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All communications for the Institution should be addressed to.—
The Secretary,
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percentage of the population of a territory are so employed it is obvious that cultivation must suffer. The only advantage that can be claimed for head transport is that it can be employed without any preliminary expenditure on roads or railways.

In some parts of Africa ox-drawn vehicles can be operated fairly cheaply over rough earth roads. Where such roads exist, ox transport costs about 15 pence per ton-mile by contract, but this includes no provision for the construction and maintenance of the road. Recently a very careful estimate was made in one of our African Colonies of the capital and recurrent costs of a road constructed, operated and maintained, under purely hypothetical conditions, where freight rates would be charged to cover all recurrent charges in respect of interest, renewals, maintenance and operation of freight carrying plant on the assumption that the Government would not only provide the road, but also oxen, wagons and accessories and the necessary grazing lands, outspans, water supply, camps, etc. The total capital expenditure, including oxen, wagons, etc., was estimated to amount to £1,822 per mile. The total annual expenditure was estimated to amount to about £800 per annum, and a charge of rather over a shilling per ton-mile would be necessary to cover all outgoings on the assumption that traffic would amount to at least 40 tons per day in one direction and 10 tons per day in the opposite direction.

Motor transport is another alternative to rail transport, and light lorries—like the Ford—can be operated over unmetalled roads in the dry season. If, however, a continuous service is required, metalled roads are necessary and these will cost about £2,000 per mile to construct under fairly easy conditions where suitable stone is available and about £100 per mile per annum to maintain. By petrol operated lorry the cost of transport would be about two shillings and sixpence per ton-mile exclusive of the cost of road maintenance and interest on the money expended on its construction.

The consideration of motor transport raises, naturally, the question of the relative economy of road and rail transport, but it is exceedingly difficult to reduce all the factors affecting these two forms of transport to a comparable basis. A railway is constructed, equipped and operated by a single authority who controls and makes charges for all uses to which the railway is put. A road motor service, on the other hand, may make use of roads already constructed and used for other purposes or may construct new roads. In the latter case roads so constructed would, doubtless, be available for use by the general public. While, therefore, the total cost of operating a railway, including the cost of maintenance of way and structures, is fairly chargeable against the traffic transported, it is difficult to determine what proportion of the cost of road construction and maintenance is properly debitable to a motor service using

SOME FACTORS AFFECTING RAILWAY PROJECTS IN UNDEVELOPED TERRITORIES.

A Lecture Delivered at the S.M.E., Chatham, on 13th November, 1924, by J. W. Spiller, Esq., M.I.C.E.

The provision of cheap transport facilities is, perhaps, the most vital factor affecting the development of our Tropical possessions. Even in this country of short distances we realise the extent to which the cost of transportation affects the price of all commodities, but consider for a moment how much greater is the necessity for cheap transport in those undeveloped countries of vast distances within the British Empire if the interiors of those countries are to be opened to trade and their products placed on the world's markets at a reasonable price. It has been said that "Trade follows the Flag," but it would, perhaps, be more correct to say that "Trade follows the Rail," for trade can only prosper where economical forms of transport exist.

It is my privilege to talk to you to-night about some of the factors affecting railway projects which require consideration before the construction of a railway can be justified. I want you to assume that someone has suggested that a railway should be built through some particular territory and that we have been asked to report upon the proposal. We will then consider, step by step, the procedure which should be followed and the matters which must be brought under consideration to enable us to deal in an intelligent manner with all questions which may affect the cost and ultimate prosperity of the proposed railway. For the development of long-distance communications a railway naturally suggests itself as the most suitable method, but railways are costly to construct, and it is necessary in the first place to consider what alternative means of transport are available. The most primitive form of transport, one which has been employed in Tropical Africa for countless generations, is the head load. A native porter can carry on his head a load of 56 lbs. over a distance of 15 miles in a day. If he is paid a shilling a day for the forward journey and sixpence a day for the return journey light, it will be found that the cost per ton-mile amounts to four shillings. This is clearly a costly form of transport. Further, it is slow, it involves breaking bulk, it exposes the goods to risk of loss by theft or damage from the weather and it is wasteful of man power. Men employed as porters are performing duties of an unproductive character, and if a large such roads in conjunction with other users. A railway involves heavy constructional cost and requires special equipment. The interest on capital invested is, therefore, considerable, but the operating expenses are low. A motor road, on the other hand, does not involve such costly construction and equipment charges, but the operating expenses are higher. A railway service will, then, be more economical than a motor road service if the amount of traffic to be transported is sufficient to make the saving on operating expenses justify the cost of its special construction and equipment. There is, in fact, a certain critical volume of traffic, the transport of which can be performed with equal economy by a rail service or a road service; for a greater volume a railway, and for a smaller volume a road service, would prove the more economical. It will be seen, then, that the question as to the relative economy of these two different forms of transport really involves a comparison between the critical volume of traffic and the amount which is likely to be offered, and before a decision can be reached as to which form of transport should be adopted it is necessary to estimate the volume of traffic which is likely to make use of such transportation facilities as may be provided.

In connection with the consideration of motor transport, it should never be overlooked that the tractive resistance of a steel wheel on a steel rail is about 8 to 10 lbs. per ton, while the tractive resistance of vehicles on macadam roads is about 75 lbs. per ton for roads of good surface and about 100 lbs. per ton for roads of inferior surface, a difference of 10 to 1 in favour of rail transport. This fundamental difference will always militate against cheap motor transport. In England to-day, in spite of the heavy cost of wages and materials, the total freight of the country is being handled on the railways—excluding the cost of collection and delivery—at an average cost of 1.37 pence per ton-mile. Motor transport can never hope to compete with such a figure. In Nigeria an extensive service of motors is operated by the Railway department as feeders to the railway. In 1923, 21 motors ran a total van mileage of 121,952 miles at a cost of 21 pence per ton-mile exclusive of the cost of depreciation of plant and interest and maintenance charges on the roads used. The services made use of roads having a mileage of 172 miles. If the roads cost £2,000 per mile to construct and £100 per mile to maintain yearly, and if we assume that interest charges on one-half the cost of construction and also half the cost of yearly maintenance were debitable to the motor service, the cost of operating the motor service would amount to 43½ pence per ton-mile, and this figure includes no provision for depreciation. The average receipts per ton-mile on the railway only amounted to 2.29 pence and the railway was operated at a considerable profit.

It will be seen, then, that while transport by head load involves no preliminary expenditure, it is slow, inconvenient, wasteful of man power and costly. Where oxen are available transport by ox wagons is cheaper than head loads, but is slow and likely to prove unreliable on earth roads in the wet season. Motors are quicker and more reliable than ox wagons, but require metalled roads which are costly to construct while a motor service is expensive to operate. Railways, while more costly to construct than metalled roads, can be operated more cheaply than motor transport if the volume of traffic is considerable. Before the building of a railway can be justified it is necessary, therefore, to make an estimate of the volume of traffic which is likely to be offered, and this involves an economic survey of the area to be served.

PRELIMINARY EXAMINATION OF AREA TO BE SERVED.

A close estimate of the cost of building a railway cannot be prepared until a detailed survey has been made, and this involves time and money. In order to determine if the cost of a detailed survey can be justified, it is necessary to make a preliminary examination of the area to be served, and as the result of such examination, to prepare approximate estimates of the cost of construction, equipment and probable working results. It may appear to incline to optimism to hope to make even an approximate estimate of the cost of building a railway until the detailed survey has been completed, but in the case of a pioneer railway the cost of materials and freight will amount to about one-half of the total cost of construction, and this portion of the expenditure can be estimated with considerable exactitude. Of the work in the field the quantity of earthworks is the most difficult item to estimate, but the cost of earthworks in moderately easy country does not usually exceed 15 per cent. of the total cost. An experienced engineer, after he has travelled through the country between the terminal points as close to the proposed route as may be possible, should be able to estimate, from his knowledge of what other lines built through similar country have cost, within a margin of 10 per cent. It is, however, more difficult to estimate the probable revenue.

