THE ROYAL ENGINEERS JOURNAL.

Vol. XXXI. No. 1. JANUARY, 1920.

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THE ROYAL ENGINEERS JOURNAL.

VOLUME XXX.

JULY—DECEMBER, 1919.

CHATHAM:
ROYAL ENGINEERS INSTITUTE.
AGENTS AND PRINTERS: W. & J. MACKAY & CO., LTD.

VOLUME XXX.

LIST OF PLATES.

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Original Articles are entered in thick type; Reviews and Notices of Magazines in thin type.

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Authors alone are responsible for the statements made and the opinions expressed in their papers.

MONTGOMERIE PRIZE.

ATTENTION is invited to the conditions under which this prize, in value about £10, is offered for competition each year.

1. The Prize shall be awarded by the R.E. Institute Council in the manner considered best for the encouragement of contributions on professional subjects, by R.E. Officers, to the Corps publications. From the beginning of 1920 it has been decided that the Prize shall be confined to Officers on the Active List not above the rank of Substantive Major.

2. The Prize shall consist of (*a*) a book on Survey, Exploration, Travel, Geography, Topography, or Astronomy; the book to be whole-bound in leather, and to have the Montgomerie book-plate with inscription inside; (*b*) the remainder of the year's income of the Fund in cash.

3. The name of the recipient of the Prize shall be notified in the Corps publications; and copies of the contribution for which the Prize was awarded shall be presented to the representatives of the donors.

The following are suggested as subjects for contributions :—

(*a*). Descriptions of works actually carried out in peace or war.
(*b*). Inventions.
(*c*). Design (excluding works of defence).
(*d*). Labour organization on work.
(*e*). Scientific investigations generally.
(*f*). Accounts of exploration work and surveys.

EARTH-CURRENT TELEGRAPHY.

By CAPT. L. C. CARUS-WILSON, M.C., R.E.

IT has long been known that if a battery is placed in series with an insulated wire earthed at each end, the ground forming the return circuit, the current which flows does not confine itself to the straight line joining the two earths, but spreads out over a large cross section of the ground. Thus in *Fig.* 1, C is a battery connected by two insulated wires to earths A and B. The current flows through the primary circuit BCA and then through the earth from A to B, its passage through the earth covering a wide area as indicated by the lines of flow in the diagram.

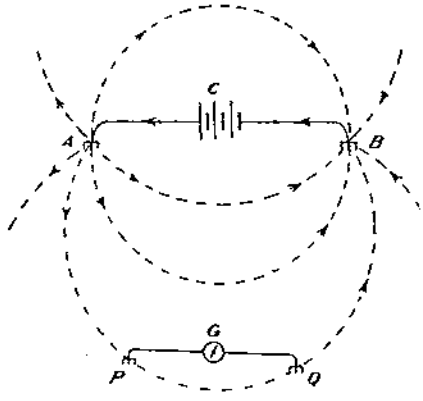


Fig. 1

These lines of flow can be regarded as a number of conductors in parallel, along each of which a fraction of the total current is flowing, and there is therefore a difference of potential between any two points P and Q. Such that if earth connections are made at these points and joined by a secondary insulated wire to a galvanometer a current in the primary circuit will produce a deflection in the galvanometer. The current in the secondary is diminished if these points are moved further away from the primary circuit.

Experiments show that these lines of flow assume definite shapes —approximately arcs of a circle—which are not appreciably affected by irregularities encountered in their course through the ground.

In order to get the maximum current in the secondary circuit it is necessary for P and Q to be on the same line of flow, and to ensure this, the line joining P and Q must have a definite direction relative to that joining AB.

If a source of alternating current, such as a telephone, be substituted for the battery in the primary, earth currents will be formed in precisely the same way and an alternating current will be produced in the secondary.

Early in the war the principal means of communication at the front was the military telephone, which included, in addition to the usual speaking apparatus, a buzzer for sending messages by the morse code. This instrument is designed on the principle of the trembler bell with a very light armature and a secondary winding having sufficient turns to send a high voltage current into the line.

For reasons of economy earth return circuits were usually employed and the telephone and buzzer messages gave rise to earth currents which strayed great distances from the direct line connecting the two earths. The simplest way to detect such currents was to insert a telephone receiver in a secondary circuit. Signals could then be heard in this receiver whenever messages were being sent through the primary. The power employed, however, was so small, that overhearing with a telephone receiver was only possible from a very short distance, and for satisfactory results a much more sensitive receiver was needed.

In 1915 the French signal engineers found the receiver which was required in the instrument known to us now as the "Low Frequency Amplifier." Its principal feature, namely, the Three-electrode Valve, was based on the familiar "Fleming Valve," but in this case it was used as an amplifier of low frequency currents rather than as a rectifier of high frequency currents. The three-electrode valve is practically a relay for alternating currents. There is no definite make and break of circuits, there are no delicate contacts to adjust and clean, nor is the action of the valve in any way disturbed by external vibration. Since there are no moving parts, there is no mechanical inertia and the current in the local circuit follows every variation of the current in the primary circuit, reproducing exactly, on a magnified scale, any wave form however complicated.

In this amplifier three valves were connected in cascade, the magnified current from the first valve passing through a transformer to the primary circuit of the second valve, and so on. The magnification of each valve, allowing for transformer losses, was five to one, and the total magnification, which rose in geometrical progression with each stage of magnification, was 125 to one. This instrument was suited for connecting on to two earths with a total resistance of between 20 and 100 ohms. This amplifier acted as a receiver and

it was sufficiently sensitive to enable one to overhear telephone speech from a distance of several thousand yards.

Thus, if we imagine a German field cable near the Front with an earth return circuit and a telephone at each end as shown at A and B in *Fig.* 2, the currents produced by speaking into either telephone would spread out over No Man's Land and into our territory. If two earths are made at E and F and connected to an amplifier at X, everything that is said on the telephone will be heard on the amplifier. These amplifiers were used by the French at various points along the Front. The instrument was installed a few hundred yards from the Front and lines were laid out and earthed at their extremities, as near to the German trenches as possible. The results were very satisfactory and much information was gleaned from the intercepted messages.

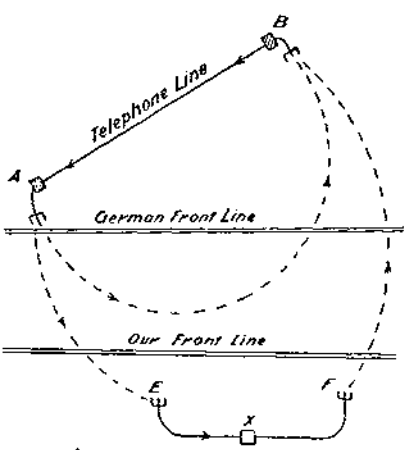


Fig 2

Unfortunately the Germans captured one of these amplifiers; they at once realized its import, and lost no time in producing a similar instrument for intercepting our messages. They were certainly conversant with the valve before the war, but till then evidently it had never occurred to them to use it for this purpose. Before long, however, they had produced a number of amplifiers and organized a thorough system of intercepting our telephone messages.

With one of these instruments most of the communications of one of our divisional fronts could be overheard by the Germans opposite, so that the enemy could obtain with ease, information which was of vital importance to him. Not only was he warned of impending local operations, but he could compile information which led to an accurate knowledge of the *moral* and disposition of our

forces. On several occasions the Germans were unusually alert at the time of a proposed raid only very shortly after our orders had been issued, or shelled places where working parties were assembling.

Much of the information which was put to the credit of the ubiquitous German spy was undoubtedly attributable to this source. Search was made for spies with concealed wireless apparatus and for lamp signalling stations, but what need had the Germans for complicated methods when they could obtain their information by such a simple means?

It was not until early in 1916 that the British began to make use of the amplifier. The instruments used were chiefly those lent to us by the French, but we had some which were made by the Marconi Company. "Interpreter-Operators" selected for possessing a combined knowledge of the German language and the morse code, were trained in the working of the amplifier and placed at various "Listening Posts" along the line.

There was not much difference between the French methods of working and our own. The amplifier was set up in a dug-out near the Front in a remote spot so as to be away from our own telephones. Five or six earths were made as near to the German trenches as possible. These were connected to a multiple switch at the amplifier by low resistance cables, which were laid far away from our own cables to avoid the interference caused by them.

In order to obtain the maximum current in the amplifier from an enemy telephone it was important that the resistance of the whole circuit, including the amplifier, leads and earths, should be kept low. The main element in this resistance was that of the earth connections. It was impossible to bury large plates or drive iron pipes into the ground within a few yards of the enemy's trenches. If the soil was suitable, fairly good results could be obtained by using a number of small iron earth pins, which could be pushed into the ground. Trials were made connecting the cable with the enemy's barbed wire, but this wire was usually so rusty that it was not electrically continuous and made a high resistance earth.

The resistance of an earth is found almost entirely at the point of contact between the conductor and the earth, so that it was necessary to get the surface of contact as large as possible As we could not secure a large enough metallic surface the next best thing was an electrolytic surface. Using this principle, a good earth was obtained in the following manner:—The end of the wire was bared for about two feet and pushed into a sandbag containing a handful of copper sulphate. It was then tied up at the mouth, taken out to No Man's Land, and dropped into a shell-hole full of water, the wire being unreeled from a drum behind. The crystals dissolved in the water and formed a large conducting surface in contact with the ground, giving an earth resistance of under ten ohms.

An interesting encounter took place with the Germans on one occasion. It happened that one night one of our earths, A *Fig.* 3, on being tested proved to be broken. The fault was eventually located at the earth itself. We found that our line had been cut off its earth and another line coming from the German trenches had been put in its place, thus connecting our earth A with his earth C. Here was a problem. If we removed the German line and replaced our own the change would certainly be noticed on the German amplifier. If we connected our line on to the German line and disconnected the earth altogether, working through earths B and C, the enemy could pick up as much from us as we could from him. Added to this we knew that the enemy could hear on the amplifier anyone tampering with his line, and might at that moment be lying in wait for us So we decided to leave the line untouched and the next night a pair of lines was run out to the spot, joined carefully on to the bare earth connection about six inches apart, and then the earth connection was cut between our two lines, leaving our earth A and the enemy's line and earth C, connected through on to our amplifier. (See *Fig.* 4). By this means he was not aware that any change had been made, but we had the benefit of his line and earth C inside his lines, while he could hear no more from us than with the original earth.

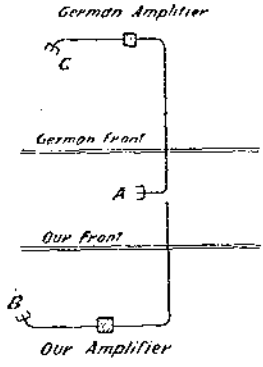


Fig 3

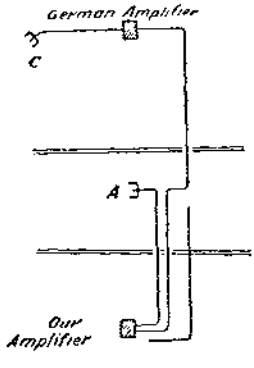


Fig 4

A good deal of information was obtained by us from the enemy by the use of the amplifiers when first installed, but the Germans soon became very cautious in their telephone conversations. They had probably learnt their lesson from the amount of information which they obtained from us by this means. They spoke but seldom, keeping their telephones for use in emergency rather than for the normal routine of trench warfare, and when they did speak they tried to hide the true purport of their conversation from eavesdroppers by evasive statements. On one occasion they unwittingly

betrayed the presence of one of their amplifiers, and also gave away the fact that they used their amplifiers for policing their own telephones. A telephone conversation was in progress between two Germans, when a third voice intervened telling them to stop talking as the line they were speaking on was faulty and was being overheard on their amplifier. Later on they evidently considered it hopeless to prevent telephones being overheard, and came to the conclusion that the only way to prevent the leakage of information by this source was to abolish the use of the telephone altogether near the Front; evidence showed that they had even gone to the length of installing speaking tubes to take its place.

A curious occurrence took place on the Italian Front, which showed that telephone overhearing was practised on that Front as regularly as on the Western Front. A message in some simple cipher was intercepted by the Italians on one of their amplifiers. It proved, when deciphered to be one of their own messages, which had evidently been intercepted by the Austrians, put into cipher, and was being sent back by telephone to Austrian headquarters.

We were not slow to realize the danger of being overheard and we soon took steps to prevent it. The first precaution was naturally to use metallic circuits and to prohibit altogether the use of earths. Theoretically a pair of lines properly twisted and perfectly insulated was free both from induction and earth leakage. Unfortunately the average trench cable fell very short of this ideal. Only in exceptional cases was the rubber insulation protected by anything more than cotton braiding. Usually it was laid in that busy thoroughfare of trench life—the communication trench—where it was often pulled taut across the corners, threatening to decapitate everyone that passed, or if laid at the bottom of the trench it became involved in the excavations of the trench maintenance party, who ignorant of the true function of insulation were quite happy so long as the wire was not actually broken. Thus it is not surprising that the cable, quite apart from the damage done by shell-fire, soon developed earth faults along its whole length. The conductors were of a high resistance so that much earth leakage took place and such a cable soon became hardly any safer than an earth-return circuit.

The next method of preventing overhearing was to jam the enemy's amplifiers by sending a strong alternating current to earth in order to produce a noise in his receiver by which it would be rendered useless for hearing our messages. For this purpose a buzzer was constructed which could be switched on and left working continuously. Two earths were employed about five hundred yards apart in the front line. In the later patterns of this instrument the buzzer was designed to give a wavering note or a series of dashes, as this was found more distracting to read through than a continuous buzz.

The invention of the " Fullerphone " afforded a partial solution of the problem of overhearing, since by that instrument messages could be sent in morse code without risk of being picked up. In that instrument the current is converted by an interrupter at the receiving instrument into an intermittent current, so that a direct current sent out to line is heard as a buzz in the receiver. The alternating current thus produced is confined to the receiving instrument by a suitable arrangement of condensers and choke-coils. The choke-coils also have the effect of preventing a sudden rise and fall of current in the line, thus avoiding the clicks produced at the beginning and end of a morse symbol. So long as the Fullerphone is in good condition, it affords for all practical purposes, complete protection against the overhearing of morse signals.

