the forest. It would be well to note that we had advised very strongly against towing the pontoon equipment behind motor trucks, and this trip reduced the efficiency of the equipage about 50 per cent. All tongues were broken, braces twisted, bolts sheared and in some instances entire wagons overturned. On Oct. 31st, about 4 p.m., 15 French motor trucks arrived for the purpose of convoying the balance of the equipment to Bethelainville. Seventy-five horses were again borrowed from the ammunition train of the 92nd Division, and by working all night the 29 wagons were hauled up on to the main road and hooked in pairs ready for the trucks. At 5.20 a.m., Nov. 1st, all supplies, rations and office and equipment were loaded on the trucks at Pompey. The train then proceeded to Harbach where the wagons were lashed on and convoy started off at 8 a.m. The last truck reached Pierfeitte at 9 p.m. the same date ; some motor trouble was experienced, but the greatest trouble was due to broken tongues and wheels on the pontoon wagons as those wagons were never made for this method of transportation. At 4.30 a.m., Nov. 3rd, four trucks (attached from 23rd Engineers) were started out with billeting detail, kitchen detail, all supplies and office equipment. At 5 a.m. Captain Goodwin left with 17 boat wagons drawn by four horses each, thus using all horses fit to work. It was found *en route* that four horses were not sufficient for handling the wagons over the rough and muddy roads encountered, and in many cases it was necessary to put 8 or 10 horses on a wagon to get through some of the bad spots. At 6 a.m. 18 of the promised trucks arrived and left with 18 wagons. At 1 p.m. same day all horses fit to move were sent forward on a moving picket line."

A pontoon wagon to transport the baulks and boats, a chess wagon to transport the chesses, and a trestle wagon for the trestle equipment, all capable of being drawn with equal facility by animals, tractor or truck, were designed, manufactured and tested. The wagons weighed approximately 2,400 lbs. each and were equipped with 40-in. rubber-tyred wheels, suitable pintles, lunette rings and draw-bars, and constructed in accordance with the general type of automobile design and practice. The wagons were reversible and capable of being turned or steered from either end when used as a single wagon or in trains of two wagons or more.

Tests of those wagons were conducted on the roads in and about the Camp. A horse-drawn test of 10 miles was made. The loaded pontoon trailers were drawn by six-line mule teams and the loaded chess and trestle trailers by four-line mule teams. On the whole the march was very satisfactory, the roller-bearing wheels reduced the friction so that the team pulled the greater loads with greater ease than the standard equipage. The route included several very steep grades, both up and down, ditches and several soft spots where the wheels cut in from 12 to 16 in. The day was warm and the mules came in sweated but showing no lather, and were apparently good for 10 miles more.

Various types of trucks, including the 1½-ton Garford, 3-ton Liberty and 5-ton Mack, were used to haul from one to three trailers over various types of roads, including concrete, gravel and dirt, at various speeds for distances up to and including 15 miles. These tests indicated that the 1½-ton Garford and 3-ton Liberty trucks were on the whole more successful for this work than the 5-ton Mack and that the lighter trucks were better for the poorer roads. More than two trailers should not be drawn by trucks except under very favourable conditions, when the truck may operate over a two-way road with little opposing traffic. The speed should not exceed 12 miles per hour. At higher speeds the trailers skidded away from the crown of the road towards the ditch, especially for speeds exceeding 15 miles per hour.

The Cadillac 2½-ton tractor, the 5-ton and 10-ton Holt tractors, were used to draw trains of one to five wagons. The vehicles tracked as well as could be expected. On narrow roads with a high crown the third wagon would often slide off the road into the ditch. On turning a train made up of two pontoon boat wagons and one chess wagon, drawn by a 5-ton Holt tractor, on a 60-ft. curve, the rear wheels of the third vehicle tracked 9 ft. inside the track of the front wheel of the first wagon. Trains of two or more wagons could not be backed in any desired direction. No more than three vehicles should be hauled by a tractor on a good road and not more than one on a poor narrow road. The stability of the load was increased materially when the pontoon boat was loaded on the wagon bottom-side up. In general the tests were severe and the wagons stood them well, but many weaknesses in the design developed which indicated that the trailers tested would not stand up under service conditions for a very long period. When the vehicles were drawn by animals, the brakes, which were of the automobile type, were applied over long periods of time, which caused them to overheat and wear rapidly. The rubber tyres wore out too rapidly, indicating the necessity for wider treads. The requirement of reversibility introduced many intricate features in the designs, requiring a two-point suspension similar to that of the Ford automobile, which obviously is inferior to a three or four-point suspension. It also necessitated a complicated brake mechanism which quickly became unserviceable. However, a direct-action brake precludes the use of rubber tyres which are considered essential for a truck-drawn vehicle. The springs proved to be too light. The radius rods proved to be weak and were badly bent when the pontoon boat wagon was mired in a mud hole and drawn therefrom. In general, all small parts such as steering-arms, brake-rods, tongues, pintle-hooks, chains, etc., were too lightly constructed, due to an effort made to develope a pontoon wagon trailer weighing less than 2,000 lbs., and would soon become unserviceable under severe service conditions. The superstructures of the various vehicles proved satisfactory.