Before commencing his investigations, the engineer should obtain all maps and statistics relating to the area and should collect all possible information from those who have knowledge of the country, such as, in a British Colony, the Director of Agriculture, the Director of Forests, Political Officers, etc. Such information as he may be able to obtain should not be accepted as correct, but should be verified by actual investigation. His investigations should be directed to obtaining information on the following matters:—

to travelling by train, and passenger receipts may be expected to be not less than 20 to 25 per cent. of the revenue from goods traffic. There will also be further revenue from the carriage of mails, parcels and miscellaneous receipts.

The locomotives and rolling stock necessary to equip the line can be determined when the probable volume of traffic has been estimated. Where the traffic is seasonable and not equally distributed throughout the year, the number of locomotives and vehicles must be based on the most intense period plus an allowance of 20 per cent. for locomotives and 10 per cent. for carriages and wagons to provide a margin for vehicles out of commission while under repair. Additional engines will also be required for shunting purposes.

The operating expenses will depend mainly—but not entirely—on the volume of traffic and are usually based on the actual cost of operating similar railways, but modified as may be necessary if the cost of labour, coal, etc., is materially different. The estimate of operating expenses should be divided under the following main heads :—

(*a*) Maintenance and renewal of permanent way.

(*b*) Maintenance and renewal of locomotives and rolling stock.

(*c*) Locomotive running expenses.

(*d*) Traffic expenses.

(*e*) Management and general charges.

If the amount by which the gross revenue exceeds the working expenses is capitalised the justifiable expenditure, viewed from the economic standpoint only, on the proposed railway is obtained.

While a commercial company who builds a railway will expect to make a profit sufficient to pay a fair return on its outlay, a Government or State may consider it is justified in constructing a line, even though the likelihood of its paying its way is remote. It may be desirable for strategic reasons, or by opening up new country it may improve trading facilities from which the State may benefit indirectly, which may justify a loss on working. A concrete example will be quoted of a British Colony increasing its revenue indirectly, as well as directly, from railway extensions. Railway construction in the Gold Coast was commenced in 1898 and in that year cocoa exports amounted to 185 tons. By 1921, 276 miles were open for traffic, and in that year cocoa exports amounted to 133,195 tons, of which 109,114 tons were brought to the coast by railway. The export dues collected by the Colony on cocoa during the six years 1916 to 1921 amounted to nearly two million pounds or one-third of the total capital cost of the railway. Without the means of transport provided by the railway the bulk of the cocoa exports could not have been marketed at a profit.

(*a*) Area and chief physical features of country to be served.
(*b*) Monthly rainfall.
(*c*) Names, situation and population of chief towns, villages, markets, etc.
(*d*) Fertility of soil and area suitable for cultivation.
(*e*) Chief industries and where situated.
(*f*) Situation of mines and yearly output.
(*g*) Situation and approximate area of forests and proportion of marketable timber.
(*h*) Acreages of principal estates, proportion of area cultivated, tonnage of produce and where it will be placed on railway.
(*j*) Probable increase of production if railway is built.
(*k*) Present means of transport, cost and saving anticipated if railway is constructed.
(*l*) Amount of vehicular traffic on existing roads and number of licensed vehicles in district.
(*m*) The topography and geology of country along line of proposed railway.
(*n*) Any factors that may materially affect the cost of construction, such as necessity for tunnels, bridging, rock cuttings, etc.

The various estates should be tabulated with particulars of acreage under cultivation, commodity produced, estimated production per acre, tonnage available for export and length of haul. The production per acre of different crops will vary materially according to the fertility of the soil and the ability of the farmer. Estates supervised by Europeans will produce more per acre than native cultivations. The following figures give an indication of the probable yield of certain Tropical crops :—

Seed Cotton	300-600 lbs.	per	acre.
Lint Cotton	100-200 lbs.	,,	,,
Maize	1 ton	,,	,,
Tobacco	4 cwts.	,,	,,
Sugar Canes	20 tons	,,	,,
Sugar	$1\frac{3}{4}$ to $2\frac{1}{2}$ tons	,,	,,
Molasses	80 gallons	,,	,,
Rum	27 ,,	,,	,,
Cured Cacao Beans	5 to 6 cwts.	,,	,,
Cocoanuts	2 tons	,,	,,
Copra	1000-1300 lbs.	,,	,,

The "Inwards" tonnage of each estate with respect to food supplies, fertilisers, plant, etc., should be ascertained. The output of mines, forests, etc., must also be estimated and the probable traffic therefrom determined. The receipts from passenger traffic will depend largely on the density and earning powers of the population. Experience shows that the African native takes readily

Again, it should be remembered that a branch line, which may itself be operated at a loss, may bring such additional traffic to the main line that the net gain to the main line may exceed the loss on the branch.

The information obtained in the preliminary examination must be embodied in a report with the estimates already referred to. It should be accompanied by a small scale map showing the approximate route of the proposed railway, the ruling points, existing roads and paths, chief towns, etc., and we will assume that the report is sufficiently encouraging to justify the comparatively small cost of making a detailed survey, but before the survey can be commenced it is necessary to determine the economic values of the major and minor details of railway location.

Major Details of Railway Location.

The two factors which affect to the greatest extent the cost of construction in the field are the ruling gradient and the radius of the sharpest permissible curve. It is clear that if there is no limit to the gradients and curves that may be employed the cost of earthworks can be reduced to a small amount. There is, of course, a limit to the grade which it is possible for an adhesion locomotive to climb even though it is hauling no load; on a steeper grade the wheels will slip. A gradient of 1 in 25 is generally regarded as about the steepest gradient which ordinary adhesion locomotives can operate successfully, but examples can be quoted of even steeper grades. On two Colonial railways of 2-ft. 6-in. gauge gradients of 1 in 23 have existed for many years, while on the Guagaquil and Quito railway of 3-ft. 6-in. gauge there is a continuous 49-mile grade averaging over 4 per cent. with many long stretches of 5½ per cent. It is, of course, only in mountainous countries that such grades can be justified, and in average country it is generally possible to obtain much easier grades without excessive earthworks.

Ruling Grade.—The ruling grade is so called because it is the gradient which limits the number of wagons per train, and it is not necessarily the steepest gradient on the profile. One of the objects which should be aimed at when laying out the line is to make the demand on the locomotive as nearly uniform as possible under normal operating conditions. If, at a certain point, the velocity of the trains has to be increased, as when starting from a station, in addition to overcoming the normal grade and rolling resistances, the gradient is in effect increased at that point. If at another point velocity can be acquired before reaching it and then surrendered, the grade is in effect reduced. There is little objection, therefore, to a short steep ascending gradient following a descending grade and such short steep gradient would not be the ruling gradient, although possibly the steepest gradient on the section. If a locomotive is increasing the speed of its train it is in effect overcoming the train resistance of a level track, the grade resistance of whatever gradient it may be on and that of a grade equivalent in effect to the acceleration resistance. It is then exerting the total effort for a grade equal to the actual grade plus the grade of acceleration. Such a grade is called the "virtual grade" because the locomotive is said to be doing the work corresponding to uniform speed on such a grade. A "velocity" profile for any proposed railway can be drawn when the grade profile is known by calculating the probable speeds at a sufficient number of points and plotting them as ordinates and connecting their tops. It is the velocity profile which must be studied in connection with locomotive work and in the design of gradients, for the gradient of the track may be virtually steeper or less steep than its nominal rate. The steeper the ruling gradient adopted the less the cost of construction, but the greater the cost of operation, and considerable skill is required to select that gradient which will ultimately prove the most economical having regard to interest charges on the cost of construction and the cost of operation.

On the level, train resistance at constant velocity is due to journal friction, rolling friction, air resistance, imperfections of the permanent way, etc., and varies considerably for different speeds. At starting it may amount to as much as 18 lbs. per ton, but rapidly drops to perhaps 10 lbs. per ton at a speed of one mile per hour; it drops still further—but less rapidly—to a minimum which occurs at a speed of about eight miles per hour. It then rises gradually and, at high speeds, may reach the resistance at starting. It can be assumed that, with modern rolling stock on pioneer railways, train resistance amounts to from 8 to 10 lbs. per ton at ordinary freight train speeds. On gradients there is the further resistance of gravity, and since the total resistance on gradients is made up of two factors, one of which does not vary with the gradient, the train loads on gradients do not vary directly with the slope.