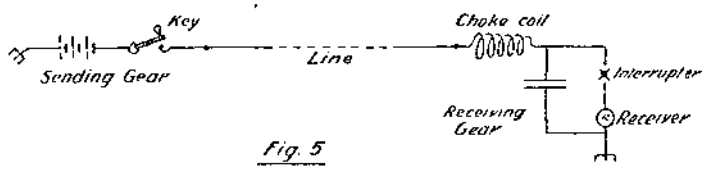


Fig. 5

It may be asked why signals cannot be picked up from a Fullerphone by putting an interrupter in the amplifier circuit. This is theoretically possible, but for practical purposes is useless for the following reason. There is always a slight difference of potential between any two earths. This potential is not constant, but varies from one minute to another, and has to be balanced by a potentiometer, which requires such continual adjustment that the reception of a message is very precarious.

One useful piece of information came through capturing a German " Interpreter-Operator," who had been a waiter in London before the war and on account of his excellent knowledge of the English language had been employed on the German listening posts to intercept our telephone conversations. He gave us some useful information regarding the German system of overhearing. He said, for example, that they used to hear our telephones so loud in their amplifiers that the operator had to take the telephone receiver off his head in order to read them. He also told us that he could sometimes hear faint signals probably emanating from an instrument which was supposed to be free from overhearing. On further inquiry this proved to be the Fullerphone. In order to investigate this we set up two Fullerphones connected to an earth-return circuit in the usual manner in close proximity to two earths joined to an amplifier. The German was told to listen at the amplifier and to hear the Fullerphones if he could. To our astonishment they could be heard, faintly, yet clearly enough to be readable. These instruments were immediately tested, and it was found that

owing to long exposure to the damp the wooden framework of the choke-coils was only a partial insulator and offered quite a low resistance to the alternating currents produced in the receiving instrument, thus enabling them to leak out to the line. In consequence of this episode all Fullerphones in use were tested regularly. The test could be made quite simply by putting an ordinary telephone in series with the Fullerphone. If nothing could be heard in this receiver when the Fullerphone was working, it was quite safe to assume that the Fullerphone was inaudible to any German amplifier, which had approximately the same sensitivity as our own.

The use of the Fullerphone enabled us to keep up our communications through the medium of morse telegraphic signals without risk of being overheard, but it did not enable us to carry on telephone conversations unheard. One proposal for doing this was to use an amplifier for reception and an ordinary telephone receiver in place of a microphone. This however was too cumbersome for general use. Another ingenious device used a combination of earth-return and metallic circuits. The current produced in the telephone was diverted, by means of a vibrating contact, alternately to a metallic and to an earth return circuit. At the further telephone the signal strength was about the same whether the current arrived by the metallic or by the earth-return circuit, consequently connnected speech was heard. At the intercepting amplifier the earth-return signals were much louder than those from the metallic circuit and consequently confused speech was heard, which was quite impossible to interpret. In practice, however, it was difficult to arrange that the strength of the two signals at the receiving telephone were the same, so that speech was rather indistinct.

The conditions under which signalling was carried on during stationary warfare were materially changed when any movement took place. It became impossible for either side to maintain the lines and instruments necessary for overhearing, and the vital consideration was to keep up communication of any kind. The increasing intensity of shell-fire and the constant movement made the upkeep of lines exceedingly difficult. Wireless aerials were too conspicuous and were constantly being broken by shell-fire. Visual signalling was not reliable, since at the critical moment vision was liable to be obscured by early morning mist or by the smoke and dust created by shell-fire. An apparatus was needed which could signal for about a mile, requiring neither a high aerial nor long lines, which was mobile and could be worked from a protected position. It was found that the method above described for overhearing enemy telephones could be effectively adapted to this end. If instead of the enemy telephone we imagine one of our own telephones connected to two earths 100 yards apart, signals from this will be heard on an

amplifier several hundred yards away, and messages can be sent from the telephone to the amplifier. In order to get signals over a sufficient distance a new instrument was designed called a "Power Buzzer." This as its name implies, was an enlarged reproduction of a telephone buzzer and about fifty times as powerful, and, connected (see *Fig.* 6) to two earths, forming a so-called earth base, perhaps a hundred yards long, constituted the transmitting station. The amplifier was connected to a similar base at the receiving station, with its two earths as a rule two hundred yards apart. Thus in order to send messages from one station to another it was only necessary to set up at each station the instrument with its short length of cable, which could be buried if necessary, to protect it from shell-fire. This system was introduced almost simultaneously by us and by the French, though for the most part we used Power Buzzers made by the French.

The Power Buzzer was constructed very much on the lines of a spark induction coil, with separate primary and secondary circuits. (See *Fig.* 7). The source of energy used, was a ten-volt twenty ampere-hour accumulator, the buzzer taking about four amperes in the primary circuit and delivering approximately half an ampere at fifty volts in the line circuit. The armature was designed to vibrate at a high speed, thus producing a musical note with an average frequency of five hundred periods per second.

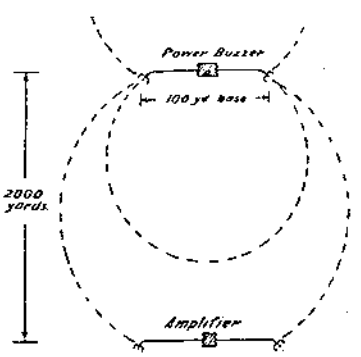


Fig. 6

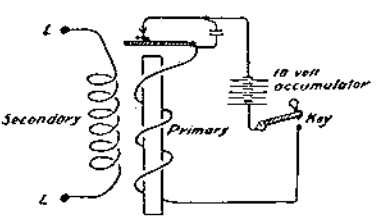


Fig. 7

The distance over which communication could be maintained with this apparatus varied considerably with the nature of the ground. In the muddy soil of Flanders signals could be obtained over a distance of two thousand yards, using a hundred yards base at each station. On the Somme, however, where the soil consists of a layer of earth about six feet deep and chalk underneath, the earth currents were for the most part confined to the surface and the possible distance was more than doubled. This effect was also observed in ordinary soil after a frost, when at the surface the soil having thawed

was conductive, while underneath being still frozen it was an insulator. By using longer bases, communication has been established over more than twelve thousand yards.

In the course of a few months the Power Buzzer was converted from an interesting electrical experiment into a practical and simple means of communication. The instruments were improved, simplified and standardized as far as possible, and an enormous reduction in bulk and weight was effected, the amplifier for example, being reduced from an instrument weighing 60 lbs., which had to be carried about by two people, to a weight of only six pounds. Compared with other wireless apparatus the Power Buzzer had the great advantage of simplicity, and did not require such highly trained *personnel*. Both Power Buzzer and amplifier were easily tested and adjusted and were free from the complications of "tuning."

Two points which received attention during this time were the quality of the earths and the relative direction of the two bases, upon which a considerable number of experiments had to be made before the best results were obtained.

To get good results it was essential to have as large a current as possible in the earth circuit of the Power Buzzer. But we found that a certain current at a high voltage did not give such good results as the same current at a low voltage. It appeared that the high voltage had a tendency to reduce the spread of the earth currents. The only method of getting the required current at the low voltage was to use a very low resistance earth, and this proved to be the dominating factor in securing success. For a permanent earth the simplest method was a large tin buried and saturated with a solution of common salt, while for a mobile earth three or four iron earth-pins about three feet long, pushed into the earth at the wettest spot available, usually sufficed Another consideration was that the resistance of the earths should be equal to the impedence of the secondary circuit of the amplifier or Power Buzzer. This was considered to involve too great a complication for our use, but it was arranged for in the German instruments.

With regard to the arrangement of bases we obtained the best results when both earths of the receiving station lay on the same line of flow of the earth currents emanating from the transmitting station. Assuming that the lines of flow were circles, the best results were obtained when the two bases were parallel and opposite, as in this case the minimum circle of flow was utilized. (See *Fig.* 8). When three stations were working together a more complicated calculation was necessary. For example, supposing a station A was working to a station B and for this purpose had its base laid out at an angle X° with true north, when a station C wished to communicate with A the two earths R S at C would have to be laid out so that they were on the same line of flow of currents emanating from the two earths P

and Q at A ; that is to say, that PQ and RS would have to be chords to the same circle. For the purpose of taking bearings it was sufficient to assume that they should be tangents to the same circle, *i.e.*, they should be equally inclined to a line joining their centres. If the bearing of C from A was Y°, it followed that the base RS should have a bearing of 2Y°—X°. (See *Fig.* 9). This bearing could therefore be easily found for any similar case and in order to simplify this process still further a " Calculator " was used whereby the bearing could be read off on a sliding scale.

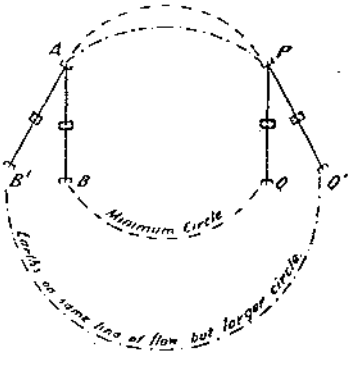


Fig. 8

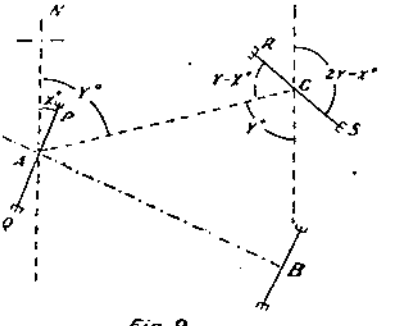


Fig 9

The Power Buzzer and amplifier were finally combined into one instrument, thus effecting a further simplification in the necessary connections and enabling communication to be carried out almost as easily as with an ordinary telegraph circuit. Thus improved, the Power Buzzer became one of the main methods of forward communication in battle, relieving considerably the burden of the runner and the linesman.

This system cannot be regarded as ideal, but it filled an awkward gap in forward communication before it was superseded by high-frequency wireless sets of more efficient design. Several difficulties were encountered whilst working it in practice, chiefly owing to the high sensitivity of the amplifier. Any telephone circuit in the vicinity of the base was overheard, and it required practice and not a little patience on the part of the operator to concentrate on the signals which he wanted to hear to the exclusion of all others. This was facilitated to a certain extent by making the Power Buzzer note of a higher pitch than the note of the average telephone buzzer, so that when heard, it could be distinguished as a Power Buzzer and also read with greater ease.

Atmospherics and stray earth currents were an almost constant source of trouble, producing crackling and sizzling sounds in the telephone receivers. During the summer of 1917 there appears to

have been a continual magnetic storm in the earth; dwindling at nights but coming on with great violence towards the middle of the day. This was afterwards confirmed by the aforementioned German operator, who stated that the interception of our signals was almost impossible during that period. Alternating current power systems occasionally caused interference notably near Lille and also in Italy.

On one occasion an amplifier gave warning of an enemy mine near Ypres. Every night a faint hum was heard in the amplifier, not the steady hum of a dynamo, but the rapidly changing note of a motor under a varying load. This was assumed to be a motor used by the enemy for boring a mine gallery, and this assumption proved to be correct as a mine went up under one of the amplifier earths a few days afterwards.

Efforts were made to get rid of interference by tuning the receiving circuit either mechanically or electrically to the frequency of the incoming signals. To a certain extent this was effective, but the Power Buzzer signals were considerably weakened, probably owing to the number of harmonics present in the Power Buzzer note, so that a receiving circuit tuned to one of these would not get the whole signal strength.

It is interesting to note that the Germans declared that bad forward communication was one of the main reasons for their defeat at the beginning of the Somme battle. They made great efforts to improve their communications and amongst other things took up the Power Buzzer.

The German Power Buzzer was typical of German ideas on instrument making, aiming at theoretical efficiency rather than at simplicity and mobility. Every contrivance and adjustment that could possibly increase its efficiency was included, with the result that it was very much heavier and bulkier than ours. So complicated, in fact, was its mechanism that it is doubtful whether anyone but a professor of physics could really understand it and work it to its full advantage.

THE WORK OF THE ROYAL ENGINEERS IN THE EUROPEAN WAR, 1914—1919.

BRIDGING.

CHAPTER III.

(Continued).

BRIDGING OPERATIONS—AUGUST TO NOVEMBER, 1918.

(*Reference* MAP *following* PLATE XXIV., *page* 216, R.E.J. *November*).

Haute-Deule Canal.—Lys River and Canal.—St. Quentin Canal, Escaut (Scheldt) River and Canal.—Selle River.—Canal de la Sambre.—Conclusion.

6. THE HAUTE-DEULE CANAL.

The heavy bridging of the Haute-Deule was carried out by the 560th A.T. Company, and the 250th, 257th and 3rd Australian Tunnelling Companies, all belonging to the Fifth Army.

Considerable difficulties were met with owing to the very complete destruction of the old bridges and abutments, which involved either an immense amount of clearing work, or very long new approach roads. The nature of the ground bordering the canal also made the work of assembling long span bridges rather difficult.

Projects had been carefully worked out beforehand in anticipation of an advance, and all arrangements worked smoothly. No particular difficulties were found in the actual work of erection.

Two Hopkins Bridges were put up, one of 105-ft. span, and the other 120-ft. span. In each case the actual work took about a week.

7. THE LYS RIVER AND CANAL.

The canalised Lys varies from 100 ft. to 150 ft. in width at normal water level.

When the Second Army began its advance at the end of September, 1918, every bridge was found to have been destroyed, and 17 main road bridges had to be erected or re-constructed.

Complete arrangements had been made early in September to form an Army Bridging Organisation. The *personnel* consisted of an Army Bridging Officer on the Staff of the Chief Engineer, and the 554th (Dundee) A.T. Company, R.E. This Company was specially selected as the *personnel* consisted chiefly of men who in civil life

were engaged in the manufacture and assembling of heavy structural steel-work.