In the Discussion Major C. P. Gross compared the following qualities as applied to the three boats :—Light weight, Non-sinkability, Minimum attention required, Ease of repair, Resistance to time and elements, Construction approximating boat lines, Rapidity of construction, Availability of material for construction, Immediate availability for service, Ease of loading and unloading, Ease of transporting, Behaviour under rifle fire, Ferrying capacity, Strength in bridge, Displacement capacity, and Cost, and found that in non-sinkability, ease of repair, behaviour under rifle fire, strength in the grounded bridge and in lower cost the superiority of the wooden pontoon is decisive. The wooden boat, however, is unsatisfactory when stored in a hot climate. The aluminium boat seems to offer relief in being at all times serviceable. Such serviceability is, however, more apparent than real. For instance, in unloading this equipment for test two holes were stove through the bottom of the metal boat, which required four hours for repair by welding with results none too good. In the field such repairs are not easily made and such condition would frequently invite abandonment. An undisputed merit of the aluminium boat is that for the same loading it has 2 in. higher free-board, and as a support, therefore, has a buoyancy greater by two tons than the wooden pontoon.

The equipment tested, with numerous minor modifications, does contain the elements of a bridge carrying the loads for which designed. All elements are not, however, properly balanced. The pontoon will support greater loads. The chesses, doubled, will not. No matter for what load intended, in the field the bridge will get all it can take. Chesses, $1\frac{1}{16}$ in. thick, belong to the old equipment. They have no real place in the new. This thickness should be increased to $2\frac{1}{2}$ or 3 in., one wagon carrying enough for one bay (double-chessed).

The placement of the trestle requires 16 men. The baulk is still a two-man load. The chess, even if 2½ in. thick, continues as a one-man load. The side rail section has a slightly easier task than formerly. A section of four men must be added to place the transverse baulks and baulk collars.

No satisfactory transportation has yet been developed. That tested failed beyond hope of recovery by simple modification. The requirements asked were far from simple, demanding construction not even commercial. The basis of military success is utter simplicity. It would seem apparent that to require a vehicle to be horse-drawn, motor-drawn and reversible must necessarily produce a hybrid. Reversibility is not essential. In a country of poor highways, the railroad rather than the motor truck should be used for the longer hauls. The vehicle must be horse-drawn. For controlled speeds it can be made capable of being tractor-drawn. Sure mobility, even though slow, is far more successful in campaign than bursts of speed separated by wild scrambles for spare parts.

Captain R. Whitaker gives further details of the tests. He mentions two more instructive cases of failure. In several cases when the train seemed to be about to stall, the men riding worked the brakes with such enthusiasm that the iron handles were completely broken off. During a test run over a concrete road the steel pole of a pontoon trailer broke and before the brakes could be applied the trailer ran off the road, smashing running gear and springs.

Major A. A. Keebler, E.O.R.C., thinks that rubber tyres are not essential. It is entirely practicable to construct a steel-tyred wheel which will maintain speeds up to 15 miles per hour, and the cushion for vehicle and load should properly be obtained by means of spring suspension. The outstanding requirement for a vehicle to be hauled by truck, tractor or animals interchangeably, is that it be mounted on a frictionless bearing such as balls or rollers, and it must be borne in mind that mounting a vehicle on ball or roller bearings does not particularly decrease the force required for traction. It will move much easier on level roads, but in ascending a grade the problem is one of foot-pounds.

NOTE BY R.E. BOARD.

In the light of our own recent investigations on this subject, as published in the *R.E.J.* for September, the following observations suggest themselves when considering the American principle of one large pontoon for all purposes in its possible application to our own requirements :—

(1) Whilst in our case it is necessary to provide for small wars, possibly in more or less hilly country, in which many of the rivers to be dealt with will be comparatively small, the Americans are no doubt basing their considerations on large wars in countries where rivers for the most part will be very much broader.

(2) In the American organization no heavy pontoon equipment is to accompany the Division. It will remain with the Army and be allotted to Corps and Divisions as the situation may demand, the American intention apparently being to allot to the Division a light bridging train of canvas boats only (probably 185 ft. of bridge to each Division).

(3) For any given length of light bridge (*i.e.*, a bridge for the rapid passage of the fighting troops) the American equipment will require at least 50 per cent. more road space than ours. Thus, if the road space for our Divisional Bridging Train is to be restricted to the present limit, the length of Divisional bridge possible with the American form of equipment would be less than 130 ft.

(4) The length of the American pontoon waggon loaded (32 ft.) is likely to be too cumbersome for the conditions of road traffic which may be expected during operations.

(5) It is claimed that the 32 ft. American pontoon can be easily handled by a party of from 18 to 20 men. It seems very doubtful if this would be the case when the pontoon has to be rapidly off-loaded and handled under fire for the formation of "Light Bridge" for the passage of the fighting troops of the Division. The wooden pontoon, which seems on the whole to be the type most favoured in the report, would mean a load of 110 lbs. per man for a 20-man detachment, whilst the *lightest* American type projected (aluminium) would give a load of 80 lbs. per man, which latter load we consider as the extreme limit allowable.

The method of loading proposed for the American pontoon (upside down) does not appear conducive to ease and rapidity of off-loading for a boat of that length, and in fact the pontoon seems to have been rather damaged in the process of off-loading.

(6) A bridge of single pontoon piers of the American form will take an 8-ton rear-axle load (equivalent approximately to our commercial lorry) *singly*, but probably not in a string, whilst the means of providing for any greater loads than this does not seem to have been considered. The necessity for *doubling* the first boat piers at the shore ends which is suggested in order to obtain the required free-board under the above load, detracts somewhat from simplicity and expediency of construction.