A resistance of 18 lbs. at starting on the level is equivalent to a virtual gradient of 1 in 125, and since a locomotive must be competent to overcome this resistance, it would appear that there is no advantage gained in securing a flatter ruling gradient. It must, however, be remembered that freight trains usually have slack couplings and the wagons, in consequence, start one at a time. The locomotive has, therefore, attained some speed when it receives its full load and train resistance has fallen materially. It does not appear, however, to be worth while spending money to obtain ruling gradients flatter than 1 in 250, and we can assume that our ruling gradient should be somewhere between the extreme limits of 1 in 25 and 1 in 250.

Where the volume of traffic is considerable an appreciable reduc-dúction in the ruling grade may permit a reduction in the number of trains necessary to handle that traffic with a corresponding saving in operating costs depending upon the number of train-miles saved. At the present time the cost of running freight trains on Colonial railways amounts to about twelve shillings per train-mile, but it will be realised that not all the items which make up train-mile costs are affected by a reduction in train mileage. No change in the salaries of general officers, cost of advertising, etc., can be anticipated from any small change in the number of trains. Again, a considerable portion of the cost of maintenance of way is due to weeding, trimming banks, cleaning drains and culverts, painting bridges, etc., which are quite independent of train mileage. Further, any small alteration in the number of trains is not likely to affect the number of station staff, signalmen, etc. On the other hand, the cost of trainmen's wages, fuel, maintenance and renewals of locomotives, etc., will vary almost directly with train mileage. The actual percentage of train-mile costs saved by a small reduction in train mileage will vary on different railways, but will generally be between 40 and 50 per cent. If we assume the saving is 40 per cent. and a train each way is saved per week the total annual saving will amount to $\frac{2 \times 40}{100}$ of 12 shillings x 52 = £25 per mile of track. If we can borrow money at 5 per cent. we are justified in spending an average sum per mile of £500 in order to effect a reduction in the ruling gradient which will have the result of saving one train per week in each direction. This figure is somewhat on the full side since, if the number of trains is decreased by increasing their weight, the cost of running the heavier trains will be higher, but the correction necessary on this account will be small. This example serves to show the importance of correctly choosing the ruling grade. It will be seen, then, that steep grades can be justified where the traffic is light, but where a heavy traffic may be anticipated the saving on train working will justify a considerable expenditure to obtain low ruling grades.

Balance of Grades for Unequal Traffic.—If the movement of traffic is likely to be permanently heavier in one direction than in the other the ruling grade opposed to the lighter traffic may be made heavier than that in the opposite direction on the assumption that a portion of the wagons will be unloaded in one direction. For pioneer railways ruling grades of 1 in 100 against the heavier traffic—usually exports—and 1 in 80 against the lighter traffic—usually imports—are common.

DEGREE OF MAXIMUM CURVATURE.

Just as there is a limit to the gradient which a locomotive will ascend, so also is there a certain limit of curvature which a locomotive can traverse depending principally on the length of its fixed wheel base. While gradients limit train loads it would be quite exceptional to find it necessary to introduce a curve in any alignment which would have the effect of limiting train loads. Even locomotives with eight coupled wheels can traverse curves of very short radius provided some of the driving wheels have thin or blind flanges and the gauge is slightly eased. On the hill railways in Ceylon of 5-ft. 6-in. gauge many curves of five chains radius exist, and although such curves limit speed and increase the cost of maintenance it cannot be said that they limit train loads provided the gradients are adequately compensated for curvature. It can be assumed that under ordinary topographical conditions the necessity will rarely, if ever, arise of introducing curves which are likely to limit train loads or prevent the use of engines of normal design.

MINOR DETAILS OF RAILWAY LOCATION.

The minor details of railway location are :—

Distance.
Rise and fall.
Curvature.

Distance.—It is obvious that the shorter the line the less will be the cost of operation, other things being equal, and additional expenditure on construction is justifiable in order to secure a shorter route. Distance affects fuel costs, maintenance of way costs, wear and tear on rolling stock, etc., and, if the distance saved is considerable, may affect train wages. Wellington, in his book on "The Economic Theory of Railway Location," estimated that for small changes in length about 40 per cent. of the total cost per train-mile was affected—assuming a saving in train wages—and about 25 per cent. if train wages were not affected. For greater changes in length he estimated the corresponding percentages would be about 50 per cent. and 36 per cent. respectively. In Nigeria, before the war, location engineers assumed that a saving in length of line would result in a saving per annum per daily train in each direction of £80 per mile for distances affecting wages of train men. Train-mile costs were then about six shillings; they are now twelve shillings, so the above figure should at the present time be increased by 100 per cent.

Rise and Fall.—Gradients affect train running costs in two distinct ways; in the first place the ruling grade, by limiting the number of wagons per train, increases the cost of operating the entire line, while in the second place there is the direct cost for wear and tear and fuel of ascending to and descending from any given elevation, instead of running on the level; in other words, the cost of rise and fall. While the latter objection to gradients is less important than the former, it requires consideration.

Rise and fall is the rise in feet on an ascending grade and the corresponding fall on some descending gradient. Between any two stations the amount of rise and fall is obtained by adding half the sum of the rises to half the sum of the falls. This is not strictly correct for a journey in one direction only, if the stations are at different elevations, but most calculations in which this quantity is used are based on trains running the round trip, and in these circumstances the rule is satisfactory. Rise and fall can be divided into three classes:—

A. Not requiring the shutting off of steam nor use of brakes.

B. Requiring the shutting off of steam at the head of the grade, but not the use of brakes.

C. Requiring the use of brakes in the descent.

Class A does not affect operating costs to any material extent, but since the speed of descent must be greater than the speed of ascent, the wear and tear on rolling stock and permanent way will be increased slightly.

Class B.—The steam used to run an engine any distance will be about the same whether the work is uniform for the whole run or is all done during the first portion in taking the engine up an easy grade from which it descends by gravity over the second portion, but while steam is shut off there will be wastage of fuel by radiation and slow combustion. Further, additional fuel will be used on the ascent since economy of fuel consumption decreases as work of engine increases.

Class C.—The use of brakes in class C materially adds to the wear and tear of rolling stock.

In Nigeria before the war it was estimated that the elimination of one foot of rise and fall would result in the following savings per annum per daily train in each direction:—

Class B.—	5s.	on minor grades.
	9s. 6d.	on ruling grades.
,, *C*.—	10s. 6d.	on minor grades.
	14s.	on ruling grades.

These figures are for a line of 3-ft. 6-in. gauge.

Curvature.—Train resistance is increased by curvature, which also adds materially to the wear and tear on rolling stock, and permanent way. Wellington estimated that in America the addition to operating costs per degree of curvature amounted to .0593 of the cost per train mile. In Nigeria, before the war, it was estimated that the elimination of one degree of curvature would result in an annual saving per daily train in each direction of two shillings on an uncompensated road and 1s. 8d. on a compensated road. It is usual to compensate for curve resistance by reducing the grade on all grades where the combination of curve resistance and grade resistance would more than equal the grade resistance of the ruling grade. A usual allowance is 0.03 ft. per 100 ft. per degree of central angle; this is equivalent to assuming that curve resistance is equal to 0.67 lbs. per ton per degree.

It will be seen that just as there is a certain cost of operating each train-mile of distance, so there is a certain cost of operating each train-foot of rise and fall and each train-degree of curvature. The amounts will vary in different countries, but the locating engineer must estimate their value in order to be able to compare alternative routes when engaged on the survey.

SURVEY AND LOCATION.

The type of country which presents the greatest obstacles to railway location is that covered with dense jungle. Let us assume that our hypothetical railway has to be taken through such country. How should the survey be conducted in order to ensure a satisfactory location?

It should be remembered that railway location is really "the collection of data to permit the designing of an economical plant to handle a certain volume of traffic." Further, between the two terminal points there may be any number of alternative routes which may comply with the prescribed conditions regarding ruling grade and maximum curvature, but varying as to cost, distance, rise and fall and curvature. One of those many routes is the best, and it is the object of the survey to find that best route. Experience in jungle countries shows that the following separate surveys are necessary :—

(*a*) Reconnaissance of route.
(*b*) Preliminary survey.
(*c*) Trial survey.
(*d*) Permanent survey.