Two Bridging Depôts were formed, an Army Base Depôt at Les Attaques (Calais), and an Advance Depôt at Bailleul. Two sections of bridging stores were kept at Les Attaques, and one section at Bailleul, where in addition about 10 stock spans were kept ready for immediate use. These two Depôts proved of great value, and the system of the army running its own depôt at the base was most satisfactory.

Owing to the rapid advance of the Army during October, the forward Depôt was moved by train to Heule, North of Courtrai, on the 4th November.

The transport used for conveying bridging material and stores from the Advance Depôt to the sites of bridges consisted of two 5-ton Berna lorries, one 7-ton trailer, F.W.D. lorries with trailers from No. 9 Pontoon Park, and such 3-ton lorries as could be provided by Corps or Army.

The 554th Company was continuously employed throughout the months of September, October, and November on the following duties:—

Unloading, checking, sorting and stocking stores and bridge parts at the advance depôts.
Issuing spans and stores, and loading them in correct lorry loads.
Supervising the correct delivery of stores at bridge sites.
Repairing bridging stores and equipment, and making replacements of lost parts.
Making up complete bridges from R.S.J.'s and timber.
Dismantling bridges in back areas.
Salving bridging material in captured areas.
Assembling a power pile driver and training crew for same.

This unit also provided a little skilled *personnel* for bridge erection, and the *personnel* for the base depôt and the office of the Army Bridging Officer. An opportunity was also taken to train certain Field Companies and the 255th Tunnelling Company in the handling of steel girder bridges, and these units dismantled the Arques High Level Bridge which consisted of one 120-ft. Hopkins, and six short spans. *Photographs* XXXVI. and XXXVII. show the construction of a 150-ft. Hopkins Bridge at Pont de Nieppe.

No features of interest occurred in the actual erection of road bridges except the building of two R.S.J. heavy pontoon bridges at Halluin and Harlebeke. These were quickly put together and proved of great value in getting heavy guns across the river before the completion of the steel bridges to take A. Loads.

The traffic across the Halluin bridge between October 23rd and November 3rd was as follows :—

Lorries	4,813
Horse Transport	1,275
Tractors and Heavy Guns	97
Steam Wagons	20
Light Cars	1,690

Some difficulty was experienced in getting certain heavy tractors and caterpillars across these bridges owing to the great width over the wheels, which is 9 ft. 6 in. in one class of tractor.

The service chesses used for decking are only 10 ft. long, and when the ribbons are fixed it is not possible to obtain anything like this clear width.

8. St. Quentin Canal. The Escaut (Scheldt) River and Canal.

Four points were selected for bridging the St. Quentin canal, but when the Fourth Army crossed it early in October, only two bridges were found necessary, as the Germans had left the other two crossings intact.

At each of the two points bridged a rectangular Inglis Bridge was first put up, and replaced as soon as possible by a 60-ft. Class A span with short R.S.J. extensions on standard piers. These two crossings were made by the 283rd and the 216th Army Troops Companies. *Photograph* XXXVIII. shows the bridges at Bellenglise. A Tank crossing was also made by the conversion of a German concrete dam into a causeway.

The Escaut (Scheldt) River and Canal, of which the St. Quentin Canal is a continuation, extended across the entire British front, and threatened to be a most serious obstacle.

On the front of the British Third Army the Escaut river flows independently of the canal, sometimes to the east and sometimes to the west of it.

The river was just passable by Infantry, but had to be bridged before guns or transport could get across.

The water in the canal was too deep for the passage of Infantry. Most of the approach roads are of necessity on a higher level than the canal itself, and the retaining banks of the canal are in many places themselves higher than the surrounding country. Under such conditions long approach ramps would generally be required, and the building of semi-permanent road bridges threatened to be a very slow process.

As the enemy was becoming more and more disorganised, the problem of enabling our advance to proceed unchecked was a highly important one. A solution was found by bridging the numerous

locks with rolled steel joist spans capable of carrying the heaviest loads.

On the Third Army front alone there were 18 locks, and this method of bridging was carried out with the greatest success. The actual erection was only a matter of hours, and it was found possible to build such bridges during the night at a comparatively short distance from the enemy. Examples are shown in *Photographs* XXXIX. and XL.

Cambrai definitely fell into our hands on October 8th, and a large amount of bridging was done by both the First and Third Armies here. Traffic conditions through the town were very difficult owing to the wholesale destruction carried out by the enemy before he evacuated it, and bridges had to be built not only over the river and canal on the west side of the town, but also over the railway. *Photograph* XLI. gives an idea of this sort of work.

Very heavy work was also entailed in the removal of *débris* of destroyed overhead railway bridges.

On the Fifth Army front the most important bridge constructed was at Tournai, where an 85-ft. Class A span was erected by the 284th and 552nd A.T. Companies. A scheme was already complete, but work only actually commenced on the 11th November. A great deal of time was occupied in the removal of the steel-work of the destroyed bridge, much of which had to be effected by means of gun cotton charges. The river runs through the centre of the town, and this involved clearing the streets and houses in the neighbourhood, and also interrupted the work of assembling new girders. The new bridge was opened to traffic on the 21st November.

On the Second Army front the Escaut river varied from 100 ft. to 120 ft in width at normal water level.

All existing bridges had been destroyed by the enemy, and in most cases the shore masonry abutments were also completely demolished.

The river was crossed on the 9th of November, and two R.S.J. heavy pontoon bridges were completed for all traffic before the Armistice was proclaimed on the 11th.

Six other semi-permanent bridges were constructed subsequently on the main routes. *Photograph* XLII. shows a typical series of R.S.J. span crossings; XLIII. and XLIV. are both 60-ft. Mark II. spans.

XLV. shows a bridge at Pecq consisting of two 30-ft. standard spans with three 10-ft. approach spans at each end. The two trestle piers in deep water are built on timber cribs, loaded and sunk.

9. THE SELLE RIVER.

With the successful attacks by the First, Third and Fourth Armies in the second week of October, the enemy fell back behind the river

Selle, where he took up a strong position on the eastern bank, having first destroyed all bridges and approaches.

This river was about 40 ft. wide and 5 ft. deep, running through open fields almost level with the banks, except in towns or villages. The western approaches generally sloped gently towards the river, and were almost everywhere overlooked by the enemy.

Under these conditions the work of Divisional Field Companies was very arduous and dangerous, but the heavy bridging, which consisted almost entirely of short spans, was of no particular interest. *Photograph* XLVI. shows a Bridge in Neuvilly, consisting of R.S.J. spans on a central pier of steel cubes.

During the period that elapsed between the crossing of the Escaut canal, and the Selle river, much work was done, especially by the Fourth Army, in the removal of bridges from back areas—work of considerable importance owing to the small reserve of stock spans that was left at the base. This Army also had to establish a new Advanced Bridging Depôt, and over 70 tons of bridging material was transported to an old German Pioneer Park at Bohain, where in addition large quantities of heavy timber were collected from the Army Forestry Depôt.

Bohain remained the Advanced Army Depôt up to Armistice day

10. Canal de la Sambre.

This was crossed by the Fourth Army in the first days of November. The advance had proceeded so rapidly and distances became so great that Army control had become very difficult. Bridging material was therefore despatched direct to Corps and left to be used by them to the best advantage.

A number of stock R.S.J. bridges were erected, but owing to the existence of locks, and the comparatively small destruction of abutments, these were all of short span and presented no difficulties. Typical examples are shown in *Photographs* XLVII. and XLVIII.

The Third Army reached the Sambre river shortly before the Armistice, but up to the 11th November only pontoon and temporary crossings had been made.

11. Conclusion.

Numerous other small streams and tributaries had to be bridged, and involved much work on the part of Corps and Army R.E.

A complete summary of the semi-permanent bridges erected during the advance is given below.

These bridges were all made to carry heavy loads of 12-ton axle load and over, and the great majority would carry from 17 to 30-ton loads. *Photographs* XLIX. and L. show examples of road bridges across main lines of railway.

LI. is a road Bridge 350 ft. long of R.S.J.'s on timber trestles at Valenciennes station.

LII. shows a bridge across the moat at Vieux Condé, and is a good example of the use of steel cube piers.

The accompanying map, which is a portion of the $\frac{1}{100000}$ Valenciennes sheet, gives an idea of the amount of bridging that had to be done. The figures on this map are the numbers allotted to the various bridges in the Engineer-in-Chief's Register.

It is not too much to say that the power of the British Army to advance depended upon the speed with which the Royal Engineers could construct bridge crossings. Railways were so completely destroyed that they were totally unable to keep within sight of the advance, whilst the steadily increasing depth of territory occupied made it equally impossible for the Roads Directorate to keep pace. Fortunately, main roads in the occupied territory were generally in good condition, and once bridge crossings were made good, lorry traffic was able to proceed unchecked.

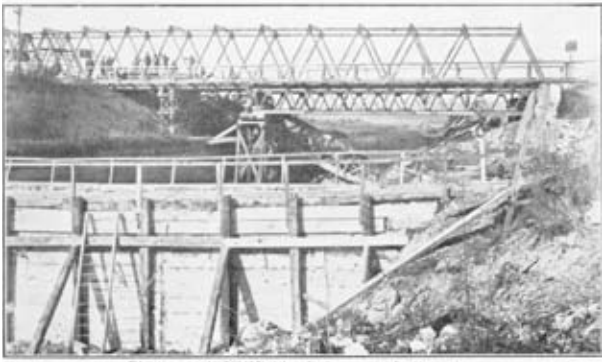
The success of the Corps in meeting all demands that were made upon it in this respect was due not only to the devotion and energy of all engaged in the work of reconstruction, but also to the less obvious but at least equally important work of organisation and training that had been done during the preceding four years.

SUMMARY OF HEAVY BRIDGES ERECTED AUGUST—NOVEMBER, 1918.

WATERWAYS.	STANDARD STEEL BRIDGES.	HEAVY TIMBER OR SALVED MATERIAL.	TOTAL.
Ancre River	14	—	14
Somme River and Tributaries	44	16	60
Scarpe River and Tributaries	28	21	49
Haute Deule Canal	7	6	13
Lys Canal, Lawe Canal, Aire—La Bassée Canal	18	9	27
Lys River	16	7	23
Canal-du-Nord	10	10	20
St. Quentin Canal, Escaut Canal and River ...	60	32	92
Selle River and Tributaries	26	21	47
Ecaillon River, Harpies River and St. George's River	13	15	28
Rhonelle River, Annelle River, &c.... ...	30	17	47
Sambre River and Tributaries	21	16	37
Miscellaneous Canals and Streams	39	43	82
	326	213	539

Photograph XXXVI.—Construction of 150-ft. Hopkins Bridge, Pont de Nieppe.

Photograph XXXVII.—Construction of 150-ft. Hopkins Bridge, Pont de Nieppe.



Photograph XXXVIII.—Bridges at Bellenglise.

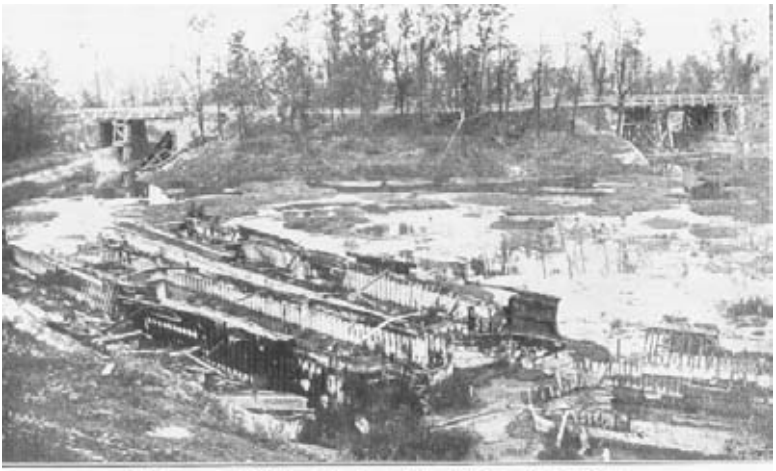
BRIDGING - PICTURE 1

Photograph XXXIX.—Bridging Locks.

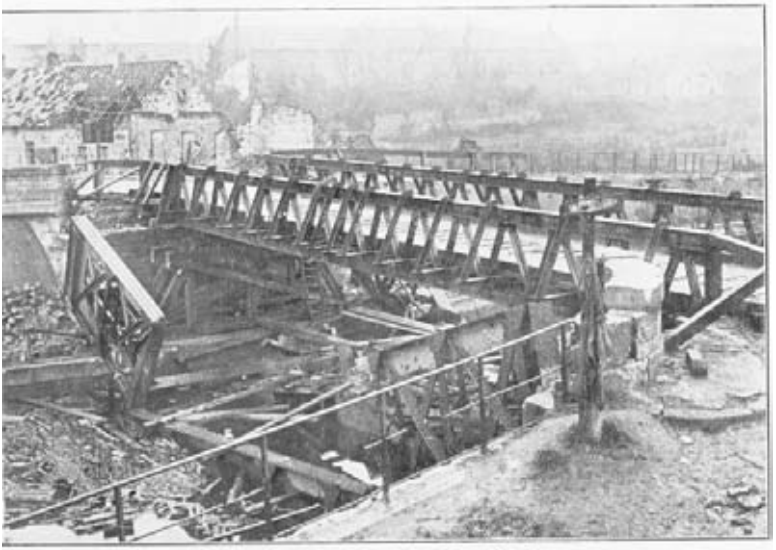
Photograph XL.—Bridging Locks.

Photograph XLI.—Cambrai.

BRIDGING - PICTURES



Photograph XLII.—Typical R.S.J. Span Crossings.



Photograph XLIII.—60-ft. Mark II. Spans.

Photograph XLIV.—60-ft. Mark II. Spans.

Photograph XLV.—Pecq Bridge.

Photograph XLVI.—Bridge at Neuvilly

Photograph XLVII.—R.S.J. Bridges at the Canal de la Sambre.

Photograph XLVIII.—R.S.J. Bridges at the Canal de la Sambre.

Photograph XLIX.—Road Bridge across Main Lines of Railway.

BRIDGING – PICTURES

Photograph L.—Road Bridge across Main Line of Railway.