(7) Strength to resist crushing when grounded is considered by the Americans as well as by ourselves to be an important requirement. The only American type, however, which appears to have withstood this test satisfactorily was the wooden one, and the *weight* of the latter (2,250 lbs.) would seem to preclude its suitability for "light bridge," as pointed out in (3) above.

(8) The road bearers, which consist of 7 heavy wooden baulks, 2 steel rails and a transverse transom, do not seem to lend themselves to the rapid construction of "light bridge," for which they are, moreover, unnecessarily strong.

(9) The American design is for gunwale loading. Our investigations have led us to the conclusion that this method is neither so sound in theory nor so efficient in operation as saddle loading.

REVIEWS.

AEROPLANE PERFORMANCE CALCULATIONS.

By HARRIS BOOTH, B.A., A.M.I.C.E. (Chapman & Hall. 21/-).

This is a highly technical treatise and should be very valuable to engineers interested in the design of aeroplanes. By the term "performance" is meant the numerical evaluation of everything a machine can do under assigned conditions as to weight, engine power, etc. The book is more than a mere theoretical treatise; very full and clear explanations are given how to work out the very intricate calculations necessitated in aeroplane design. J.M.W.

ENTROPY AS A TANGIBLE CONCEPTION.

By ENGINEER-COMMANDER S. G. WHEELER, R.N. (Crosby Lockwood. 8/6.)

Entropy has been defined by a prominent physicist as the "Logarithm of the Probability of a State," which, though not altogether a bad definition, conveys little to the tyro. In this modest little treatise, after a clear exposition of "Thermal Inertia," the subject of temperature charts is introduced, the final objective being the elucidation of "added heat," and "adabiasis," and it appears that Entropy may be regarded as the degree of adabiasis. It is, of course, impossible to convey in a few lines what entropy really is, and anyone wishing to grasp this point cannot do better than consult this treatise. Mathematical investigations have been avoided and the subject has been presented in such a way that little mathematical knowledge is required for an understanding of the text. J.M.W.

MEX FUEL OIL.

(George Philip & Son. 10/6.)

A copy of the second edition of this book, full of interesting details of oil engines and machinery, with many explanatory illustrations, has been presented to the R.E. Library by the Anglo-Mexican Petroleum Company, Ltd., 16, Finsbury Circus, E.C.2. F.E.G.S.

THE CHRONICLES OF A GAY GORDON.

By BRIG.-GENERAL J. M. GORDON, C.B. (Cassell & Co. 10/6).

There is not much gaiety in this book, but it is a very readable account of the strenuous career of a nineteenth-century soldier of fortune, half Spaniard, half Highlander, which began at the Shop in 1873 and ended in the appointment of Chief of the General Staff in Australia just before the outbreak of the Great War. The advice given him by his relative, General Charles George Gordon, deserves quotation—"Never allow your pleasure to interfere with your duty." The description given in Part III., Chapter 3, of the introduction of Universal Service in Australia is especially interesting. F.E.G.S.

NOTICES OF MAGAZINES.

MILITÄR WOCHENBLATT.

No. 14.—"*Technique in the War of the Future.*"—The writer points out how the never-ceasing effort to concentrate great power within a small compass has led to great, and will in the future lead to still greater, development of mechanical weapons. He does not agree with the idea, which seems to die very hard in the German Army, that skilful and determined infantry can cope with tanks, and foresees great possibilities for this weapon. The apparent emptiness of the battlefield, which was becoming such a feature of the later stages of the war, will be still more accentuated and attack and defence will assume ever-increasing depth.

For the personnel of the battle of the future, he says discipline will more than ever be necessary, but it will not be the mass-discipline of the past; rather will it be that of the single-handed machine-gunner who forces himself, while under the heaviest barrage fire, to correct a stoppage in his gun. The more the individual has to fight on his own, the more independence must he have; and the finer his weapons the more self-control and technical skill will he require. Instead of the former hot-blooded thrusting onwards, the fighting man will have to show cool and calculating determination, and the victory of the future will belong to the army which disposes of a highly developed material and a personnel physically and technically competent to use it, and mentally and morally equal to the strain which its use will entail.

The West Hungarian Crisis.—An Austrian correspondent, who contributes an article on the Burgenland crisis, thinks that the collisions between the Austrian troops and the Hungarians will have ultimately a good effect on the former. Their weakness in equipment and material, due not only to the action of the Entente, but also to the criminal wastage of army property which went on unchecked during demobilisation, has been brought home to the Austrian people in forcible form. The writer expresses the hope that the latter will now appreciate the necessity for a well-disciplined, non-political and well-equipped force, and that the weaknesses of the Austrian Defence Force, in these respects, will now be made good.

No. 15.—"*Who caused the War?*" General von Zwehl brings up this question once more and trots out all the old one-sided arguments to prove that Germany is innocent. England's fear of the ever-stronger German Fleet, Russia's longing for Constantinople and France's lust for revenge made these three plan the world war, for which the Austrian adventure on Serbia offered a welcome opportunity. Needless to say that Belgium is not mentioned, and no incriminating dates regarding German, nor any Austrian action.

General von Zwehl says it is necessary to peg away at this question of Germany's guilt, because the Versailles Treaty is founded on it, and until it is disproved and her innocence accepted, no amendment of the treaty can be hoped for.