Following the preliminary survey, a preliminary location is made on which the trial survey is based, while the final location is based upon the permanent survey.

Reconnaissance of Route.—The reconnaissance is really an exploration of the country between the controlling points, and usually the exploration of more than one route is necessary. It involves the examination of as wide an area as possible along all promising routes and the elimination of as many of these routes as possible. The natural drainage lines of the country generally point the way to the best line. Precision is not required and distance can be determined by pacing, direction by a pocket compass, and heights by an aneroid. Notes should be made of all mountain ranges, hills, rivers, geological formation, vegetation, hardwoods, softwoods, towns and villages, mines and plantations, the fertility or otherwise of the country, the density of the jungle, points for collection of traffic, etc. The information obtained on the reconnaissance should be embodied on a small scale map and report.

Preliminary Survey.—The preliminary survey is run over routes considered acceptable under the reconnaissance survey and serves to eliminate the unsuitable and to determine the possibility of constructing a line over a selected route. More precision is necessary than is possible on the reconnaissance, but a detailed topographical survey is not required.

A width of 150-ft. or so on each side of the centre line should be surveyed along the most rational location and notes recorded of all suitable alternative lines which should be further examined on the trial survey. It should be made with a prismatic compass and chain and levels should be taken every 100-ft. with a dumpy level. On ground sloping transversely clinometer cross sections should be taken to assist in plotting a contoured plan on which to project the location. The preliminary survey should define an "area of economic location" without attempting to obtain the best available location in detail. It should be plotted to a scale of 20 chains to one inch and a working plan of four chains to the inch should also be made. A longitudinal section should also be plotted from the levels taken, to a horizontal scale of four chains and a vertical scale of 20-ft. to one inch.

Preliminary Location.—When plotted the preliminary survey enables alternative locations to be compared, first with regard to probable traffic, second with regard to ruling grade, and last with regard to the minor details of distance, rise and fall and curvature. The projection should commence at terminal and other ruling points and be sketched in tentatively at first. Two or three alternative projections should be tried and carefully studied, and their examination will indicate the approximate position of the best route on which the trial survey should be based.

Trial Survey.—On the trial survey all alternative lines should be examined and the topography elaborated to permit of the projection of the most economical line. Longitudinal sections should be taken along the centre lines of roads, tracks, water courses, etc., which are within five chains of the centre line. Major details will have been determined before the trial survey is commenced, but every possible route should be compared from the point of view of minor details. While the preliminary survey determines the "area of economic location" the trial survey is run with the object of selecting the best route in that area. Careful notes should be made of the annual and highest flood levels of all rivers and information obtained to enable an accurate estimate of the cost of construction to be made, *e.g.*, materials available for use in construction such as timber, gravel, sand, stone, etc., sites for brickfields, camps, etc., means and cost of transport, probable average cost of jungle clearing, nature of ground to determine the rate of earthwork, etc.

Permanent Survey.—On the permanent survey a strip of country lying within a distance of 300-ft. on each side of the centre line should be completely surveyed in such detail as to be suitable for plotting to a scale of four chains to one inch. Cross sections for 100-ft. on each side of the centre line should be taken at every 100-ft. and plotted to a natural scale of 20-ft. to one inch. From these cross sections accurate contour lines should be plotted on the survey. In addition, longitudinal and cross sections should be taken of all rivers crossed by the railway. Not less than three cross sections are necessary, one where the centre line crosses the river and one 100-ft. up stream and another 100-ft. down stream. A complete survey of each river requiring a waterway of over 200-lin.-ft. should be made within a distance of half-a-mile on each side of the centre line and cross sections should be taken. Borings or trial pits should be sunk to determine the nature of soil in cuttings and the probable depth and character of foundations.

Final Location.—The final projection is made on the permanent survey, from which it is set out with theodolite on the ground.

It will be seen, then, that the reconnaissance is really an exploration of the country and serves to determine that one or more routes are possible. On the preliminary survey these routes are examined in some detail, the least suitable routes are eliminated and an "area of economic location" is established. The trial survey enables the most suitable line within the "area of economic location" to be determined and provides the material for making an accurate estimate of cost, while from the permanent survey the centre line is set out and the railway is built.

It may not generally be conceded that four separate surveys are necessary to establish the route of a railway, and the outline I have given you of how the survey work should be conducted may be regarded by some people as a policy of perfection. The description I have given you is applicable to jungle country. In more open country of easy character the preliminary and the trial or the trial and the permanent survey may be combined into a single survey. It should, however, be remembered that a serious error in major details cannot afterwards be rectified except at great cost and may seriously affect the ultimate efficiency of the railway. It has occurred too often in the past that insufficient time and money have been allowed for the survey although every additional pound spent on the survey might quite conceivably have saved £5 in the cost of construction. More money can be saved by careful survey than can ever subsequently be saved by the most efficient carrying out of the work of construction.

With the completion of the permanent survey the final estimate of cost can be made, but before we consider the question of estimating I want to say something with regard to the choice of gauge.

SELECTION OF GAUGE.

If a railway exists to which the proposed railway may some day connect, the gauge of the new railway should be the same as the existing line, even though the prospects of connection are exceedingly remote. Cases have occurred in the past where the construction of a railway has commenced which it was thought would never be extended to such an extent as to permit connection with existing lines located many miles away, but both lines have subsequently been extended towards each other, and, in course of time, the possibility of actual connection becomes a practical proposition. It is necessary, therefore, to take a wide view and to bring under consideration the gauges of all railways with which the possibility of connecting to is not a physical impossibility.

Some of the evils of break of gauge, such as the actual cost of transshipment, the delay involved thereby and the loss due to breakage and pilfering, are obvious, but there are even greater objections which are less apparent, such as the detention to rolling stock necessitating a larger reserve of stock and the impossibility of pooling the stock of the two systems, when an unusually large amount of traffic is offered on one of the systems. If, however, a line is projected in a territory where connection to another line is considered to be impossible, it is necessary to determine with great care the gauge which is likely to prove the most appropriate. Railway gauges can be conveniently divided into three groups :—

(*a*) Narrow gauge with width between rails of 2-ft. 6-in. and under.

(*b*) Broad gauge with width between rails of 4-ft. 8½-in. and over.

(*c*) Medium gauge with gauges between the limits of the narrow and broad, but usually metre or 3-ft. 6-in.

Owing to the fact that the actual cost of constructing broad gauge railways in the past has generally materially exceeded the cost of building lines of medium gauge, the assumption is sometimes wrongly made that a broad gauge railway must, of necessity, cost materially more to construct than a railway of smaller gauge, but this is not the case. Provided the bridges and permanent way are designed for equal axle loadings, the cost of a railway is not greatly affected by variations in the width of gauge of moderate amount. It is by no means impossible to build a broad gauge line cheaply, and the Northern railway in Ceylon, of 5-ft. 6-in. gauge, was constructed before the war for £3,617 per mile, its only differences from the standard form of construction in the Colony being the employment of a lighter permanent way and the omission of passenger platforms at the less important stations. There are over 3,500 miles of 2-ft. 0-in. and 2-ft. 6-in. gauges in India, and their average cost of construction exceeded the above figure for a 5-ft. 6-in. gauge line.

It is sometimes argued that the cost of constructing a narrow gauge railway is materially less than a railway of broader gauge owing to the possibility of eliminating costly earthworks by the introduction of curves of short radius, but the importance of this factor can be very easily exaggerated. The length of fixed wheel base is the chief factor determining the limiting radius of curve, and as wheels of small diameter are usually employed on narrow gauge railways the fixed wheel base is less, but wheels of small diameter can be used with broad gauge engines. The customary limits of curvature are :—

Broad gauge	5	chains radius.
Medium ,, ...	3	,,
Narrow ,, ...	$1\frac{1}{4}$	,,

Curves of 5 chains radius have been freely used on the 5-ft. 6-in. gauge hill railways in Ceylon and the 4-ft. $8\frac{1}{2}$-in. gauge railways in Jamaica, and curves of shorter radius would not generally be recommended on railways of smaller gauge except in very difficult country.