Photograph LI.—R.S.J. Bridge on Timber Trestles at Valenciennes, 350 ft. long

Photograph LII.—Bridge, Vieux Conde, with Steel Cube Piers.

BRIDGING - PICTURES

FUTURE OF PERMANENT FORTIFICATION.

By Lt.-Col. J. C. MATHESON, R.E.

PERMANENT land fortification had, for a long time before the great war, become practically of academic interest only for us. Still, the existence in our army of certain technical units served as a reminder that it might fall to our lot to make closer acquaintance with examples of existing European fortresses.

During the war, however, this was not the case, except to a small extent at Antwerp. But it is necessary to bear in mind that many fortresses still exist and it behoves us not to ignore totally this branch of the military art.

In 1912, the present writer ventured to put forward* some ideas as to the direction which fortification on land was taking, based on a study of the history of the subject and the current opinion of the time in Europe.

Since then the deluge has occurred, and in all branches of war we naturally desire to take stock of our ideas and see where they need revision in the light of the flood of experience which the deluge has brought.

It will, however, be difficult to fulfil this desire satisfactorily yet as we are too near to the events which have occurred. Sufficient time has not yet been given for the digestion of reports, which concern, not only aspects of war of which we have a fair knowledge already, but also new elements which have arisen, notably war in the air.

The *R.E. Journal* has already had several articles on this subject, and as a rule the writers have dealt with it on very general lines. This would seem to be most advisable just now.

At the time of the capture of the Belgian fortresses several pronouncements appeared in the public press to the effect that the military engineer must revise completely his ideas on permanent fortification. But, as has occurred before when newspapers discuss technical matters, the knowledge displayed by the writers was very sketchy and in any case the assertion was not really justifiable.

For many years before the war numerous authorities had pointed out that fortresses like Liège and Namur would almost certainly prove to be of little use against modern attack.

* "*The Growth of the Offensive in Fortifications*," *R.E. Professional Paper*, 4th Series, No. 2.

As far back as 1887 the anonymous author of "*Les forts et la Mélinite*" advocated the vast expansion of a work of defence into what was practically what we should now term a large defended locality, and the German "*Feste*" at Metz partook largely of the same idea. They were the most recently constructed works before the war.

The French General Langlois, about 1906, said that field fortification was tending more and more to become a substitute for the old permanent fortification, for the following reasons:—

(*a*). The perfection of firearms has given to field fortification an extraordinary power of resistance, due to the fire, not to the obstacle.

(*b*). These light fortifications escape to a great extent the effects of the artillery of the attack, not because they are strongly built, but because they are so extended.

(*c*). Permanent fortifications (of the type generally understood as such) consisting of forts of high profile but of small area, can offer only a feeble resistance to large shells. The strength of resistance lies more in invisibility and in extension of numerous and relatively feeble objectives, than in the accumulation of concrete and armour. For the latter an engine of destruction will always be found which will get the better of them.

Can we not say that the results of the war have justified the above, and do we need completely to revolutionize our ideas of fortification? One would venture to reply in the negative and to plead that on general lines fortification has proceeded in the direction forecast. Naturally on general lines only. There were many things no one had foreseen, for instance, the enormous masses of artillery.

From about 1885 onwards, continental engineers were divided roughly into two schools, concentrated fortification and dispersed fortification, the former having its adherents mainly among the smaller nations. The war seems definitely to have proved that the dispersed school was right.

At first sight there would seem to be five general points which require settlement as the result of the war. Here one would confine oneself to European continental war as we have known it. Other theatres of war, other scales of warfare, will necessitate other outlooks.

I.—As time has gone on, fortresses have expanded from the compressed walled towns (of which Le Quesnoy in the theatre of this war formed such a striking example of early 17th Century work) to such enormous "entrenched camps" as Paris with its diameter of 40 or 50 kilometres. But now, is even Paris large enough to withstand modern attack? In order to defend such a place would

not the line of defence have to be so far in front of the object of defence that the perimeter will become so enormous that the garrison will eat up too large a proportion of the army? In other words has not the ring fortress practically ceased to exist and will not any future fortification become that of selected positions only?

II.—What type of work will be used in future fortification?

It would seem that General Langlois was fully justified in saying that the strength of resistance lies in invisibility and in the extension of numerous and relatively feeble objectives. The war has given us such examples of the resisting power of what may be called (for lack of a better term) trench systems, that one is forced to the conclusion that this dispersed form of fortification is the best for the present time. In other words, field and permanent fortification are practically merged.

III.—The Brialmont works of the Meuse fortresses have now been condemned and rightly so. But in doing this we must be careful not to be too sweeping in our condemnation of all use of dense material, such as concrete. The old forts of Verdun played a noble part in its defence and took many a hard knock, while the lavish use of concrete by the Germans in their trench systems showed that they, at any rate, considered that concrete could still be used profitably. The amount of punishment that these concrete shelters would stand was very noticeable.

The Meuse forts were tried too high and too many eggs were being carried in one basket. In the scheme of defence the forts loomed up far too much, in the same way as most of them, *e.g.*, Forts de Liers, Pontoise, etc., loomed up physically far too much on the ground. A gunner could hardly have asked for a better target. The Verdun forts had a much better chance, they were not asked to do too much.

It would certainly seem that concrete will still find a place in future works but not in large enclosed forts. Such would seem to have been relegated to the limbo of the past.

IV.—Within the limits specified before, how much fortification work can be undertaken in peace?

It would appear to be very doubtful if any fortification, in the narrow sense of the word which is generally employed, can be undertaken in peace time in the future. To construct and keep in repair a trench system on any selected position can hardly be considered as coming within the scheme of practical policy. Nor would it seem wise even if possible, to construct concrete shelters, deep dug-outs, or underground communications in peace. Conditions of all kinds change so quickly in these days that all the work might easily be useless.

So far as this class of work is concerned it would seem that all that can be done is to draw up the scheme and work it out in its entirety

and keep it constantly up to date. But in the larger meaning of the word fortify, to make strong, actual work can be done in the vital necessity of communications of all kinds. These conclusions have already been put forward by Brig.-General G. Walker in his article published in the *R.E. Journal*, March, 1919.

V.—The war has brought forward several new features, the chief of which is aviation. As General Walker suggests, the best anti-aircraft defence would seem to be offensive action. Some local means of protection will doubtless be necessary against aircraft, but, as regards this, the actual menace of aircraft to works on the ground, by bombing, really means that aircraft constitute a very long range artillery and, up to the present, a necessarily very inaccurate artillery. A bomb dropped from an aeroplane flying at a speed of 100 miles an hour, leaves the machine with a forward velocity of about 150 feet per second. This very soon drops off and the bomb is then practically under the influence of gravity only and exposed to the impulse of the wind. So that, under existing conditions, bomb-dropping cannot be accurate, while the case of hovering or low-flying aircraft can be dealt with by anti-aircraft guns.

Summing the matter up the conclusion would seem to be that, for European continental warfare in the future, permanant fortification is merged in field (to use the old terms) and the adjective "permanent," to denote a type of fortification, might now be dropped.

This is not to say that good defences might not still be made from existing works now considered obsolete. The garrison is always greater than its fortifications, as Verdun showed.

WATER LEVEL IN CHALK.

By COLONEL WM. PITT., C.M.G., LATE R.E.

IN the October number of the *Geographical Journal* there is an interesting paper by Capt. W. B. R. King, O.B.E., formerly Geologist to the Engineer-in-Chief, G.H.Q., France, on "Geological Work on the Western Front." In his paper, Capt. King refers to the remarkable periodical fluctuations in the level of the water table in saturated chalk and draws conclusions which, although they may be correct as regards the particular part of France to which they refer, are at variance with my own observations in England, and should not, I think, be accepted as of universal application.

What happened in many cases was that mine-galleries and dug-outs were constructed just above the water-table when at its lowest, consequently, when the periodic rise came they were flooded. A previous knowledge of this phenomenon, and of the time of year at which it occurs, would have avoided this trouble.

Capt. King gives a brief description of a typical chalk area with its valleys, mostly dry, and explains how the rainfall on the surface is absorbed into the ground and permeates the chalk until it is held up by the green sand or other impermeable stratum underneath. The lower part of the chalk thus becomes saturated with water and forms a reservoir, the surface of which is known as the "water-table." The level of this surface rises towards the hills and falls towards the valleys. It is also subject to a periodical fluctuation, being at a maximum in spring and a minimum in autumn. The explanation given is that, although there may not be much difference between the amount of the rainfall in summer and in winter, a large proportion of the former is lost by evaporation. Capt. King goes on to quote Colonel David, Geological Adviser to Controllers of Mines, 1st, 2nd, and 3rd Armies, as showing "that there is a lag of only from two to three weeks to a month between the peak of the rainfall (after correcting for evaporation and run-off) and that of the chalk water-table." What I have observed as regards this "lag" is entirely different, as I will proceed to describe, but first I will say that it seems doubtful whether there is really much loss due to evaporation and run-off.

About ten years ago an elaborate series of investigations into the subject of dew-ponds was carried out by Mr. E. A. Martin, and recorded by him in his book *Dew-Ponds*. He found that the average annual evaporation is from 17 to 18 inches, on the South Downs.

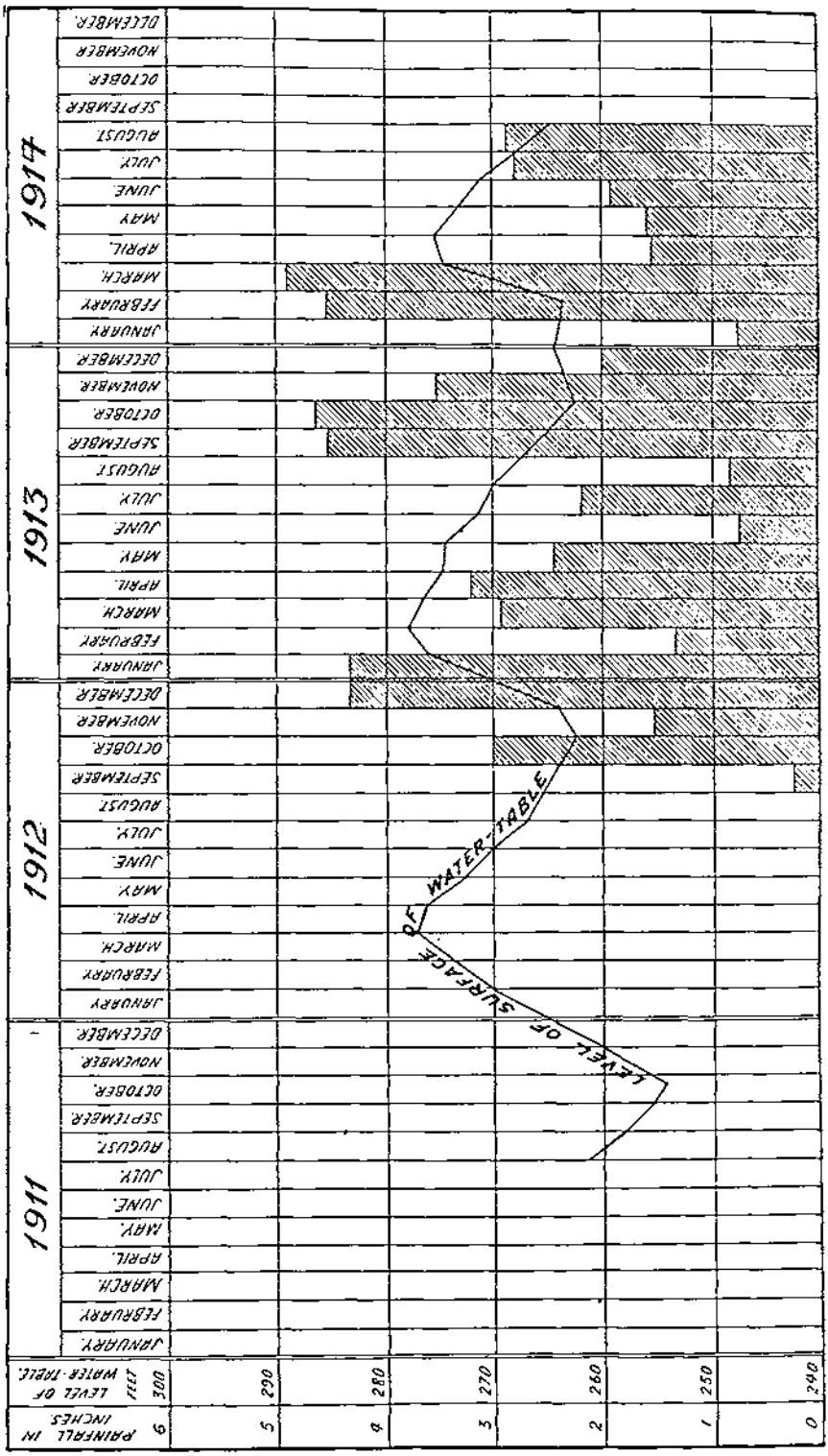


Diagram of Levels of Watertable and Rainfall at Knights Enham, Andover

But this is the loss from the surface of ponds exposed to the sun. Rain falling on the ground quickly soaks in, especially in chalk, and it is difficult to believe that the evaporation is more than a portion of the amount stated above. Then again as regards run-off. There are rarely streams to which the water can get access and so escape. If it does not soak in where it falls it does so elsewhere and consequently is not lost.

During the four and a half years immediately preceding the war I lived on the chalk near Andover. The house stood on the 300 ft. contour, and was 19 ft. above the bottom of a shallow dry valley. The water supply was derived from two wells, one at the house and the other in the stable yard which was in the bottom of the valley. The former was 54 ft. deep and the latter 36 ft.; consequently the bottom of the house well was a foot above the bottom of the other. The distance apart was about 75 yds.

My attention was attracted by the more or less regular fluctuations in the level of the water in the wells and I soon started a record, taking measurements on the 1st of each month. The result is shown plotted on the diagram (See Plate). This entirely bears out the fact noted by Capt. King that the level of the water-table is at a maximum in spring and a minimum in autumn, the curve being fairly regular.