"*Officer-baiting.*"—The *M.W.B.* deplores the fact that this is still carried on in many papers, and that efforts are now being made to raise ill-feeling between officers of the "noble" and "bourgeois" classes. These efforts naturally take the form of gross abuse of the former, but it is curious that their personal courage should be so much attacked. "Telephone-generals" is a nice form of reproach; "'Noble' is synonymous with 'Candidate for an appointment on the L. of C.'" is another.

"*Wearing of Uniform.*"—The regulations governing the wearing of uniform by demobilised and retired officers have been modified to some extent, in spite of some rather coarse cartoons in the *Lustige Blätter*, and uniform may be worn on certain specified non-political occasions; special badges of unions and associations are forbidden.

No. 16.—*Leadership.*—General von Freytag Loringhoven has tried to analyse the qualities which must be united in a leader before he can expect to be accepted by history as one of the great generals of the world. Starting with Alexander, Cæsar and Hannibal, he depicts Napoleon, Gneisenau, Blücher, Wellington and Lee and associated with them Hindenburg, Ludendorff and, curiously enough, Falkenhayn and Hotzendorff. Although success may not necessarily be the test of greatness, it seems as if the last two were included chiefly with the idea of swelling the Teutonic ranks. The *M.W.B.* welcomes the book and hopes that the more Germany may be disarmed materially, the more she will steel her heart and arm her soul with patience.

The Campaign of the 9th (German) Army against the Roumanians and Russians.—General von Falkenhayn has published the second part of his book. He appears to have suffered from interference both by G.H.Q. and the Austrians, under whom he was at one time placed, but in spite of this his army must have done very fine work. In ten days the cavalry corps under von Schmettow, supported by Kuhne's group of divisions marched and fought over 200 kilometres of bad mountainous roads in the depth of winter. At a critical moment, when Mackensen's group was in danger of being attacked in rear, a Bavarian battalion captured a copy of the Roumanian orders, the situation was met just in time, and the Roumanian army was destroyed. The bulk of the Germans covered a daily average of 9 miles for a period of 26 days, which, under the conditions described, must have been a great performance. Taking together the size of the forces on both sides, the variety of the country fought over, and the very mobile nature of the campaign, it should provide material for many generations of military students.

The situation in the Far East.—The *M.W.B.* has news of events in Eastern Siberia, which is definite, if not necessarily accurate. Semenoff is said to have been disappointed in his hopes of Japanese support, and let down by treachery among his own people. After the Kappel troops mutinied in Vladivostock, Semenoff led his own formations to the Ussuri district, but the Japanese declared that they would not interfere in the private affairs of the Far East Republic, (having seen, says the *M.W.B.*, that Semenoff's star was waning) disarmed many of the White troops, and seized all the funds they had deposited in Japanese banks.

Semenoff had no choice but to resign, advising his successor to adhere to Mirkuloff, a social-democrat, who had meanwhile gained the upper hand in Vladivostock. It was, however, too late and the Bolsheviks gained control of the latter place and instituted a thorough "Terror."

It appears as doubtful as ever if the Japanese can really tell which horse to back, as some of Semenoff's troops may re-organize in Manchuria and the complete collapse of the Whites is still by no means certain. The latest news credits them with substantial successes near Irkutsk and Petrovsk, and at the former place the entire 33rd Red Division is said to have gone over to them.

No. 17.—"*The prospects of an Officer in the Reichswehr.*"—Many parents, particularly widows of old army officers, have been asking for advice before putting their sons into the Reichswehr. The *M.W.B.* thinks that the admitted difficulties of present conditions should not deter young men of good families from a military career. The first four years, which must be served in the ranks, will be hard, but the tone of the army is good and the mixture of classes that is being effected is likely to have good results. From a national point of view it is hoped that the "Noble" classes will not hold back.

L. Chenevix-Trench, *Major, R.E.*

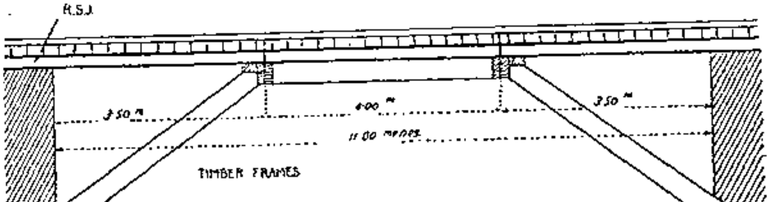
REVUE DU GÉNIE MILITAIRE.

May, 1921.

An article on the crossing of the Lys and the Escaut by the French Army in Belgium.—By Captains Soubret and Gex.

This article is divided into two parts (1), a historical summary, and (2) a technical survey of the methods employed.

The bridges were required to take heavy traffic, up to 20 tons total load, and, it not being possible to bring up materials from the rear, had to be constructed of stores found locally. For spans up to 20 ft. rolled steel I joists, up to 7 in. in height, were used, braced together at one or two points along this length. From 20 ft. to 60 ft., steel joists



strengthened as shown in attached sketch were used. Corbelling was extensively used to reduce the clear span. These bridges were found to be much lighter and much quicker to erect than pile bridges.

Measuring the width of a river.—By Major Tricaud.