If a comparison is made between alternative estimates for a metre gauge and a broad gauge line to carry similar axle loads, it will be found that while economy can be obtained by adopting the metre gauge with regard to earthworks, bridging and permanent way, the remaining items in the estimate are not affected to an appreciable extent. It is usual to adopt a sleeper 6-ft. 6-in. long for metre gauge track and 8-ft. 6-in. long for a 4-ft. $8\frac{1}{2}$-in. gauge track. There should be a sufficient width of ballast outside the ends of the sleepers to give them lateral support and a sufficient cess outside the edge of the ballast to prevent it being lost down the slopes. It will be seen then, that it is only necessary to make the width of formations in cuttings and embankments greater on broad gauge lines than on narrow gauge lines by the difference between the lengths of the sleepers. Assuming a 14-ft. width of formation for the metre gauge line and a 16-ft. width of formation for the 4-ft. $8\frac{1}{2}$-in. gauge line, the approximate number of cubic yards of embankment per mile with side slopes of 1 on $1\frac{1}{2}$ for the above two widths are as follows :—

Depth of fill or cut.	14-ft. width of formation.	16-ft. width of formation.	Increased earthwork due to greater width.
3 ft.	10,900 cub. yds.	12,100 cub. yds.	11 per cent.
6 ft.	27,100 ,,	29,500 ,,	9 ,,
9 ft.	48,600 ,,	52,100 ,,	7 ,,
12 ft.	75,400 ,,	80,100 ,,	6 ,,
15 ft.	107,500 ,,	113,400 ,,	5 ,,

It will be seen that the additional earthwork required for the wider gauge is likely to be less than 10 per cent. Savings will be effected in the cost of permanent way by the adoption of the narrower gauge of perhaps 20 per cent., due to the shorter sleeper and reduced width of ballast, while there will be a saving of perhaps 5 per cent. on bridging on account of the shorter culverts and reduced lengths of cross girders and bracings between main girders of bridges. In a particular instance where the relative cost of the two gauges was investigated in connection with a railway project in one of our Colonies, it was found that the total difference amounted to about 10 per cent. Alternative estimates for the construction of a North to South Transcontinental railway in Australia indicated that a 4-ft. 8½-in. gauge line would only cost about 10 per cent. more than a line of 3-ft. 6-in. gauge.

With regard to the cost of equipment, it is generally agreed that the cost of rolling stock for a given volume and description of traffic is approximately the same for metre gauge as for broad gauge. Similarly with working expenses, for equal average earnings per mile the working expenses are nearly the same on the two gauges, assuming permanent way and bridges of equal strength, but are slightly in favour of the broad gauge.

It will be seen, then, that with permanent way and bridges of equal strength a medium gauge railway costs about 10 per cent. less to build and can be operated nearly as cheaply as a broad gauge line. A broad gauge railway does, however, possess definite advantages over lines of narrower gauge. It has a wider load gauge and, owing to its greater width of base, can be operated at higher speeds and the ultimate capacity of a broad gauge line is probably twice as great as a medium gauge line. If, therefore, the amount of traffic which may be developed in the future is likely to exceed the capacity of the narrower gauge, the additional cost of constructing the broader gauge is justified.

It must not, however, be overlooked that the capacity of a railway of any gauge can be increased by strengthening the permanent way, bridges, etc., to take heavier engines. Assuming the maximum axle loads on a 45-lb., 60-lb. and 80-lb. rail are 9 tons, 12½ tons and 18 tons, respectively, the tractive power that can be developed with eight coupled wheels is 20,000 lbs., 27,000 lbs. and 47,000 lbs., respectively. It is possible, therefore, to increase the capacity of a pioneer line laid with 45-lb. rails by relaying with 80-lb. rails and strengthening the bridges to take 18-ton axle loads. This is the normal method of increasing capacity and, incidentally, reducing the cost of operation, and this method has actually been employed in several countries. The South African Railways show what is possible on a 3-ft. 6-in. gauge line, and although over 15,000 miles of metre gauge railways have been built in India, in only a very few cases has traffic developed to such an extent as to render widening of the gauge, or duplication of the line, necessary. In undeveloped territories of smaller population than India it is not likely that traffic will develop for many years to come to justify the construction of railways with a wider gauge than 3-ft. 6-in.

So far we have only considered the relative merits of broad and medium gauge railways, but it is necessary also to consider the possibilities of the narrower gauges of 2-ft. and 2-ft. 6-in. The primary objections to these small gauges is the lack of lateral stability, necessitating slow speeds, and the limited space available for the firebox and the moving parts of the locomotive. In consequence of these limitations it is impossible to design a locomotive with a tractive power comparable with metre gauge engines. The tractive effort, at 75 per cent. of the boiler pressure, of the 60 c.m. (1-ft. 11⅝-in.) gauge locomotive used during the war was only 5,415 lbs. The axle loads of these engines did not exceed 3½ tons. With a gauge of 2-ft. 6-in. it is possible to design locomotives with a tractive effort of 11,000 lbs. with axle loads of 5 tons. This very serious limitation of the possibilities of narrow gauge railways has been reflected in the very small mileage of such lines which have been constructed. In India, where there are over 18,000 miles of broad gauge and over 15,000 miles of metre gauge, there are only about 3,600 miles of narrow gauge, the bulk of which has a gauge of 2-ft. 6-in. Most of these narrow gauge railways are feeder lines.

The only advantage of the narrow gauge is cheapness in first cost. The light axle loads of the locomotives permit the use of a light standard of permanent way. A 20-lb. rail will suffice for the 3½-ton axle loads on the 2-ft. gauge and a 30-lb. rail for the 5-ton axle loads on the 2-ft. 6-in. gauge, with a corresponding reduction in the size and cost of the sleepers and all fastenings. When comparing, therefore, the cost of the narrow with the medium gauge we must not forget that we are doing so from a somewhat different standpoint to that on which a comparison has been made between the medium and broad gauge railways, where the assumption was made that the permanent way and bridges would be of similar strength for both gauges.

About three years ago tenders were obtained from British contractors for the construction of a railway in Africa, 125 miles long, of 3-ft. 6-in. gauge and alternatively of 60 c.m. gauge. The 3-ft. 6-in. gauge line was to be laid with rails weighing 45-lb. per yard and steel sleepers weighing 70-lb. each, and the 60 c.m. line with 20-lb. rails and 18-lb. sleepers, but it was stipulated that earthworks and bridges should be the same in both cases and designed for 12-ton axle loads. The amounts quoted for the 60 c.m. gauge line were approximately 70 per cent. of those quoted for the 3-ft. 6-in. gauge line. If earthworks and bridges for the 60 c.m. gauge line had been made sufficient only for that gauge, an additional saving of perhaps 4 per cent. would have been obtained. The line proposed was in easy country and the cost of the 60 c.m. gauge line—exclusive of the cost of rolling stock, land and compensation and supervision—would have amounted to about £4,088 per mile.

While the cost of construction is materially less the saving on maintenance will not be so marked. One of the chief factors affecting maintenance costs in tropical countries, where vegetation grows at an appalling rate, is the time spent on weeding the track. Owing to the slightly reduced width of formation some saving will be effected in this respect, while the cost of materials used on maintenance should also be less. On the other hand, the lighter permanent way is more easily displaced under working conditions and by heavy rains, while the cost of patrolling the line will be the same for both gauges.

With regard to running costs there can be no question that they will be higher on the narrow gauge line unless the volume of traffic is exceedingly small. With a 3-ft. 6-in. gauge line and 9-ton axle loads it is possible to design locomotives with a four times greater tractive effort than with a 2-ft. gauge line and 3½-ton axle loads. It is therefore necessary to run four trains, with four train crews, on a 2-ft. gauge line where one train with one crew will suffice for a similar quantity of traffic on a 3-ft. 6-in. gauge line. In India the average cost of moving traffic on the 2-ft. gauge lines is more than double that on the metre gauge.