Unfortunately it was not till a year later that I began to keep a record of the rainfall and to see if a relation could be established between the peaks of rain-fall and water-table. This was, however, done for two years and the result is given in the diagram.

Now it appears from this diagram that Colonel David's theory, that the peak of the water-table only lags from two weeks to a month behind that of the rain-fall, does not hold good, at any rate as regards the place where these records were kept. For example, there was heavy rain in September, October, and November, 1913, yet the water-table fell, and did not begin to rise again till the end of February, 1914. Again, from the beginning of April to the end of August, 1914, there was a rainfall increasing every month, yet the water-table fell steadily.

I was anxious to ascertain what the lag really was. To establish a definite law it would be necessary to extend the records over a long series of years but they were unfortunately brought to an end by my removal from the locality. I should not be surprised, however, to find that two years is nearer the mark than two weeks. Much must depend on the contour of the country. The place I have been referring to was near the foot of the slope of a chalk range which rose gradually for some three miles to a height of 700 ft. and then dropped with a steep scarp to about the same level, in half a mile, into a long deep valley in the bottom of which was a "winter bourne." Rain falling on this hill must soak down straight through it, some in

fissures and the remainder through the solid chalk at an infinitely lower rate. The only outlet on reaching saturation level is at right angles to the crest of the ridge. Consequently there is a regular gradient on the water-table surface from under the crest to the point of escape. When the periodical rise of the water-table brings it above the level of the bottom of the valley the "bournes" begin to flow. It is a peculiar feature of streams in chalk valleys, where there are any, that they are fed entirely from below, as just described.

It would be interesting to ascertain by experiment the rate at which water would percolate through solid chalk. It would then be possible to calculate how long it would take rain to get through say 400 ft. This would probably run into very large figures. I have heard it stated that some of the water now flowing in the Test in Hampshire may have fallen as far back as the reign of Charles II.

The point I wish to make is this—Capt. King stated in his paper that before fixing on the level at which to drive mine galleries in chalk the local rainfall should be studied. I do not think that this is a safe guide. It would be much better to ascertain the maximum height to which water in local wells ever rises, and keep above that.

Capt. King also deals in his paper with water supply from wells in chalk, and here he rather contradicts what he said before as he states that "The gradual falling in the water-level throughout the summer and autumn was a source of worry to some of the water-supply officers, especially when rains had no effect on the steady fall of the water, until it was shown that no rise in the water could be hoped for until late in the autumn." This entirely agrees with my diagram and knocks on the head Colonel David's theory of the two weeks lag.

The subject is a complex one and well worth further investigation. It was with great regret that I abandoned my records. I still live on a chalk hill but at a height of nearly 700 ft. above the sea, and there is not a well within miles, as it must be some 400 ft. down to the water-table. Moreover, in north-west Kent the water level has been seriously interfered with by the pumping operations of the various water companies, and measurements of the depth of the water level in wells might give misleading results.

THE BATTLE OF THE SOMME.

THE 21ST DIVISIONAL ENGINEERS IN PREPARATION AND IN THE ATTACK.

Extracts from the report of the C.R.E. 21st Division.

1. PREPARATIONS.

Communication Trenches.—During the preparatory period 6,700 yards of new trenches were constructed. Of communication trenches two, one up and one down, were prepared for each Battalion in the front line. Owing to the configuration of the ground it was not possible to arrange for all of these to start in the Bécourt Valley, and several were run from an approach trench named Aberdeen Avenue, which was doubled to allow of up and down traffic.

Where up and down trenches crossed they were taken one over the other, so that there might be no block, and in some cases this entailed a considerable amount of work. A trench named Middlesex Avenue was continued back along the whole length of Bécourt Valley to connect up with the Dressing Station dug-outs, for use as a down trench in case of heavy shelling, and a long trench was dug from Meaulte to Aberdeen Avenue, in case the valley route to Meaulte came under heavy shell fire. This trench also served gun positions about Bécourt Wood. In addition, existing trenches were deepened and improved and several abandoned trenches were reclaimed.

Assembly Trenches.—650 yards of Assembly trenches were made by blind sapping in the front area, and were reached by 950 yards of approach sap. All the spoil was got away under cover of night.

The whole system was opened up during the night of 23rd—24th June, 1916. Contrary to expectation this new trench was hardly shelled at all, and on the 1st July a party, consisting of two sections R.E., one company Pioneers, and two platoons Infantry, remained in it all day, after the Infantry had advanced, without suffering any casualties.

The Close Support and Support Lines were deepened and improved.

Communications across No Man's Land.—Blinded saps were made from two trenches, Purfleet and Dinet Street, to within about 30 yards of the German front line, and a third was commenced at the head of Balmoral Street but was not finished. It was intended that these saps should be opened up on the day of the attack to serve as communication trenches.

Gun Positions.—Material was supplied for the construction of about 80 gun emplacements. Steel segments were used until the supply failed, and after that improvisations of rails were used with complete success.

Water Supply.—380 yards of 1½-in., and 1,450 yards of 1-in. water pipe were laid in order that water might be available close behind the front line. Tanks and barrels were placed in niches in the trenches, and storage for about 4,000 gallons of water was provided in this way, in addition to that stored in petrol tins.

A certain amount of damage was done to the pipe lines during the bombardment, but the supply was kept running, and water was always available near the front trenches.

Dug-Outs were constructed for Divisional, Infantry and Artillery Brigade, and Battalion, Headquarters, for Trench Mortar units and ammunition, Regimental Aid Posts and Dressing Station, and for Reserves in Queen's Redoubt and Bécourt Valley. They were dug in chalk and at least fifteen feet of overhead cover was allowed. There was no case of any of them being broken in. In addition, small dug-outs and recesses were made for S.A.A., hand grenades, and R.E. stores.

Trench Tramways.—A 60-cm. Decauville track was laid by the R.A. from about Bellevue Farm to Bécourt Wood. This was used to bring up ammunition, and proved of the greatest value.

A mono-rail was also laid up New Aberdeen and part of Bon Accord trenches, made of 1½-in. water pipe carried on brackets. The idea originated with an officer of the R.F.A., to whom great credit is due, It was used for getting up Heavy Trench Mortar ammunition, amongst other things. A Heavy T.M. was also taken up it, the work being done in one night which took four where there was no mono-rail. More tramways would have saved much labour. Very large working parties had to be detailed nightly for carrying purposes for about ten nights before the attack.

Roads.—A metalled track, 2,000 yards in length, was made on the south of Meaulte, for use in case the village was heavily shelled.

The main Meaulte—Fricourt road was prepared for lorry traffic as far as possible, by propping up dug-outs underneath it and bridging trenches which crossed it, and a track leading forward from Bécourt was prepared for First Line Transport by bridging trenches.

Stores.—During the preparation there was a great shortage of sawn timber and joists, and to provide these poplar trees were purchased, and were sawn up by one of the Field Companies. Timber, steel rails and joists were also purchased in Amiens.

Trench Ladders and Bridges.—Large numbers of these were provided. The ladders were used to some extent, but men preferred to climb out where shells had blown in the trenches.

Only in a few cases were bridges placed by the troops across the trenches; they were mostly left lying at the bottom, but our own trenches did not appear to have presented any obstacle to the rear lines of Infantry.

2. The Attack.

1. It was decided that 21 points, chosen on the map, within the enemy's lines, should be converted into strong points when captured.

Three parties were told off for the consolidation of these strong points:—

(*a*). 2 Sections, 98th Field Company, R.E.
1 Company, 14th Northumberland Fusiliers (Pioneers).
2 Platoons, 62nd Infantry Brigade.

(*b*) 2 Sections, 97th Field Company, R.E.
1 Company, 14th Northumberland Fusiliers (Pioneers).
2 Platoons, 62nd Infantry Brigade.

(*c*). 126th Field Company, R.E.
2 Companies, 14th Northumberland Fusiliers (Pioneers).
2 Platoons, 62nd Infantry Brigade.

2 Sections, 97th Field Company, R.E., and 2 Sections, 98th Field Company, R.E., were kept in reserve, ready to reinforce the remainder of their companies if no unexpected R.E. work had to be undertaken.

Party (*a*) was kept in dug-outs in Bécourt Valley till zero. It was then moved into the assembly trench, which had been made by sapping, ready to move forward. The officer commanding the party remained at Infantry Brigade H.Q. in order to get early information of the capture of the ground to be occupied by the strong points. As already mentioned, this party remained in the trench all day without suffering any casualties, and at nightfall it was moved out to help consolidate the line gained by the Infantry.

Party (*b*) assembled in the trenches with the Infantry, being placed between the two leading and the two supporting battalions of the left Brigade. By some misunderstanding this party got entangled in the attack and were able to do very little consolidation work.

Party (*c*) was kept back till zero, when it was moved forward to Bécourt Valley and occupied the dug-outs vacated by Party (*a*). It remained there all day, and did not advance, as the ground which it was intended to consolidate had not been captured. At nightfall it moved out to help to consolidate the line gained.

The Reserve moved up into Bécourt Valley after Party (*c*), and remained there all day. At nightfall they were ordered out to make a fire trench across No Man's Land facing south, to join the original front trench line on to the captured position.

The 178th Tunnelling Company, R.E., with attached miners of the 21st Divisional Infantry and two platoons 62nd Infantry Brigade, were detailed to :—

(*a*) Make the Becordel-Fricourt road fit for lorry traffic ;

(*b*) Make a track from the Bécourt Valley to the Sunken Road, leading north from Fricourt, suitable for First Line Transport and Field Artillery ; and

(*c*) Open up the blinded saps across No Man's Land for use as communication trenches, and continue the trenches on through the German lines as far as the Sunken Road.

Work (*a*) was commenced about zero and was successfully carried on as far as our front trench, despite the fact that Fricourt was still held by the enemy.

Work on (*b*) was commenced at zero and was successfully carried on into the German defences. Great difficulty was experienced in selecting a route across the German trenches as the ground was pitted with small craters. This track was used during the night of July 2nd—3rd, by the 62nd Infantry Brigade transport for getting up rations, S.A.A., etc.

Work on (*c*) was to be commenced at zero. That on the Dinet Street sap was successfully carried through, and a communication trench was made up to the Sunken Road. The entrance to the Purfleet sap was blocked by enemy shell fire. Work was commenced on clearing this entrance, but was not continued as that part of the German trenches to which it led was not captured.

In conclusion experience showed that the R.E. should be ready to move forward as soon as ground to be consolidated has been captured. Even if work cannot be carried out before dark it is a great advantage to get to the spot whilst it is light, and to know that it is the right place and see what defences are required. Where work is possible during daylight it appears to be safer to carry it out then. The biggest casualties suffered by a Field Company of the 21st Division occurred at night in a wood, when two Sections got into an enemy Artillery barrage and could see no way to move out of it. The experience of the party employed in repairing the Fricourt Road shows what can be done in a battle during daylight with the enemy in position only two or three hundred yards away.

REVIEWS.

MIND AND METHOD IN MODERN MINOR TACTICS.

(Issued by the General Staff, July, 1919.)

The above small pamphlet, originally written by Lt.-Colonels Forster and Franklin for officers at a convalescent hospital, should be of considerable assistance in the training of company and platoon commanders, and junior officers of all arms. The difficulty of assimulating the concentrated essence of Field Service Regulations without examples is well known to us all.

This pamphlet provides many examples, and consists of a series of minor tactical problems, including map-reading and the writing of messages and orders, with a narrative and solutions, all worked out on the "allez allez" principle. It embodies the lessons learnt during the open warfare of 1918, and includes problems of the employment of the Infantry's many helpers—Artillery and Engineers, Cyclists, Machine Guns, Trench Mortars, Tanks and Aeroplanes. Stress is laid on the importance of considering human nature in all tactical situations, and the necessity for sifting evidence before forwarding reports.

A few problems on night advances would have added to the value of the pamphlet. The map is the squared $\frac{1}{20000}$ Artillery Training Map, extra copies of which can be readily obtained from the Ordnance Survey, Southampton. Altogether an admirable pamphlet, which should be of considerable use to both teachers and students of minor tactics.

E.H.K.

STRUCTURAL ENGINEERING.

By J. HUSBAND and W. HARBY. (Longmans, Green & Co.).

This is one of the best books of its kind that we have seen. Without being too bulky or detailed, it contains in readily accessible form, a great deal of valuable information. The methods of design are modern and are treated in a very thorough and practical way, and are easy to follow. Chapter I. deals with materials; Chapter II. with loads and working stresses; and includes Tables of Traffic loads on highway bridges, and equivalent distributed loads on railway bridges for varying spans. Table of Stones' "Range" formulae, etc. Chapter III. Bending moments and shearing force. Chapter IV. Beams. Chapter V. Columns and Struts. Chapter VI. gives the design in detail of a plate girder. Chapter VII. Lattice girders. Chapter VIII. Deflection, including the deflection and horizontal deflection of braced girders by the method of "Work." Chapter IX. Roofs. Chapter X. Miscellaneous, and tall buildings. Chapter XI. Masonry and masonry structures, foundations, gravity dams, arches, rigid and hinged, and tall chimneys.

H.L.L.

NOTICES OF MAGAZINES.

THE MILITÄR-WOCHENBLATT.

October, 1919.

The organization of regimental clubs, the extension of the Kriegerbund and other means of keeping touch with the members of the old army still go on. The Tugendbund of 1812 should not be forgotten. There is an interesting commentary on Lord Allenby's final Palestine despatch in No. 49.

No. 39.

The Battle of the Marne.—A disappointing article by General von Kuhl (Chief of Staff to von Kluck), which criticises the books on the battle which have appeared, but adds nothing to our knowledge, except that von der Marwitz's Cavalry Corps which opposed the British was supported by a whole infantry division, not a strong brigade, as other accounts have said.

The Entente and the Great Coalition against the Russian Soviet Republic.—This article pokes fun at our puny efforts.

Rolls of Honour.—Foot Artillery Regiment No. 18: 72 officers and 1,835 other ranks killed. Fusilier Regiment No. 35: 206 officers and 3,700 other ranks killed or died of sickness. Infantry Regiment No. 70: 96 officers and 2,198 other ranks killed.

No. 40.