The author points out that the margin of error in ascertaining the width of a river by field methods is very large and analyses this error compared to probable errors in the measurement of distances and angles. He comes to the conclusion that the greatest accuracy is obtained when the base is approximately 1·2 × the width, and one of the angles at the base is a right angle. He gives a table for the value of e with various methods of measuring such that the error in measurement of the width lies between $(1 + e)$ times the width and $(1 - e)$ times the width. In this table e varies between ·0110 and ·215.

June, 1921.

The Evolution of the French Defensive Doctrine.—The author, Colonel Normand, of the 12th Regiment of Engineers, traces the evolution of the French system of defence between 1914 and 1918, as necessitated by the ever-changing conditions of modern warfare, and summarizes his article in the table given below :—

August, 1914.	
Rifle fire predominant. Light and heavy field guns. Machine Guns.	Linear organization ; soldiers elbow to elbow. Disconnected trenches. Light shelters.
November, 1914.	
Stabilization. Fortification has the upper hand of artillery. Positions instead of trenches.	Three successive continuous trenches (Supervision, principal and reserve). The first line is the line of resistance. Machine guns in the front line. Short communication trenches. Loop holes and covered trenches. Shelters covered with three layers of pit props, separated from the trenches. Curved iron sheets. Telephones.
June, 1915.	
Grenades. Trench artillery. Balloon and aeroplane observation. Close contact with the enemy. Very lights. Searchlights.	Centres of resistance. Passive intervals, believed impregnable, covered by flanking fire. Decrease of personnel in the front line. Listening posts in the wire. Infantry arranged in depth. Small mined and concrete shelters. Obstacles wider, at least two layers. Netting on the parapets, against grenades. Mines. Improvement in camouflage. Artillery barrages. Casemated batteries near the front line. Flanking guns. A second position three or four kilometrès behind.
December, 1915.	
Development of heavy artillery. Minenwerfer. Gas. Flame throwers.	Continuous lines with intervals lightly held ; *points d'appui* surrounded by obstacles and grouped into centres of resistance. Reverse slope positions. Support trenches. Machine guns in the open, echelonned in depth, Short field of fire, but artillery O.P.'s with long observation, sometimes armoured, and well camouflaged. Sectors. Main C.T.'s organized for defence. A second strong position six or eight kilometres behind. Intermediate positions. Immediate counter-attack. Bomb-proofs ; metal shields ; portable O.P.'s. To do the greatest possible amount of damage to the enemy.

August, 1916.	
Artillery development. Abundance of munitions. Gas. Flammenwerfer. Automatic rifles; rifle grenades V.B. Improved portable tools (France).	Centres of resistance joined by trenches; *points d'appui* hidden by the same. Alarm posts. Immediate counter-attack to regain lost trenches. Cover as far as compatible with observation and fighting. Armour. A second position six to eight kilometres behind. Artillery defence line. Artillery echelonned in depth. Counter-preparation fire. Barrage fire. Communication (visual, pigeons. etc.,)
March, 1917.	
Gas.	Material rather than personnel in the front line. Machine guns and automatic rifles echelonned in depth outside the trenches. The principal rôle of infantry is movement.
August, 1917.	
Aerial photography. Artillery overwhelms defences. France: 37 mm. guns.	Dispersion of fortification. Automatic arms separated and concealed. *Groupes de combat* connected laterally and from front to rear. Numerous underground galleries. Switch lines. Artillery counter-preparation. Concentration of fire. Grouping of machine guns for indirect fire.
December, 1917.	
France: very powerful, heavy artillery. Anti-aircraft artillery. Tanks. Offensive aviation. Stokes Mortars.	Active defence; troops in echelon for immediate counter-attack or deliberate counter-offensive. The garrisons fight on the first position, but the possibility of the decisive battle being fought on the second position is realized. Defence plans. Reinforcing plans. Multiplied methods of communication, *e.g.*, wireless. Organization of artillery into Divisional, Corps and Army, with separate rôles and calibres. Batteries distributed in depth. Second positions pressed on.
April, 1918.	
Numerous German reserves. Very powerful artillery of all kinds. The gun is stronger than fortification.	Resistance in depth, without retreat; *Groupes de combat* staggered. Active zones and passive zones. Everyone must fight to the end wherever he may be.

June, 1918.

Massed tanks. Smoke screens. Numerical superiority of the Allies.	Limited withdrawal; a position of resistance (three-quarters of the effectives) on which the enemy is to be brought to battle; covered by advanced posts. A back position to arrest an enemy advance, occupied by elements of Army Troops. Manœuvring to regain lost ground; definite objectives for counter-attack, supported by fire. Artillery behind the line of resistance; batteries echelonned in depth and organized for defence.

Bridges made from barges from the Ourcq Canal.—By CAPT. NETTER. The problem of bridging the Rhine presented difficulties and the possibility of using the above barges was suggested. The barges were 28·5 m. long, 3·05 m. wide, 1·28 m. high at their centres, weighed 20 to 22 tons empty with a displacement of 75 tons. 275 of these existed in 1914, of which 250 were of steel. It was found that each barge could be carried on five railway trucks and could then pass through tunnels, under bridges, etc. Three roadways were used, the centre one with road bearers of wood for troops, light motor vehicles, etc., the two outer ones for the heaviest traffic, with steel I girders as road bearers. A bridge of 200 metres' length was tried on the Rhone and proved a complete success. Two such bridges of 500 metres were formed and kept in readiness for use if required.

C. LA T. T. JONES, *Captain, R.E.*

REVUE MILITAIRE GÉNÉRALE.