The ultimate capacity of a single line of railway depends upon the number of trains which can be passed over the railway during any definite period. This will depend mainly on the distance between crossing stations and the speed. If the permissible speed on the 3-ft. 6-in. gauge is double that on the 2-ft. gauge and the carrying capacity of each train is four times greater, then the ultimate capacity of the wider gauge is eight times that of the smaller. It will be seen, therefore, that while the cost of constructing a 2-ft. gauge is materially less and the cost of maintenance slightly less than the cost of a 3-ft. 6-in. gauge line, the working expenses are likely to be materially greater per ton-mile, and its ultimate capacity will only be a fractional part of the wider gauge. Owing to its limited traffic-carrying capacity a narrow gauge railway cannot be regarded as suitable for a railway of any considerable length as, though the volume of traffic in immediate sight may not be sufficient to justify the present construction of a wider gauge line, if the railway is to fulfil its primary purpose of opening for development an extensive tract of country, the growth of traffic may necessitate the conversion of the narrow gauge railway in a few years hence. When this eventuality occurs the cost of conversion will probably amount to double the present saving and the line will subsequently be burdened by interest charges on a considerable amount of dead capital. At the same time it must not be overlooked that the volume of traffic is independent of the gauge, and a revenue, which might give a satisfactory return on a small capital outlay, may prove inadequate to pay the interest charges on the larger expenditure which the construction of a broader gauge may involve. Generally it will be found that this condition exists in the case of branch or feeder lines only.

The foregoing analysis of the characteristics of a 2-ft. gauge line is applicable—but in a lesser degree—to railways of 2-ft. 6-in. gauge. The additional six inches in the width of gauge enables the tractive power of the locomotives to be increased 100 per cent., while higher speeds are possible. While, therefore, the ratio between the two gauges is as 4 is to 5, the ratio of the ultimate capacities is nearer 4 to 12.

Having regard to all the circumstances, the most suitable gauge for a pioneer railway is probably the metre or 3-ft. 6-in., and this view is confirmed by the extensive mileage of these gauges which has been constructed.

Final Estimate of Cost.

The estimate of the cost of construction should be sub-divided under convenient main-heads, such as :—

(1) Survey.
(2) Purchase of land and compensation.
(3) Clearing.
(4) Earthworks.
(5) Bridges and culverts.
(6) Ballast.
(7) Permanent way.
(8) Stations, buildings and water supply.
(9) Telegraph.
(10) Sanitation and maintenance of labour camps and hospitals.
(11) General charges, supervision, etc.

The main heads should be sub-divided where necessary into :—

(*a*) Cost of materials f.o.b. British Port.

(*b*) Cost of freight and transport to site.

(*c*) Cost of work at site.

The cost of materials can be estimated with little difficulty and may amount to 50 per cent. of the total cost of the work. Ocean freight will be in the neighbourhood of £2 to £3 per ton weight or bulk, to this must be added insurance at, say, eight shillings per £100. Landing charges will depend upon the facilities available and may be between 7s. 6d. and 15s. per ton. Freight up country over existing railways should not exceed 2d. to 3d. per ton-mile.

When materials have to be transported a considerable distance into the interior, the cost of freight and transport may reach a considerable sum. In the case of one of the railways to which I have referred it was necessary, after landing on the other side, to transport the materials over four different railways as well as to ferry them across a big river. Freight and transport was estimated to amount to over £7 per ton. It will be readily seen how seriously this affected the cost of construction. A ton of cement which could, perhaps, have been purchased here for £4 was worth £11 at rail base. Similarly, rails which might be purchased here for, say, £9 per ton would be worth £16 delivered at site.

The cost of work at site should be based on recent costs of similar work when such information is available. It will depend on the quantity, quality and physique of the labour available as well as on the rate of wage paid, although, if comparisons are made between different countries, it is usually found that the cheapest labour is generally the least efficient, being deficient in either skill or physique, and more often in both.

The following unit rates are representative of present-day costs in Tropical Africa :—

Clearing Light bush . .	4/6 to 6/-	per square of 100-ft.
,, Heavy bush . .	9/- to 15/-	,, ,, 100 ,,
,, Light forest . .	20/- to 45/-	,, ,, 100 ,,
,, Heavy forest . .	45/- to 100/-	,, ,, 100 ,,
Excavation Soft earth .	9d. to 1/3	per cubic yard.
,, Hard earth .	1/3 to 2/-	,, ,,
,, Rock (soft) .	2/- to 3/-	,, ,,
,, Rock (hard) .	4/6 to 7/6	,, ,,
Concrete	60/- to 70/-	,, ,,
Steel Bridgework (erected)	£30 to £45	per ton.
Ballast (1,500 cub. yds. per mile)	3/- to 8/6	per cub. yd.
Laying, lifting and packing permanent way . . .	£140	per mile.

Telegraph (3 wires), materials delivered at site . . .	£140 per mile.
Erecting telegraph . .	£50 ,,
Major Stations	£2,500 each.
Minor Stations	£1,200 ,,

The following details of the most recent estimate I have seen for a railway extension in Africa, 79 miles long, are of interest :—

	Cost per Mile.	Percentage of total cost.
	£	
Survey	65	0.92
Land	31	0.44
Earthworks	968	13.72
Major Bridges	288	4.08
Minor Bridges	441	6.25
Fencing	11	0.16
Telegraph	238	3.37
Ballast and Permanent Way	3057	43.31
Buildings and Fixtures	517	7.32
Station Machinery	270	3.82
Furniture	47	0.67
Plant	41	0.58
General Charges	1084	15.36
Total Cost per Mile	7058	100.00

In this lecture it has been possible to treat in a general way only the matters brought under consideration, and experience shows that it is dangerous to generalise on transport problems as they are almost invariably affected by particular circumstances peculiar to each locality. While it must not be forgotten that the physical characteristics, climatic conditions, labour costs, etc., all of which affect transportation costs, vary in different countries, and even in different districts of the same country, I hope that the information I have been able to give you will some-day prove helpful when considering transport developments.

THE ROYAL BOMBAY SAPPERS AND MINERS.

UNVEILING CEREMONY OF THE WAR MEMORIAL AT KIRKEE.

THE War Memorial of the Royal Bombay Sappers and Miners was unveiled by H.E. The Governor of Bombay on 10th September, 1924. The Corps was drawn up in three sides of a square round the Memorial. On arrival of H.E. he was received with a Royal Salute by a Guard of Honour, consisting entirely of men who had fought in the Great War, and of whom the large majority were wearing the 1914 or 1914-15 Star. After inspecting the Guard of Honour, H.E. took up his position facing the Memorial. At the conclusion of the dedicatory prayers by the Chaplain, Moulvi, Granthi and Pandit, Colonel on the Staff G. H. Boileau, C.B., C.M.G., D.S.O., R.E., as the most senior officer present, who had served with the Royal Bombay Sappers and Miners, asked H.E., on behalf of the Corps, to unveil the Memorial. H.E. then made the following speech :—

"I consider it a great honour to be asked to unveil this Memorial to-day to the memory of the officers and men of the Royal Bombay Sappers and Miners.

"The Corps, into which is now incorporated two units of the old Railway Battalion, served with credit and distinction on many fronts during the Great War, and in every theatre of operations secured high praise for its services. Two Companies, the 20th and 21st, were mentioned in despatches by name for their gallantry at Neuve Chapelle in 1914, the 17th Company was similarly mentioned for gallant service at Shaiba, as was the 22nd Company for gallantry at Sahil and Essinn, and in all these actions the Companies lost heavily in officers and men.

"On the conclusion of the War His Majesty the King-Emperor conferred the title of 'Royal' on the Corps, an honour conferred on only eight units of the Indian Army, and one which, before the Great War, had never before been conferred on any Indian Army unit. This fact alone testifies, if testimony were needed, to the services rendered by the Corps.

"The Memorial which I am about to unveil has been erected by all ranks of the Corps to perpetuate the memory of their comrades who made the great sacrifice for King-Emperor and Country, and of their 563 comrades whose memory we honour to-day, the great majority were killed in action or died of wounds. This Memorial, however, will stand on this spot for all time not only as a token of respect, affection and admiration for those who so unselfishly gave their lives, but as a reminder to the men of this and of future generations of their duty which they in their turn must do, and of the example of heroism and self-sacrifice which was set them by the men whose names are inscribed on the Roll of Honour of this Memorial.