Withdrawal of the East Army.—An excellent account with map of the retirement of the German troops from Russia, Rumania, Turkey, etc.

Rolls of Honour.—Infantry Regiment No. 83: 105 officers, 220 N.C.O.'s, and 1,781 other ranks killed. Foot Artillery Regiment No. 4: 69 officers and 1,548 other ranks killed.

No. 42. (41 not received).

Dissolution of the Prussian Army.—This is a proclamation issued on 30th September, on the occasion of the dissolution of the Prussian Army. It recalls its history during the past fifty years and its deeds of valour during the war, and exhorts its members to continue doing their duty in the same spirit of self-sacrifice as was demanded of them in the old Prussian army. On another page a comment on the proclamation is made to the effect that it only tends to rub in the tragedy of the defeat. "The German Michel has been completely deceived. He stuck the dagger into his own heart; no one else had the strength to deal the blow"—referring doubtless, to the home-front.

The Battle on the Marne.—A translation and criticism of an article by a French "poilu" that appeared in *The Times* of 6th September, 1919. There is nothing new in it, in fact, it is out of date and in some points incorrect, *i.e.*, when it says "Kluck withdrew the IV., V. and part of the IX. Corps" from south of the Marne to fight the battle of the Ourcq: he really withdrew the IV., II., IX. and part of the III. Corps.

New Books.—The reviewer of a book "Japan am Ende des Krieges" writes that the impression given is that Japan "is well-prepared for the inevitable settling-day with America." A book "Hetze gegen die Offiziere," by General Keim has been written as a warning to bring to notice the bad feeling that is being stirred up against officers by the Republicans (Republikanischer Führerbund).

Roll of Honour.—1st Battalion, Pioneer Regiment, No. 21: 40 officers, 100 N.C.O.'s and 1,016 pioneers killed. Bavarian Infantry Regiment No. 2: 120 officers, 284 N.C.O.'s and 2,668 men killed.

No. 43.

The Anti-Bolshevik Movement in South Russia.—An interesting account of the history of the Volunteer Army of General Denikin since its formation in the Spring of 1918, is given. It was originally under General Alexieff who, however, died in November of that year, and Denikin took over command. The advance of the Red Army on a broad front from the north in December, with no organized resistance against it, and the measures taken to counter it are described. In May, 1919, the Volunteer Army took the offensive in alliance with the Don, Kuban and Terek contingents, and supported by British supplies through Noworossisk, driving the Reds from Zarizyu, Charkow and the Crimea towards Kieff. The author thinks the Reds will never again get near South Russia if only because they are so thoroughly hated by the country-people. General Denikin, he says, desires a federative union of the Ukraine with Russia; otherwise, he has taken no part in political controversies. Neither reactionary nor Czarist he appears to be in favour of a national assembly based on equal suffrage for the future government of Russia.

Germany's Army and the Home-Front in the World-War.—This is an apologia for General Ludendorff, based on the "White Book on the Origins of the War" (Vorgeschichte des Krieges) recently published by the Ministry for War. The author says that the intention was to put the blame for the acceptance of the armistice terms on the shoulders of the German Supreme Command in the Field, but that the effect has been exactly the opposite. The spirit of the article is shown by the following paragraph: "From the details of the conferences that are published it is clear to what an extent General Ludendorff, as representative of the German Supreme Command, dominated all the other members from the Chancellor himself downwards . . . Ludendorff, like Hannibal, in spite of incomparable victories and endless devotion to his fatherland was defeated after years of war because his own nation, the home-front, deserted him. This stands out clearly from the discussions at the conference-table, by the publication of which, his short-sighted enemies have set up an honourable memorial to him."

Officers' Gratuities and Pensions.—This is a complaint on the war gratuity given to senior officers in comparison with junior officers who held temporary commands. The writer says that disabled men have, by an organized movement, managed to get an increase of 40 per cent. to their pension. This has not been extended to officers' pensions. Again, a captain who commanded a battalion in action draws a battalion-commander's pension with 1,200 marks gratuity, whilst a lieut.-colonel on the retired list with the same pension only gets 720 marks gratuity.

Roll of Honour.—Fusilier Regiment No. 34: 143 officers, 319 N.C.O.'s, and 2,133 men killed.

No. 44.

Disbandment of the Prussian General Staff.—A bitter plaint: "What a Scharnhorst created, what a Moltke and a Schlieffen perfected, is now to be smashed to pieces by the Entente. The Prussian-German General Staff, the heart and brain of the German Army exists no longer. The *victorious* enemy with a stroke of the pen has made an end of it.

Syria and Palestine.—A summary of Lord Allenby's final dispatch.

Appeal by the President of the German Kriegerbund.—General-Colonel von Heeringen calls upon all who have worn field-grey to join this organization of ex-soldiers. It is the most powerful of the clubs which keeps the military spirit alive and was particularly favoured by the ex-Kaiser.

Regimental Unions of the Old Army.—A further call to form these military organizations. Fifty-eight have already been organized.

Rolls of Honour.—Body Dragoon Regiment No. 24: 14 officers killed with the regiment, 10 whilst serving with infantry and Flying Corps. Infantry Regiment No. 30: 101 officers and 2,208 other ranks killed. Mounted Jäger Regiment No. 5: 15 officers killed, 1 missing. Reserve Dragoon Regiment No. 7: 10 officers and 123 other ranks killed.

No. 45.

Garrisons of the Future Peace Army.—The old Army had 340 garrisons, the new will probably have 120.

The Disbandment of the Old Army.—An official notice giving a list of 81 units that have been disbanded, but not a single fighting unit appears among them; there are schools, parks, garrison staffs, committees, inspection staffs; the only one of interest is the Staff College but this retains its demobilization staff.

Roll of Honour.—Foot Artillery Regiment No. 16: 56 officers and 850 other ranks killed.

No. 46.

The Landwehr Corps in the Battle of Tarnawka (Lublin), September, 1914.—This is a very full account of the battle. The corps, under General Woyrsch fought in conjunction with the Austrians.

Roll of Honour.—Fusilier Regiment No. 36: 104 officers and 2,558 other ranks killed; 16 officers missing.

No. 47.

Bolchevism and Asia.—The writer seems to hope that Bolchevism will do for the British what the rise of Mohammedism did for the Roman Empire.

France's Future Armed Strength.—France's evil conscience we are told will force her to maintain a large army.

The Demilitarized Michel.—An appeal to the German working man to wake up, and apparently take up arms again "after behaving like an elephant in a china shop."

Roll of Honour.—Field Artillery Regiment No. 15: 27 officers killed, 3 missing, 2 died, 24 N.C.O.'s and 214 men killed.

No. 48.

World Military Politics.—The usual article full of hatred of England. It quotes approvingly from von Tirpitz that England wished to continue the war until Germany was completely defeated, and, in italics, that she had been preparing and planning the war for years and nothing could prevent it.

The Manufacture of War Material in France during the War.—Extracted from *The Times*

Regimental Unions of the Old Army —The number of clubs is now 65.

Roll of Honour.—Infantry Regiment No. 46: 129 officers, 355 N.C.O.'s and 3,528 men killed; 4 officers missing.

No. 49.

Tanks.—Denies that the tanks had any success except at Cambrai and claims that the German Army was soon equipped to deal with them.

Syria and Palestine.—Some remarks by General Liman von Sanders on Lord Allenby's last Dispatch. He states that on the day of the decisive attack in Palestine, the 19th September, 1918, the total of the Turkish forces engaged, including baggage *personnel*, was under 30,000. At Aleppo 10,000 were rallied and formed in four divisions with the addition of 2,000 fresh troops. The prisoners taken could not therefore be more than 20,000, not 100,000; the other 80,000 must have been men not engaged at the front, labourers, transport, sick, etc. On the 19th September the Germans on the Palestine front were the Asiatic Corps with about 1,200 men, the German Infantry Regiment 146, with 1,600 men, and a few German and Austrain batteries. They only lost a few, mostly wounded prisoners. German prisoners almost exclusively belonged to small units such as motor columns, hospitals, intelligence, etc. As regards the 500 guns alleged to have been captured, the fighting troops on the 19th September had not anything like this number; it must be made up of old guns in the coast defences, and guns damaged and under repair. Guns had to be left behind because the horses were so weak that they could not draw them. He complains that the British had 14,000 cavalry against 1,200 Turkish horsemen, and that he lost 59 aviators because their machines were inferior to the British.

Military Jurisdiction.—A complaint, that in future the Army and Navy will be subject to military law only in war-time and on board ships of

war. This will impair discipline and militate against peace and quietness in the country.

Roll of Honour.—Guard Schutzen Battalion and its Reserve Battalion: 48 officers and 1,403 other ranks killed; 4 officers died of sickness.

No. 50.

The Entente Contest over the Unified Command in 1917.—A summary from French sources of General Nivelle's efforts to obtain undivided command.

The Theatre of War in France, 1870-1 *and* 1914-18.—This recalls places that were scenes of conflict in both wars.

Roll of Honour.—Guard Cuirassier Regiment: 15 officers killed, including two doctors.

No. 52 (51 not received).

Principles of the Re-organization of the French Army.—Summary of the report of the Commission of the French Senate. It may be recalled that it was recommended that the Engineers should not have a separate existence in peace, but be included in formations of other arms and take part in their work and manœvures.

The History of the English Tanks.—An account, taken from *The Times,* of the claims to have invented the tank.

The Fallen Aviators.—The total German casualties in the Air Force are given as:—In the Field-2,857 officers, 3,047 other ranks; in Germany—584 officers, 1,378 other ranks.

Roll of Honour.—Field Artillery Regiment No. 5: 36 officers and 340 other ranks killed.

No. 53.

The Employment of Cavalry in the World War.—An article by Lieut.-General Balck dealing with Field Marshal Earl Haig's last despatch, in which he defended the existence of cavalry. He points out that no break through was ever made and that cavalry successes were limited to modest surprises by small parties.

Field Marshal Graf Von Haeseler.—Obituary notice. This well-known peace commander died on 25th October, aged 83. In 1866 he was a captain of the General Staff of the First Army, in 1870-1 was major on the Staff of the Second Army.

J. E. EDMONDS.

REVUE MILITAIRE SUISSE.

No. 10.—*October,* 1919.

PERMANENT FORTIFICATIONS IN THE GREAT WAR.

The article on the above subject by Colonel Grosselin begun in the number of the *Revue* for July last (*vide R.E. Journal* for October, 1919, *et seq.*) is concluded in the number under notice: three sketch maps accompany the text.

It is pointed out that the German concentration, which took place in August, 1914, was based on fortified centres, as follows :—

(*a*) The left wing on Istein, Strassburg and Metz ;
(*b*) The centre on Metz and Thionville ;
(*c*) The right wing on Treves, Mayence and Cologne.

At the beginning of the campaign, it had been the intention to make Belgium a theatre of secondary importance only. The German plan was framed with the idea that Belgian territory would be rapidly traversed and that the main operations would alone commence when the French frontier was crossed : the object of these operations was to turn the French left flank and to destroy the Allied forces by crushing them in the jaws of the pincers formed by the German right wing of manœuvre and the more or less stationary troops under the Duke of Wurtemburg and the German Crown Prince in the centre. Further, the intention was that, if the fortified zones on the French eastern frontier should prove unbreachable, the French Army, having its flank turned from the westward, should be driven down to the Juras, and there annihilated.

The Germans desired to remain on the defensive between Basle and the Donon, holding the forces in front of them ; whilst between the Donon and Thionville, if circumstances permitted, they intended to push forward.

The early phases of the War are recounted : the concentration of four formidable German Armies on the Belgian frontier on the 2nd August ; the German demand for a free passage through Belgium ; the launching of the German ultimatum ; the violation of Belgian neutrality ; the German attack on Liège on the 5th August.

The firm stand made by the Belgians at *Liège* and at *Namur* completely upset the German calculations : the effect of surprise was therefore wanting in the subsequent operations conducted in Belgium and N. France by the Great General Staff ; and the discomfiture of the Germans was to be completed on the front between *Verdun* and *Belfort*. The safety of Paris not being seriously involved, the fate of France was decided within a few weeks of the commencement of hostilities and with it the issue of the war itself. Thus is explained why it was that Namur was not attacked till the 20th August, instead of on the 5th or 6th *idem*.

After the collision at Dinant, on the 14th and 15th *idem*, the Germans believed the French to be in force in Belgium, and felt that the moment had arrived to launch their great offensive. The German right wing, which had been marking time for a fortnight or so, crossed the Meuse and struck on the 19th and 20th *idem*, but the blow was aimed into a void.

Finding that neither the French nor the British forces were in Belgium the Germans fell back on their original plan. It was the resistance of the garrison of *Liège* that deprived the Germans of all that they had hoped to gain from surprise ; thus the Belgian defence at *Liège* produced consequences of immense strategical importance.

The French concentration was likewise based on permanent fortifications ; it was covered by the *defensive system on the Eastern frontier*.

Joffre acted on the defensive-offensive. Basing himself on *Belfort*, he attacked in Alsace on the day that the German onslaught was launched against *Liège*, viz.: the 5th August. His object was to relieve Nancy and at the same time to anticipate the Germans in Lorraine.

The French mobilization was at this period in full swing. Joffre's move failed tactically, but its strategic success was considerable: the Germans had to draw troops from *Metz* in order to disengage their centre Thus, it became possible to complete the French mobilization.

Joffre launched his second offensive in Alsace-Lorraine on the 14th *idem*, under Castlenau and Pau; his object was to weaken the German centre and right wing. To parry Pau's blow, the Germans based themselves on *Strassburg*.

Pau was successful, but Castlenau was obliged to yield ground at Saarburg. The strategic result aimed at was achieved, the German VI. Army was reinforced by three A.C.

Joffre now withdrew one Corps from Dubail and another from Castlenau in order to reinforce Lanrezac (5th Army) on his left wing.

Castlenau pushed again at Morhange and Sarreburg, on the 20th *idem*, but the Germans, based on *Metz*, had fresh troops and brought heavy artillery from the arsenal of this great fortress against the French. Castlenau, in consequence, retired on *Toul*, the Meurthe and the Grand Couronné; regions which Joffre had had prepared for defence in 1913.