September, 1921.

Great Britain and Russia.—By MAJOR A. GRASSET. The rivalry of Great Britain and Russia has continued for some three centuries, and has at times influenced the policy of the whole civilized world. If its incidents are complex, its aims are simple, *i.e.*, Russia's efforts to secure an ice-free port, and Great Britain's efforts to frustrate her. By founding his new capital on the Baltic Sea, Peter the Great forced on England, in 1801, a naval occupation of Copenhagen at the risk of alienating the Danes, and on Russia's endeavours to secure access to and from the Black Sea hinged the whole "Eastern Question." In 1854 Britain found an ally in France, and the costly Russian fortifications at Sebastopol, and at Petropavlovsk on the Pacific, were overthrown. The same nations prevented Russia from obtaining a port in Ofoten Bay on the Norwegian coast.

In 1856 Russia obtained from China the maritime province of the Amur, and founded Vladivostock, but this port is closed by ice for three months each year. In 1877 Russia made a direct attack towards Constantinople, and when signing the Treaty of San Stefano, thought that her dream was at last realized, since she obtained a wide front on the Mediterranean through her allies Roumania and Bulgaria, but Great Britain at the Treaty of Berlin was instrumental in creating the state of Eastern Rumelia, thus cutting off Russia from that sphere of influence, and by occupying Cyprus kept watch on Russian designs in Syria.

Russia now turned to the East, quietly advancing on the one hand through Persia, on the other through China, each step marked by the advance of her railways and by settlements of Cossacks along the line, who made friends with the indigenous inhabitants. Thus grew the line from Azun Ada on the Caspian (joined to Baku by a steamer service) through Merv and Samarkand to Tashkent, while projects were on foot to join the last-named by rail with Omsk and Orenberg on the Trans-Siberian line. A secret treaty with Persia gave the Russians leave to construct a line from Tauris to Bunder Abbas on the Persian Gulf, and even to lease that port as a base on the Indian Ocean. By 1901 the Trans-Siberian line, 8,000 miles long and built in ten years, connected Vladivostock with Orenberg. Since 1894 Russian influence had been extended into Mongolia, Manchuria, and Corea, but in these regions a new adversary, Japan, was met.

After the Chino-Japanese War Russian intervention deprived Japan of the best fruits of her victory, and all the great powers scrambled for concessions in China, Germany obtaining the Bay of Kiao-Chao, England Wei-hai-wei, while Russia consolidated her hold on Ta-lien-wan and Port Arthur, thus at last realizing the dream of Peter the Great. Russia's correct attitude to the South of the Great Wall during the Boxer Rebellion secured for her the everlasting gratitude of the Chinese, while the discourtesy of the British and Germans was repaid by hatred, and the moderation of the French by tolerance. To the north of the Great Wall Russia acted alone; diplomacy was out of place, there was only revolt to be broken, and this General Grodekoff's army accomplished thoroughly, occupying without firing a shot the whole of Manchuria, the coasts of which are open to the ocean. The Trans-Siberian railway was at once extended from Vladivostock to Stretinsk, and a branch from Kharbin laid to Port Arthur. With the connivance of Li-hung-chang a Russo-Chinese Bank was opened at Urga in Mongolia and a Trans-Mongolian railway projected to connect Kailar on the Trans-Siberian with Kalgan on the high road from Peking to Kiatkha. To protect this line Cossacks at once swarmed into Mongolia and fortified a post at the entrance to the Sewantze Pass, within 100 kilometres of Peking. Scientific and religious missions penetrated into Zungaria and Thibet, and an alliance was concluded with the Dalai Lama, fore-runner of a protectorate.

Great Britain was on the watch; but relations with Persia and Thibet were unfortunate. The military occupation of Sikkim threw Thibet into the hands of Russia, while the dispatch of a fleet for a cruise in the Persian Gulf alienated the Shah. On the Japanese side her policy was more successful, and affairs in Corea soon drew Russian attention away from India. With the aid of funds from England an anti-Russian Society, the "Tairo Dashikwai" was founded, which united almost all the influential men in Japan, dominated the Chamber, and, in spite of the opposition of the Mikado, and his Prime Minister, Count Katsura, impelled the Empire to direct action. On various pretexts war was declared, Russia was defeated and driven from the extreme East. About this time British statesmen began to wonder if their policy of trying to withstand the irresistible tide of Russian expansion was not a mistake. Arrested everywhere else, that tide must flow towards India, where England, far from her base of supplies, and threatened also by internal dissensions, stood alone to oppose it, but Russia had wounds to heal, her forces to reorganize, the Austro-German frontier to guard, and before she could pull herself together the great war of 1914 broke out.

In this war Russia has been defeated, her army destroyed, her throne uprooted, and the nation is plunged in anarchy. But her dream of the sea is not ended, and, denied the far East by Japan and China, has turned to the Middle East, where the division of the Ottoman Empire between the governments of Constantinople and Angora opens a new vista. The precepts of the Koran are against revolutionaries, still help is required against Greece assisted by England, and joining hands with Lenin does not imply that the embrace need be more intimate. An agreement between Angora and Moscow was signed on 16th March, 1921, by which the latter guaranteed the integrity of Turkey, accepted the internationalization of the shores of the Black Sea and of the Straits, and subscribed to the abolition of the capitulations. Not content with this victory, the Soviet Government instigated an agreement between Angora and Afghanistan proclaiming the principles of self-government, and mutual material and moral support in case of an attack on either by a third party. Afghanistan recognized the religious supremacy of the Sultan, and a Turkish military mission was to reorganize the Afghan army. In spite of this alliance, and probably because Angora has not invoked it, Russia has remained inactive during the duel in Asia Minor, still her armies are massed on the frontier ready in case of a Turkish defeat, and only the future can show whether British diplomacy is right in supporting King Constantine and forcing the Turks into the arms of the Bolsheviks.