"In villages, and in great towns, in Europe, Asia and Africa stand Monuments or memorials, great and small, all testifying to the gallantry of Troops of the King-Emperor in the Great War, all bearing their message to the citizen of to-day and of to-morrow —a message which cannot but instil into the hearts of all a determination to be worthy of those who died that we might live free men, under that flag which flies in every quarter of the globe—a flag which means, for all who live under its shadow, justice and liberty.

"Of those officers and men of the Corps of the Royal Bombay Sappers and Miners, truly it can be said

"Splendid they passed, the
Great surrender made,
Into the light which
Never more shall fade."

"To the glorious memory of 563 officers and men of the Corps of the Royal Bombay Sappers and Miners, I now unveil this Memorial."

Just previous to the actual unveiling, H.E. handed to Subadar-Major Muhammad Din, Bahadur, I.O.M., an Urdu translation of his speech, which the latter read to the whole Corps after the departure of H.E. H.E. then pressed the switch and the flag draping the Memorial fell away. The Roll of Honour was taken from its escort and placed in its position on the Memorial by Subadar-Major Muhammad Din. The Corps then presented arms, while the buglers played the Last Post followed by the Reveillé. After this, wreaths of evergreens were placed round the foot of the Memorial by the Officiating Commandant, the Regimental Sergeant Major, and the senior Indian Officer of each of the three castes enlisted in the Corps. At the conclusion of the Ceremony, H.E. took his departure under a salute from the Guard of Honour. Among others who attended the ceremony were Major-General Sir Edwin Atkinson, K.B.E., C.B., C.M.G., C.I.E., Major-General R. N. Harvey, C.B., C.M.G., D.S.O., Colonel Commandant A. Rolland, C.B.E., D.S.O., as well as a number of pensioned Indian Officers of the Corps.

The Memorial stands on the Parade Ground about 40 yards back from the centre of the side facing the lines. It was designed by the consulting architect to the Government of Bombay and built almost entirely by men of the Corps. As will be seen from the photographs, it consists of a stone cenotaph; the English inscription on the front face is repeated in Urdu, Gurmukhi and Marathi on the three remaining faces.

THE EARLY YEARS OF THE ORDNANCE SURVEY.
(*Continued*).

V. The Directorate of William Mudge (Continued).

Colby joins the Survey.—Thomas Colby was born in 1784, and received his commission, as a Second-Lieutenant in the Royal Engineers, on the 21st December, 1801, being then just over 17 years old. His commission is signed by George III and countersigned by Lord Chatham, Master General of His Majesty's Ordnance. A short account of Colby's career will be given later on; meanwhile it is sufficient to say that it is to Colby that the Survey owes its present organization, and to Colby, also, were due most of the methods which were in use for nearly a century. It was, indeed, Colby who eventually gave the Survey its distinctive character. Three weeks after being commissioned he was appointed to the Survey by the following minute, addressed to Major Mudge, from the Chief Engineer's office, Westminster :—

12th January, 1802.

Sir,

I am directed by Lt.-General Morse to acquaint you that Second-Lieutenant Thomas Colby, of the Corps of Royal Engineers, is ordered to put himself under your command to be employed upon the Trigonometrical Survey. . . . . ..

I am Sir,
Your most obedient humble servant,
John Rowley.

Major Mudge, &c., &c.

Colby soon showed his capacity, and, even as a mere lad, he was entrusted by Mudge with a large share of the work. When, in 1809, Mudge was appointed Lieutenant-Governor of the Royal Military Academy, he left the detailed conduct of the operations largely to Colby, who was then aged twenty-five; and still more of the work devolved on Colby when his chief was, in 1810, given the additional appointment of Superintendent of the College at Addiscombe. The arrangement was probably on the whole, a good one. The larger matters remained under Mudge's control, but Mudge seems to have, rightly, left the actual superintendence and almost all personal work to Colby, who was too young to act effectively with the chiefs of the Board of Ordnance. The position was well known to the friends of both officers. Thus, Olinthus Gregory, Professor of Mathematics at the R.M.A., writing to Colby shortly after Mudge's death in 1820, says, the Survey "has been for so many years conducted and carried on so entirely by yourself, that I should have thought that the Master General would have settled the appointment the next day." But until 1809 Mudge worked in the field as well as in the office. The relations between the old man and the young were always most friendly; the letters which passed between the two show complete understanding and co-operation.

It is curious that Mudge should have been effectively in charge for the seven years that Williams was nominally the Director; and that, for the last ten years of Mudge's life he should have been obliged, in his turn, by pressure of other duties, to hand over much of the work to Colby.

Progress of the Work, 1800-09.—In the third and last volume of the *Account of the Trigonometrical Survey* will be found a description of the operations from 1800 to 1809. The triangulation was continued with great rapidity, the two 3-ft. theodolites, and one 18-inch theodolite being used. The angles were observed by Mudge, Colby, Woolcot and Gardner.

By the end of 1809 the triangulation of the whole of England and Wales had been completed, except for the counties of Lincoln, Norfolk and Suffolk, and this operation included not only the main, or principal, triangles, but also the secondary triangles required for the "interior" survey.

When tested by the later triangulation the old work of this period stands well as regards the bases, but not so well with respect to the observed angles. It was found that there was an error of about 170 feet in the arc measured between Dunnose and Clifton, a distance of 196 miles; that is to say there was a linear error of about 1 in 6000. This is larger than Mudge expected, for he stated that he thought it unlikely that there was an error of as much as 100 feet, or say 1 in 10,000. But the matter is not now of any importance. It is clear that the work was of ample accuracy for the one-inch map, and it should be understood that the whole triangulation was recast some forty or fifty years later. In fact, the old angles at only six stations were used by Clarke in his reduction of 1858. We need, therefore, only consider Mudge's work with reference to the immediate purpose that he had in view, and for this purpose the work was more than sufficiently exact.

In the year 1806 a base, about 4½ miles long, was measured, by Colby and Woolcot, on Rhuddlan Marsh, near St. Asaph. Clarke, writing in 1858, says, "The extremities of the line were marked, as at Misterton Carr, with blocks of wood, but of these unfortunately every trace has been lost."

Heights of the Hills.—An interesting feature of the work of these years was the calculation of the heights of about three hundred hills scattered over England and Wales. The "low water mark" was used as the datum, so that the heights are not directly comparable with modern values. It is stated that "in deriving the numbers expressing the heights, the several differences have been mingled together, and the means always taken." The results were fairly accordant; two independent values of the same height differed, as a rule, by some 6 or 7 feet. *Sca Fell* came out 3166; modern value, 3162; but the old value should have some feet taken from it to allow for the difference of datum. *Skiddaw*, old value 3022; new value, 3053. *Cader Idris*, old, 2914; new, 2927. *Leith Hill*, old, 993; new, 965. *The Wrekin*, 1320 and 1335; and so on. Anyway, for the first time, the public had available fairly good values for the heights of many British hills; sufficiently good, no doubt, in most cases, to correct the exaggerations of local patriotism. But none of Mudge's heights remain on the present day maps.

The Account of the Trigonometrical Survey.—The third volume of this account, which brings the operation up to the end of 1809, was published by W. Faden in 1811. It is much to be regretted that no further volumes were issued. After this date the history of the Survey must be sought in memoirs and private letters, and in technical publications, such as the Lough Foyle Base of 1827, the Latitude Observations of 1842-50, and so on.

In later years we come to the official Annual Reports, which were presented to Parliament and published. But these, for a long period of years, became dull and colourless to the last degree. The first of these reports was not issued, moreover, until 1856. So, in order to find out what was really going on from 1810 to that date, we are driven, perhaps, not unwillingly, to study Portlock's Memoir of Colby, Flint's Memoirs of the Mudge Family, and the correspondence, preserved in the Colby collection, between Mudge, Colby and their contemporaries.

Letters from Mudge.—Thirty-three letters, written by Mudge, have been preserved in the Colby collection; and of these all but one are addressed to Colby. The one exception is a letter to Lieutenant-Colonel Hadden, R.A., who was Colby's uncle, (his mother's brother). Hadden was a distinguished soldier who had served in North America. In 1793 he became secretary to the Duke of Richmond, Master General of the Ordnance; he afterwards served as Adjutant-General in Portugal, and, finally, became Surveyor-General of the Ordnance and a Major-General. Mudge's letter to him is dated, Drawing Room, Tower, 14th January, 1802, and runs thus:—

"I send you your copy of the Kent Map, and will transmit others when I obtain a fresh supply, which will be in a day or two.