Metz was a constant menace to the French and played a purely offensive *rôle*.

Pau and Dubail evacuated the Vosges and Upper Alsace without hesitation and, joining hands with Castlenau, saved the latter. The efforts made by Prince Rupprecht's Army to surround Castlenau's in *Toul* were gigantic.

Had the Charmes gap been pierced Chalons would have fallen and the jaws of the pincers would have closed on the French Army tightly.

Thus were the Germans drawn from their objective in Alsace, and hence they lost the initiative: they had to attack at points of Joffre's choosing.

At the date of the French offensive in Lorraine, the 14th *idem*, the German II. Army was engaged in a methodical reduction of the forts at *Liège*, whilst retaining at Louvain its contact with the Belgian Army.

The German I. Army, after crossing the Meuse, at Liège and Visé, marched towards *Antwerp*. The German III., IV. and V. Armies did little, apart from the capture of *Longwy*: they took up positions on the Ourthe and the Ardennes and entrenched themselves therein. After the reconnaissance of the 14th and 15th *idem* at Dinant, von Kluck, von Bulow and von Hausen attacked. The first named failed to cut the Belgians, who were retiring on *Antwerp*, off from that stronghold, but he occupied Brussels, detaching two of his Army Corps to mask the fortress.

It was not till the attack on *Namur* was begun on the 20th *idem* and the Germans had entered Brussels that the main French Army advanced, having on its left the British Expeditionary Force, which had then

completed its concentration under cover of *Maubeuge*, *i.e.*, a fortified centre.

The German right wing was in a precarious position, and could have been cut off at this period of the war.

The collision between the opposing forces resulted in a formidable battle, more than 300,000 men being engaged on each side. Joffre was not able to provide for a numerical superiority on his left flank. The French were ignorant of the presence of von Hausen's Army. The advantage in the encounter lay with the Germans, in spite of the fact that the situation had been mishandled by them: they therefore recommenced the enveloping movement with their right wing. The Battles of Charleroi and Mons began on the 22nd *idem*. The French 3rd and 4th Armies were at this time on the defensive, and Castlenau in retreat in Alsace.

It is possible that had the French 5th Army (Lanrezac) pivoted itself firmly on *Namur*, covering itself behind a strongly entrenched position on the Meuse, the doom of the German right wing in Belgium might have been sealed early in the war. The Allied front might under these circumstances, have crystallized on the Franco-Belgian frontier. However, Lanrezac retired on to the line Givet—Thuin.

The British troops came into contact with the Germans at Mons and Binche on the 23rd *idem*: their right was uncovered by Lanrezac's retreat, but the operations of the French 1st A.C. helped to relieve the pressure on them S. of Charleroi.

The British forces now fell back on *Maubeuge*: this retreat will be ever memorable and redound to the credit of the "Old Contemptibles" to the end of time. It was a regular race between the British and the Germans for *Maubeuge*: both sides arrived there simultaneously. The British were able to reach the line Jeulain—*Maubeuge* on the evening of the 24th *idem*.

The strategic situation was as follows on the 25th *idem*: the German Crown Prince was held up in the plains of the Woevre and in Belgian Luxemburg by Sarrail; the Duke of Wurtemburg was immobilized and surrounded by Langle de Cary (4th Army) in the Ardennes; von Bulow and von Hausen had failed to crush the French 5th Army (between the Sambre and the Meuse); von Kluck and von Bulow had failed to immobilize the British at Mons and to cut them off from *Maubeuge*; the Belgians had managed to gain *Antwerp* and were holding out there. Castlenau was in an advantageous position at Luneville.

At this date the Allied Armies had suffered less than the German Armies, which had, so far, captured two fortresses and gained much territory but had not secured a decisive victory.

The Germans had hoped to besiege the British in *Maubeuge*; but General French succeeded in retiring to the line Le Cateau—Cambrai, covered by the French fortress.

The French Territorials, under d'Amade, issuing from Arras, defeated a cavalry division of the German II. A.C. on the 25th *idem*, and thus compelled von Kluck to move this A.C. from Valenciennes on Cambrai: on the 26th *idem* two divisions of this Corps moved on Bapaume and one division alone advanced against the British at Le Cateau. General

French's left wing, which had been seriously imperilled, was in consequence saved. The British C.-in-C. had called on the Commandant of *Maubeuge* to cover the retirement of the British: the request was complied with; day and night every gun in the place was in action. The enemy, in consequence, found it impossible to set foot anywhere within about 10 miles from the centre of the fortress, and the detours he was obliged to make proved fatal to his chances of success.

The British retired from Le Cateau to the S. of the Somme. Had it not been for the *rôle* played by *Maubeuge*, the British would have been cut off from the French on the 26th *idem*, if not indeed at an earlier date.

Joffre decided to abandon Northern France and thus caused the Germans to conform to his movements: and it may be claimed that the eventual issue of the war was decided at this stage of the hostilities, since it was in accordance with Joffre's choosing that the Germans continued subsequently to act.

After the German enveloping movements had received a check at Cambrai on the 26th *idem*, the Great General Staff should have at once concentrated upon the capture of *Antwerp*: the choice lay between a siege of *Maubeuge* and that of *Antwerp*. The German II. Army was still in Belgium on the 24th *idem*; on the day following it entered Lille and on the 26th *idem*, it marched on Arras, only to march back into Belgium again later.

On the 24th *idem*, the first sortie was made from *Antwerp*, the Germans being driven back to Louvain.

The French counter-offensives in the Ardennes and the Woevre on the 24th, 26th and 27th *idem* should have left little doubt in the minds of the Germans that the French intended to make a stand on the Somme and the Oise. The Germans pushed onwards ignoring Calais, Boulogne and Havre.

On the 28th, 29th and 30th *idem*, Joffre delivered the Great Counter-attacks at Mezieres and Guise with his centre (the 4th and 5th Armies) and thus saved the French left wing from disaster.

At this period, Sarrail (3rd Army), defending the approaches of *Verdun*, held up the German Crown Prince (V. Army), which was attempting to cross the Meuse below *Verdun*. Meanwhile the garrison of *Verdun* harassed the German V. Army by the splendid sortie it made on the 30th *idem*. Only when Sarrail retired in order to conform to the general line taken up by the Allies, was the Crown Prince able to cross the Meuse.

Von Kluck continued his turning movement on the 2nd, 3rd and 4th September. Joffre now decided to abandon his defences on the Somme and Oise and withdrew to the Marne, with the intention, if need be, of retiring to the line of the Seine. It was at this time that the *Battle of Nancy* began: the formidable attack on the Grand Couronne was supported by 400 heavy pieces drawn from the Arsenal at *Metz*. However, the Couronne was strongly fortified and its defences rested on *Toul*.

On the 30th and 31st August, 350,000 Germans (eight A.C.) attacked Castlenau on the front Pont-à-Mousson to Dornbaste. Pont-à-Mousson and the Hill were taken by von Stranz; but a counter-attack by a French division, based on *Toul*, resulted in the recapture of this position.

On the 6th September several German attacks were launched, the Kaiser himself being an eye-witness. However, in view of the bad news from the West the Kaiser had to return to *Metz* instead of making his expected triumphal entry into Nancy.

On the 7th and 8th *idem*, the Germans delivered their attacks against Castlenau without success At the latter date, the issue on the Marne had already been decided. The Germans evacuated Luneville, which had been in their occupation since the 23rd August. Joffre, having confidence in Castlenau and having little doubt as to the result of the conflict in the Grand Couronne, did not consider it necessary to weaken either his centre or his left in order to strengthen his right.

Colonel Grosselin next deals with the Titanic Battle on the Marne. Joffre had drawn the enemy on to his chosen line between the *retrenched Camp of Paris* and the strong place, *Verdun* ; to achieve his purpose he had sacrificed much—rich provinces and prosperous towns.

The Germans could not have attacked Paris without first dealing a knock-out blow to the French Armies : on a single sector of the fortress alone the number of investing troops required amounted to two A.C. The strategic reserve under Manoury (the 6th Army) was held ready within the defences of Paris and the French 9th Army (Foch) had been secretly sandwiched in between the 4th and 5th Armies. The great historic Battle began on the 6th September. Von Kluck was, during its progress, obliged to turn to the N.W. in order to face Manoury ; in doing so he created a gap on the 8th and 9th *idem* between his army and that of Von Bulow. Marwitz's Cavalry was utilized for restoring the German line between these two Armies. On the 10th *idem*, von Kluck and von Bulow began to retire in consequence of Foch's victory of the preceding day at Fere Champenoise, where he defeated Von Hausen, who at once retreated northwards.

It is suggested in the original article that had the German A.C. left at *Maubeuge* (viz. VII. Reserve A.C. about 30,000 men) and the two A.C.s masking *Antwerp* (viz. III. and IX. Reserve A.C.'s about 80,000 men) been available as a strategic reserve, the issue of the Battle of the Marne might have been vastly different.

Whilst Joffre's main strategic front was between *Paris* and *Verdun*, the French 1st and 2nd Armies (Dubail and Castlenau) were manœuvring independently between *Toul* and *Belfort*. The Germans did their level best to reach *Verdun* in order to lay siege to the place, but Sarrail's Army (the 3rd), in spite of the tough time it had had, was more than a match for the Germans, under the Crown Prince and von Eichhorn, in the strong positions which it held. The Crown Prince attempted to surround Sarrail in Verdun on the 7th and 8th September and for this purpose the German III. and XVI. A.C.'s and the Bavarian I. A.C. advanced on Troyon and S. Mihiel : however, owing to the vigorous and magnificent defence put up at Troyon the German attempts were foiled. The French troops on the heights of the Upper Meuse played a most important *rôle* during the Battle of the Marne. It will ever be remembered to the credit of Sarrail that he held tenaciously on to *Verdun*—the intention of the French G.H.Q. appears to have been to abandon this stronghold.

In a recapitulation of the situation Colonel Grosselin points out that in the decisive operations ending in the Battle of the Marne, the French retirement was based upon *Belfort, Toul, Epinal* and the *Grand Couronne*: Dubail and Castlenau manœuvred between these fortified centres. *Verdun* was the pivot and *Paris* covered the left flank and limited the German movement; *Antwerp* held up 80,000 Germans; *Maubeuge* was right on the Lines of Communication of the German I. and II. Armies and caused much inconvenience in the supply arrangements, at the same time holding up the German IX. Reserve A.C. (from 30,000 to 40,000 men) and also a part of the VII. A.C., comprising special siege troops (about 60,000 men).

Finally, *Verdun* and the *forts of the Upper Meuse* covered the Allied right wing, permitting it to play an offensive *rôle*. Thus it was that 95,000 Germans were defeated by 80,000 Allies.

The "Race for the Sea" is next dealt with in the original article. The part played by the defence of *Antwerp* in connection with the operations by which the Germans attempted to establish themselves on the whole coast-line of Belgium is touched upon. It is pointed out that had it not been for the *fortress of Antwerp*, the Allies could not have made their stand on the Yser. Moreover, the whole of the Belgian Army would have been wiped out at the beginning of the War.

Colonel Grosselin draws the following conclusions from the experiences of the war:—

a. The Belgian permanent fortifications on the Meuse upset the German strategic plan.

b. By their existence alone the permanent fortifications assured the preliminary concentration of the various armies: the Meuse fortifications in the case of the Belgian Army; the defensive curtain on the Eastern frontier of France in the case of the French Army; Maubeuge in the case of the British Army.

c. The permanent fortifications held up the victorious invaders: Maubeuge saved the British forces after Mons and Cambrai; the beneficial influence of the part played by *Antwerp* and *Maubeuge* on the Battle of the Marne is incontestable.

d. Permanent fortifications form important pivots of manœuvre in connection with operations on a great scale; as for instance, *Paris, Verdun* then *Toul, Epinal* and *Belfort* in connection with the operations on the Marne.

e. Permanent fortifications constitute the bases necessary for offensive strokes: for example, as did *Belfort, Epinal* and *Toul* for the strokes against the Germans in Alsace-Lorraine; and *Metz, Strassburg* and *Cologne* against the Allies.

In the Great War, permanent fortifications by no means went into bankruptcy; they largely fulfilled the *rôle* for which they were provided; everything pivoted round them, for skill was shown in utilizing them to the best advntage.

In view of the existence of permanent fortifications on the strategic routes of Belgium, its ruler was able to insist that his country's neutrality should be respected, and eventually the independence of Belgium was thus preserved.

Punishments.

Questions affecting military discipline and punishments for breaches thereof have for some time past been much under discussion in the Swiss Army. Colonel C. Sarasin, the author of the original article, tells us that there are two schools of thought in Switzerland on the subject: the view of one of these schools is that matters affecting discipline should be taken entirely out of the hands of individual regimental officers and transferred to military tribunals, to be duly constituted for the purpose; whilst that of the other school is absolutely opposed to the institution of such tribunals, which they consider would not only be useless but positively mischievous.

Colonel Sarasin's views coincide with those of the latter school and he gives his reasons why this is the case. He points out, *inter alia*, that the right to punish men in respect of breaches of discipline is an indispensable corollary to the right to command them: the suppression of the first of these rights, would be to diminish the second right to a vanishing shadow, and, indeed, to render the right completely illusory.

Colonel Sarasin is of opinion that reforms are necessary in the matter of the methods of maintaining discipline, the nature of the punishments, etc., and he recommends reforms, some of which may be considered by some old-fashioned disciplinarians as somewhat drastic. However, having in view the general advance in education, etc., the suggestions made by Colonel Sarasin are worthy of serious consideration.

Formerly and To-day.

Major Robert Cotton, General Staff, United States Army, briefly compares the military situation in the United States of America at the period of the War of Secession with that at the date when America threw in her lot with the Entente Powers in 1917.