In Persia the struggle between Russia and Great Britain is equally severe. Conscious that Persian opinion was against her, Great Britain renounced the Anglo-Persian agreement of 1919 and withdrew her troops, retaining only the administration of the finances, as other nations control the other public services. The Soviet countered by renouncing all the privileges granted to the Czar, cancelling the Persian debt to Russia, and restoring the territories ceded in 1893, thus assuring themselves of Persian goodwill. In return the government of Teheran permits Russia to send troops into the country if Persia is attacked by any foreign state. On 24th of last May a cabinet still more jealous of national independence was formed in Persia, which, although not revoking the accord with Russia, lost no time in dismissing the English financial advisers, and withdrawing the concessions granted to the Persian Transport Company.

Only one state now separates India from the red flood, and that is Afghanistan. Since 1920 a British Mission under Col. Dobbs, and a Russian one under M. Suritz have been in Cabul. The former at first obtained an agreement which formally guaranteed the political and territorial integrity of Afghanistan, but bound the Amir to forbid anti-English propaganda, to receive no subsidy from Moscow, and not to allow any Russian agent near the Indian frontiers. This agreement lasted no time at all, and on 25th February a formal treaty placed Afghanistan in dependence on Russia, the latter to pay the Amir a million roubles and to furnish experts for laying a telegraph line from Herat to Cabul. Russian consulates were to be established on the Afghan-Indian frontier, and Afghan consulates in the great towns of Russia. Great Britain was only saved by famine and pestilence in Russia; M. Suvitz was recalled, and Col. Dobbs hastened to recover his lost ground. Warned of the false promises of Moscow, and persuaded of the waning power of the Soviet, the Amir, in spite of his secret preferences and the treaty binding him to Augora, signed a treaty with Great Britain which binds him to break off relations with Russia and accept an English subsidy; but, cautious to the end, he exacted delay in the execution of the treaty until the British General Staff shall have organized a strong line of resistance along the Russo-Afghan frontier, and stocked the country with food, arms and munitions.

Just in time India is saved, for besides communistic ideas, Lenin's emissaries are adepts in political and religious propaganda, potent weapons in the East. At the same time Britain's concession to the Indian races of a share in the conduct of government in consideration of their sacrifices for her in the war have not been appreciated at their proper value, and the electors have returned to the Councils a majority of irreconcilables with whom cool discussion of national defence will be difficult. Last March at Delhi a large reduction in the army was demanded, and in spite of strong opposition from the C. in C. the government had to yield. The army in India has consequently been reduced, and, although the equipment of machine guns, tanks, air-craft and armoured motor cars has been increased, it will not compensate for the reduction of effectives, nor for the moral effect produced by this defeat of British authority. The horrors brought on Russia by the regime of Lenin and Trotzky are such that they cannot be prolonged, and when they pass the need for access to the open sea will again make itself felt, and history will resume its course.

The Revision of the Regulations.—A continuation of the article by Lucius. Fourth period, *i.e.*, the German attack on Verdun (21st February to 11th July, 1916) and the Franco-British offensive on the Somme (1st July to end November, 1916) and in Artois and on the Aisne (9th April to 15th May, 1917).

The new conceptions of the attack evolved from the operations of 1915 were issued in 1916 in three sets of Instructions dated 16th, 26th and 8th January. Since the artillery cannot from its original position simultaneously prepare two enemy positions for attack, the Instruction of 16th January laid down that attacks must be successive, and to capture each position at least part of the guns may have to be moved up. Having captured the immediate objective, troops at once reconnoitre the next, and select observation posts. To reduce the period between successive attacks commanders must have already organized the next attack and try to launch it before the enemy has had time to recover. When all the positions have been taken, the cavalry will act as directed in the Annexe of 18th June, 1915, and its commander must during the infantry attack be well up, generally in the command post of a first line infantry division. This Instruction also established the separation of the two duties of observation and communication, a considerable progress; that of 26th January divides the attack into two phases, the first comprising the organization of the position, the second commencing with the arrival of the fighting troops. Before the attack of each position, plans must be prepared and issued, showing the employment of every unit, artillery plan, works plan, supply and evacuation plan, communications plan. The employment of the larger formations is definitely regulated; the corps will consist of four or five divisions, the front of attack to be of the width of two divisions; strong reserves are to be ready to replenish the attack. The division is the combat unit, its commander co-ordinates infantry and artillery action and assures their supplies; the corps is the attack unit, its commander decides the plan of battle, the direction of the attack, controls the reserves, and is responsible for exploiting the victory. The army co-ordinates the action of the corps, and sees that the pursuit is rapid and thorough. The conditions of success are good order, and artillery support for the infantry. Units in first line are to be relieved before they become exhausted. The Instruction of 8th January defines anew the attributes of infantry. It has no power against obstacles—men do not fight material; it has great potentiality for occupying ground, is rapidly expended in action, must not manœuvre in dense formations, and its *morale* is extremely sensitive. Henceforth infantry will be replaced to a great extent by gun, machine gun, and automatic rifles. All artillery employed in destruction is to be under the divisional general, a great proportion of it will be pushed as far as possible to the front, and change of position during action is to be restrained to the utmost.