The *military* population of the Southern States was some 898,180 men; but the enrolled strength probably did not, in 1863, exceed from 600,000 to 700,000 men, of whom about 400,000 were fit for the field. In March, 1865, there were some 200,000 men engaged in active operations. The casualty lists of the Confederate Army are far from complete, but records show that 133,821 men were killed in action and died of wounds and of disease. The Director of the Medical Services of the Confederate Army, in a statement prepared by him, showed that one-third of the men enrolled were killed in action or died of wounds and disease, whilst another third were taken prisoners. All males in the Confederation, between 17 and 50 years of age were under an obligation to serve in the Southern Army.

During the War of Secession, the Northerners enrolled 2,320,272 men. The casualties suffered by the Federals amounted to 912,083 men; of whom 96,135 were killed in action or mortally wounded, 199,045 deserted and 183,287 died of disease.

The Northerners raised some 280 million dollars by loans for war purposes. The cost of the War of Secession to the United States of America has been computed to have reached, up to 1909, the round sum of 15,500 million dollars (approximately £3,160,000,000).

Calculated on the basis of the average of three years, the Northerners

armed and equipped 45% of their mobilizable population and the Southerners about 90%. Little public control was imposed during the War of Secession; in matters of supply individuals and families were left to their own resources.

Vastly different was the War situation in 1917. At the date of the Armistice more than 25% of the male population between 18 and 31 years of age was serving with the colours. In the short space of 19 months, the numbers in the American Army were increased 20-fold; so that on the 1st November, 1918, 1,672,000 were serving in the United States and the Colonies, whilst 1,933,000 men were with the American Expeditionary Corps. Up to the date of the cessation of hostilities in France, 11th November, 1918, the American causalties amounted to 236,117 men (of these some 2,000 only were taken prisoners by the Germans.

On the 10th October, 1918, the Americans held the maximum extent of front allotted them, almost exactly 100 miles, or about 23% of the total length of the Allied front, which was at this date 442 miles.

Before the War the American Army was costing about 100 million dollars a year, during the War the expenditure on the Army rose to 14,000 million dollars (half of this sum being in respect of pay, clothing and food supplies). The total expenses of the war borne by the United States of America amount to 23,363 million dollars. It was announced in May last by the American Treasury Department that the United States had advanced credit to the Allies amounting to 9,370,219,000 dollars; it is probable that the Allies may be released from their indebtness in respect of this sum, which may, in consequence, be added to America's War Expenditure.

Major Cotton points out that each war becomes more terrible than the one which preceded it, and yet Governments hesitate to adopt a policy that involves due preparation being made for placing their country in a position to meet war, should it unhappily break out. Nevertheless, logically there would appear to be no choice of policies in respect of such a matter.

NOTES AND NEWS.

Switzerland.—The Reports of General Wille and of the Chief of the General Staff relating to matters affecting the Swiss Army and the part it played during the War have been recently published. It is pointed out that there is much food for reflection in these Reports, which form a sound basis for the study of reforms. Regret is expressed that political matters are touched upon therein, and, in consequence, the utility of the Reports partially destroyed.

Complaint is made of the spirit of self-advertisement which is manifesting itself in certain parts of the Swiss Military Hierarchy. Regret is also expressed that the Chief of the General Staff should have thought fit to contribute an article of a political nature to the Press; such action on his part is, it is pointed out, likely to disturb the confidence of his subordinates who have no political proclivities.

Colonel Kunz, Director of Artillery Services, has sent in his resignation owing to reasons of health. In view of the extremely important *rôle*

played by artillery in the late war, the hope is expressed that a young and active officer, free from prejudices, may be appointed to the vacant post.

Interesting developments are foreshadowed in connection with the continued publication of the *Revue*. An invitation is issued to the officers of the Swiss Army to utilize the pages of the *Revue* for the discussion of questions which interest them most.

INFORMATION.

The Public and University Library of Geneva has decided to form a special section to deal with the literature relating to the Great War: volumes on every subject connected with the War will be included in the collection, which it is proposed to make.

Bulletin Bibliographique.—Short articles relating to several works of military interest and importance are published, including General de Maud'huy's *Le Manœuvre*; M. Michel's *Journal du Commandant Ragnal, Le fort de Vaux*; Colonel Bujac's *La Belgique envahie*; Colonel Thomasson's *Le revers de* 1914 *et ses causes*; and M. Edgar Milhaud's *Plus jamais*!

W. A. J. O'MEARA.

RIVISTA DI ARTIGLIERIA E GENIO.

July—August, 1919.

ON THE USE OF FIELD FORTIFICATION DURING THE RECENT WAR.

The employment of field fortification by the various armies during the recent war has followed—like every other branch of military art—a continuous evolution, corresponding to the evolution in tactics derived from the progress obtained in the methods of the offensive and defensive. Consequently, the evolution of the views shewn in the use of fortification has undergone gradually corresponding phases, the greatest in the history of war, as each year of the operations represents the synthesis of the progress derived from the experience of the preceding year.

1914.

In the first year of the war the effects of artillery fire on field works were not very powerful, and it was thought that as the simple trenches and parapets were able to resist the bombardments, so much the more the destruction of the trenches entailed too large a consumption of ammunition, of which at that time there was but a comparatively small supply in the various armies. It was also thought convenient that the strengthening of the positions should be only on a single line, as the occupation of more lines did not permit of fortifying all, and would have debarred the defenders from accumulating all the moderate available resources on a single line on which the greatest resistance would be offered.

Besides, it was considered that the reinforcement of a position should consist of a system of supporting points that would assure converging

and flanking fire over the intervals, so that each position should be effectually occupied. Such lines, constituted on a system of centres of resistance, were necessary from the impossibility of constructing long lines of trenches corresponding to the enormous fronts assumed by the armies, and which would have characterized a war of positions when it was not opportune to resort to mobile operations. The first lines, moreover, became crowded with rifles, machine guns and other means of protection, and such an accumulation of forces weakened the defence owing to the increased losses caused by the density of the occupation and the damage ensuing during counter-attacks.

On the other hand the hope of being able soon to give to the operations a decidedly offensive character had tended to prevent improvement in the dispositions of the defence.

But, subsequently, owing to the prevailing deficiency of the forces in conflict with the enemy, the troops soon became constrained to withdraw into stronger trenches in order to resist the increasing power of the artillery. So, the field operations came gradually to assume the character of a war of positions with a tendency to immovability and equilibrium.

1915.

In the second year of the war the organization of the positions comprised generally:—A line of combat reinforced by positions of recovery and guarded by lines of barbed wire, and a zone of positions of recovery behind. Such a defensive position, of little depth, was occupied by half of the forces extended in line, the other half being encamped in a zone in the rear, as far as possible defensible. Numerous approaches for reinforcements or evacuation completed the system, and sometimes from these there extended short lengths of subsidiary trenches to which the troops exposed during the periods of bombardment in the lines of combat, were able to retire.

The barbed wire was hitherto restricted to lines—owing to want of material—which could be demolished by hand (with pincers, scissors, explosive tubes, etc.).

But when the artillery fire increased in intensity, owing to the continuous increase of guns and mortars of large calibre, these single lines of defence were abandoned, since they were easily destroyed, and the penetration of the enemy by surprise attacks became facilitated. It was then thought better to apply the system of echelons in depth without, however, diminishing greatly the occupation of the first lines, which continued the defence only with the fire of rifles and machine guns, as the artillery had not then adopted the system of barrage fire.

Therefore, towards the end of 1915, there existed a system of successive trenches, up to four or five, in communication with the approaches, and furnished with barbed wire and other obstacles, and also having flanking fire by machine guns and light artillery both near and at a distance. There were generally:—A line of advanced posts; a principal line of combat of greatest resistance; a line of resistance for the supports; and a line for reserves. Such a defensive system took additional strength from natural centres of resistance (villages, woods, heights), or artificial redoubts or forts protected by barbed

wire. Sometimes in order to ensure the best resistance, two or three such masses or groups of defence were organized, adapted to the ground and of variable depth.

1916.

At the commencement of 1916, the new methods for obtaining concentration of fire by masses of artillery of great and medium calibre rendered covered trenches useless and dangerous. These, in fact, under a violent bombardment were soon reduced to ruins which crushed the defenders, and obstructed the passages. Accordingly, the preference began to be given to simple trenches, with movable planks or gratings, and to deep dug outs, small and numerous in preference to few and large, for the protection of the troops during bombardments. Such dug-outs had a depth of about three to four metres below the ground, in gravelly soil about four to six metres, in clay soil about seven to eight metres, and in moist earth with floors of cement or concrete. It was recommended to conceal all view of the trenches, the barbed wire and the parapets, and to mask the approaches and the artillery, etc., as far as possible from the enemy's fire. Barbed wire of great depth was also used, flanked by numerous machine guns, well concealed, which prevented the enemy from closing in on the ground in front.

* * *

All the principal lines of defence were about a kilometre in depth and generally consisted of three successive trenches in which were disposed the riflemen, the supports, and the reserves, at about 100—200 metres between the first and second trenches and 600—800 metres between the second and third trenches. Natural strongholds (villages, canals, woods, etc.), or artificial systems of trenches were made use of as centres of resistance. Supplementing the principal defensive lines parallel to the front, the Germans made great use of the lines of approach, traversing or diagonal to the front, as secondary lines of defence for eventual offensive on the flanks, and to form a kind of trap in which the enemy would be exposed to homicidal converging fire.

Another characteristic of the German defensive system was the great number of approaches of assault thrust forward and eventually joined in a manner to form in a short time a new trench nearer to the enemy. The Germans also arranged their lines of barbed wire in front of the first line to cover large stretches of ground, about 60—100 metres, in order to constrain the enemy to consume large quantities of ammunition for their destruction. The dug-outs were excavated with much care, and with protected approaches. They were constructed with two stories, the upper ones well ventilated serving as dwelling and sleeping places; the lower ones for a secure refuge against intense bombardment.

The masking of the works was always a matter of the greatest care with the Germans (nets, mats, boughs, etc.).

1917.

During the spring of 1917, owing to the increasing employment of great masses of artillery of every calibre, supplied copiously with ammunition, especially against the visible lines (barbed wire, trenches

and roads) it became still more necessary to locate the troops at a depth below ground, and to conceal both them and the system of defence from the view of the enemy.

From the experiences of the war made by the various armies the general organization was as follows:—A line of observation with vidette posts, or listening places; a line of resistance, without dug-outs, at from 50—100 metres from the former; a line of circulation with small shell-proof dug-outs at 20—50 metres from the preceding; a line for reinforcements at 150—200 metres from the last mentioned, with blinded and shell-proof dug-outs; finally a line for the reserves with light trenches at 200—300 metres in rear. These several lines were in communication with the approach trenches.

The trenches were usually spanned with movable planks for about two metres in width to allow of the passage of ambulances, and had traverses, of about four to seven metres in width, in places where it was otherwise impossible to obtain protection from enfilading fire. They were also provided with numerous obstructions of barbed wire, *chevaux de frises*, and other movable obstacles. The whole of the defensive system was well concealed from the enemy's observation and preserved in every particular the natural aspect of the ground.

1918.

In the last year of the war it was confirmed from long and varied experience that the defence of a position is based essentially on resistance to bombardments; on dug-outs affording protection for the men; means for action in their vicinity, invisible and invulnerable concealed works, etc.; on its own flanking fire, which especially requires numerous machine guns; and on counter-attacks. It was also confirmed by experience that in tracing the lines of defence, the scheme should be founded on the fundamental tactics for the employment of the available troops and not on pre-conceived ideas.

From a comprehensive view of the evolution of the military art during the recent war it may be seen that the details should especially be governed by the means best adapted for preserving the men, at the expense of material. Towards the end of the war of still greater importance were surprises—by means of artificial smoke, tanks, etc., in order to obtain great issues with a minimum of forces and sacrifices.

It became also of increasing importance to use new technical detachments, corresponding to the new means of offence and defence, applying to them the principle of the division of labour. Defensive tactics consisted principally in the co-ordinated employment of offensive weapons, to break up the enemy's distant attack, and to crush the waves of assault, while waiting to launch forwards the counter-attacks.

Finally, the physiognomy of the strife tended always more towards mobility, the fortifications conserved the functions of a precious shield for the protection of the defence, but always with a less rigid character, and with a tendency to occupy a zone of depth sufficient to present an elastic resistance, and to gain the time required to concentrate the greatest number of troops.

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Chateau, Farm	Ch^x, F^m
Church or Chapel, Tower	⛪, ▯
Fort	⊡
Frontier line	
Heights in metres (10 metres 32·8 feet)	
Lighthouse	✱LH

Scale $\frac{1}{100,000}$ or 1 inch to 1·58 Miles

Mile 1 0 1 2 3 4 5 6 7 8 9 10 Miles

Kilometre 1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 Kilometres

1 Centimetre to 1 Kilometre

Contour interval 10 metres; every 100 accentuated. Woods shown in green.

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" mineral or tramway	
Road 1st class, metalled, distances in kilometres	
" " " & tramway	
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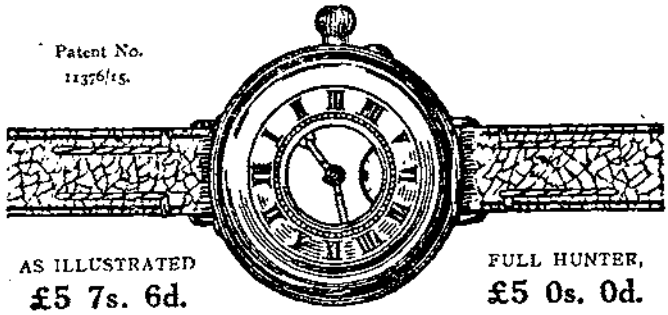

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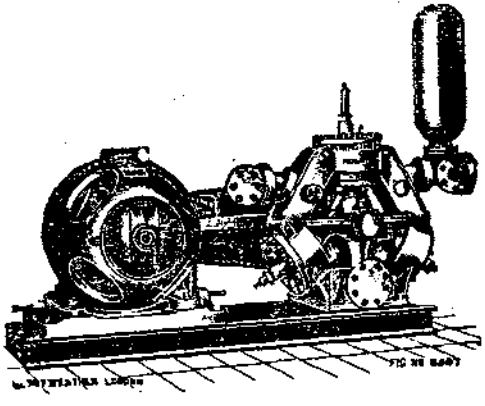

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