The three Instructions refer to trench warfare only, and, enjoining more method and order in the attack, involve some delays. In regular siege warfare where the enemy is invested time is of less importance, but under the conditions of the Great War, where he can bring up reinforcements, the period of delay between successive attacks is incompatible with the order to attack him before he can recover, and stratgeic surprise is impossible. The plans referred to above had to be approved by higher authority up to the Army in some cases, and this excessive centralization is to become more and more marked to the detriment of the initiative and responsibility so necessary in open warfare, such as the period of exploitation of the success. Although the employment of cavalry to exploit the success is prescribed, the action of the larger formations is only vaguely touched on. In the case of a partial success a warning is given not to push too far ahead partly disorganized troops, but it is also laid down that favourable opportunities must not be lost owing to undue timidity. To compel infantry not to go beyond a certain point fixed on a plan beforehand is to deny them the full use of their success.

All commanders, and especially Divisional Generals must cultivate the *morale* of their troops, and the first quality to develop is energy. —(*To be continued*).

A. R. REYNOLDS.

REVUE MILITAIRE SUISSE.

No. 6—*June*, 1921.

The Psychology of War.—The *Revue* article is a translation from the German text of a memoir by Dr. A. L. Vischer on the above subject. This memoir appeared originally in the *Allgemeine Schweizerische Militärzeitung*, and is a lucid presentment of a most important subject. Dr. Vischer points out that the decisive elements which make for victory in war lie not alone either in the armament or in the equipment of the opposing forces; the psychological faculties of the soldier, as an individual as well as a member of a group, have also to be reckoned with. For some years past, a number of scientists have devoted themselves to research work in relation to the mental capacities of men, and have framed suitable physiological and psychological tests with a view to grading them according to their aptitude for various callings and professions. The Americans, as is well known, made considerable use of examinations of this kind in connection with the selection of men for the different branches of the Army raised in the United States for the Great War; they express themselves well satisfied with the results thereby obtained. Much interesting and valuable information is contained in the original article upon the mental attitude of soldiers during the Great War. Uncertainty as to the future had, on account of the unexpectedly long duration of the campaign, a most demoralizing effect upon them in some cases, and gave birth to a carping spirit. The tendency which existed, at one time, for those in the ranks to magnify their grievances, and see alone the weaknesses in their superiors was fraught with grave mischief. Dr. Vischer remarks that General Pétain showed true insight and a just appreciation of the psychological necessities of the moment when, on June 2nd, 1917, he issued his circular, containing the simple and precise statement regulating matters connected with leave of absence, rest, rations, &c.; the wide dissemination of the information therein contained did much to clear the atmosphere and definitely to remove the disturbing influences which were sapping the *morale* of the French Army and bringing disastrous consequences in their train. The original article is most instructive and deserves to be widely read.

NOTES AND NEWS.—*France.*—A special correspondent draws attention to the fact that the text of the proposed new Law relating to the French Army has been recently published: the draft Law is intended to take the place of the basic Law of March 13th, 1875. The draft Law is divided into four chapters: in the first chapter is set out the composition of the French Army as proposed—apparently it is intended that the Division shall be the highest peace time formation permanently to be maintained; in the second chapter are given the units of the various arms, infantry, cavalry, artillery, engineers and air force—many details in relation to the various branches of the service are reproduced in the *Revue*, and it is interesting to note that, as compared with 1912, reductions are proposed in the infantry (from 173 to 162 regiments) and in the cavalry (from 89 to 67 regiments), on the other hand, increases are proposed in the artillery (from 75 to 93 regiments) and in the engineers (from 7 to

15 regiments), at the same time the air force is to be increased from 3 groups to 21 regiments; in the third chapter are given the establishments of the Corps of officers—*inter alia*, an establishment of six Engineer Generals, 1st Class, and 18 Engineer Generals, 2nd Class, is provided in connection with manufactures and military works; in the fourth chapter are given the establishments of the "staffs" and of the "special services."

United States of America.—A special correspondent writes that General Pershing has, in the new post created for him at the G.H.Q. of the American Army, been entrusted with the preparation of a co-ordination scheme in relation to the National Guard, the Reserve formations and the Regular Army, with a view to enabling the United States to put into the field a force of a million men in the event of a mobilization for war purposes. Attention is also called to the arrangements which are being made to provide instruction, non-military in character, at the Dix Camp, New Jersey, for officers and non-commissioned officers in order to enable them to acquire knowledge on subjects likely to be useful to them in civil life. It is expected that by the end of October of the current year there will be assembled at the Camp some 9,000 to 10,000 men, divided into about 100 classes (54 academic and 57 professional), under 200 instructors. The Dix Camp is one of the largest and most elaborate of the encampments constructed during the Great War: it is now the headquarters of a division of the 2nd Corps and also the summer camp of the West Point cadets.

W. A. J. O'MEARA.

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The Tank Corps is to be congratulated upon their November "Cambrai Anniversary" number. Many of the articles are of considerable historic value, and the illustrations, including "The Tank Battle of Cambrai," add to the value of this publication.

F.E.G.S.