Lord Howe I found at the Board on Tuesday. I communicated the wishes of the Master General, as to his presenting me at the Levee, but his Lordship had made an arrangement which called him yesterday out of Town. I therefore made my own way, thro' the aid of the Lord in Waiting, and presented the Map to his Majesty, who, I think, still remains to be informed, that it is *an actual map,* and not a written account similar to the last presented." . . . .

On September 5th, 1804, Mudge writes to Colby from Teignmouth:

DEAR COLBY,

As soon as possible, let the direction of the Meridian be observed. For this purpose, Woolcot and yourself must lay your heads together. Two double Azimuths that agree will be sufficient. [*Then follow technical instructions*]. Your letter of the 27th ultimo came to hand today. Thank you Colby for your attention to the Base of Altitude business; it assures me of your assiduity, and with all the work we have in hand your perseverance will supply the place of my attendance. And farewell, believing me

Ever your friend,

W. MUDGE.

. . . . .In observing the star tell Mr. Woolcot not to lean with his arm, or rest his breast on the Cover of the Instrument. Col. Hadden desires to be remembered to you, and that you would, when you write to your Father, send your letters under cover to him.

In another letter, apparently from the Tower of about the same date, he says :—" 500 Great People have been here to-day . . . . ."

Tower, May 17th, 1805.

DEAR COLBY,

I will immediately procure and send off to Holyhead, an Ephemeris and requisite tables . . . .[*Then follow instructions for the observation of a star at elongation*]. You act very properly in waiting my reply to the question you propose, in regard to the possibility of certain [changes] being introduced into our work from the circumstance you mention. I certainly do think that we should be very guarded in admitting new *succedanea* in our operations. There has been too much of it of late, but the fault was Woolcot's, not yours. If the Karn of Stones, or the heap upon it, be a fair cone, at least tolerably so, on this occasion have recourse to it instead of a P[ole] . . . .

Dear Colby,

Ever yours sincerely, W. MUDGE.

Cockington, July 9th, 1805.

MY DEAR COLBY,

. . . . . . Having got *out* of the Isle of Anglesea, get as far *away* from it as possible. Steer off towards Chester. Don't make a practice of going to all the three points of every triangle, if observations made at two of them will be sufficient. Work round spires, staffs on mountains or any other proper objects, that the Survey may get on rapidly.

. . . . .I shall be back again in 7 or 8 days. I am just now going to Mintern, or Revel's Hill in Dorsetshire. I shall not send Woolcot to you now. . . . Glad I am that I have a man with me, who can think and act as you do. . . . I wish you in all things to consult your own will, convenience and happiness, requiring you only to be punctual in writing me about all you do . . . .

The Irish Military Survey Bill has no reference to us!

There is now a gap in the sequence of letters, and the next one preserved was written six years later. The year 1811 was a trying one for Mudge. He gave evidence before Commissioners that the total expense of the Survey, during the past 20 years, had been somewhat more than £50,000. It would appear that the atmosphere of the Honourable Board was not, at this time, a very friendly one. But Archdeacon Flint quotes a letter from the Horse Guards, expressing admiration for "those exertions and talents, by which that art [of Topography] has in elegance and accuracy been brought in this country, to a degree of perfection surpassing that of any other country in Europe."

At the same time "an order came from the Master General to withhold every map from the public."

On 27th July, 1811, Mudge writes to Colby from Brighton:—

"You will hear with sorrow and with surprise that ten days have elapsed since I requested the Master General and Board permission to put the Account in the hands of Mr. Faden without receiving any answer to my Letter. This silence augurs mischief! . . . .though checked as I am at the Trigonometrical Plough, perhaps it matters but little whether I turn up the Soil or leave it in Sod. I am quite dispirited and dismayed." . . .

In August and September of 1811 Mudge's work was subjected to a Military Enquiry. He writes on the 2nd September:—

. . . "Had it not been for the *Military Commissioners* I should long since have been on the search after you. . . . .See you not the two words, Military Commissioners, aye, see you them not!—I have been before them. I cannot tell whether they imagine me to be a rogue or not, but they deal with me exactly as if they thought so. They gave me not a moment's notice scarcely for preparation, taking me literally at the *ground hop* on my return to Town from Brighton. They examined me in the twofold capacity of Lt.-Governor of the Academy and Director of the Survey. I have my own opinion of their talents, severally and jointly. I believe they thought some great secrets were hidden and that torture would be necessary to find them out. Soon, however, were they undeceived, for I very shortly told them that the day was come which I had long looked forward to with pleasure, and that I appeared before them rather with the hope of being allowed to assist them in their enquiries than as a subject for examination, for that I knew well, without my assistance, their enquiries never could suffice to satisfy the Public or myself. On this

Principle, therefore, the gentlemen composing the Board have had laid before them an account of every shilling of money expended on the Survey since the year 1791, amounting to something more than £52,000. That is to say, the Engraving, the interior Surveying, the Trigonometrical Survey, travelling, etc., amounts to that sum. From these accounts it will appear that the average expence of the Total Survey since 1800 has been about £4,300 per annum and the average expence of the mere T. Survey, included in that sum, about £1000 per annum, our salaries, with Mr. Woolcot's and Mr. Gardner's, with travelling included. So you see the anonymous author has told a d—d lie in stating that the Expences of the Survey has exceeded £10,000 per annum. I suppose the Commissioners must, and I dare say they will, make some good natured observations in their Report; they will state more particularly that the Engravers have no check on them after the hours of regular work. I care not, however, because I am conscious that, to the best of my abilities, mental and corporeal, I have discharged every trust deputed to me in this undertaking like an honest man.

I devote this month to travelling among the Surveyors, and I shall beg of you to meet me at Chepstow."

Ever in truth and sincerity, if that be not tautology,

Believe me, your sincere,

W. MUDGE.

Another letter on the same subject:—

Royal Arsenal, Woolwich.

October 1st, 1811.

. . .I know not that it would be objectionable to publish it at Charing Cross, so that I can have no scruple to let the contents of my Letter float on the Sea of Chance . . . . The Board first examined me on the score of the Academy, and the examination impressed me with the opinion, which I believe to be true, viz., that they had got at a pretty accurate knowledge of the state of the Establishment at the time I came to it, and what it was at the hour of examination. . . . In respect to the Survey I was examined on all the essentials of the operation, and finally asked the pointed question of its utility and continuation. I did my best to satisfy them in the first point, and gave for my answer in the second, that the Trigonometrical Survey of England being completed, save and except a small part of the eastern side of it, to complete which little time would be required, I thought the Survey of Scotland, in the mere triangular part, would not take more than 5 years, and that it was my intention to commence the Survey of that part of the Kingdom next year—our destination for 1812 is therefore fixed—The *Total* expence of the Trigonometrical Survey itself *ab origine* 1790=21 years, was stated at £21,000. The Commissioners considered this sum as large, and asked if they could be furnished with all the particulars constituting that expence? I told them certainly, and ***instantly*** they had these further sums given, *viz.:*

£25,347 7s. 7d. for the interior Survey, Travelling, &c.
and £7,817 18s. 0d. for the Engraving. . . .

£54,165 5s. 7d. being the total expence, which, divided by 20, the number of years £2208* for a mean annual expence; but the present mean is nearly £4,416 = the present annual expence. I dare to say the Commissioners will animadvert, pretty strongly, on the apparent magnitude of this sum; but everybody I have shown it to thinks the sum a fleabite; in fact so it is a fleabite, and I myself thought it had been more . . . . I am certain they were strongly impressed with an idea of the extreme accuracy of the work, but I think the Commissioners will stab at my plurality of offices. My last moments, whenever they do come, will not be embittered with the recollection of any of my sins of commission or omission as touching the Survey. The Work† is approved of and sells well. All publication of *future* works is stopped."

So the Board of Ordnance, in its wisdom, saw fit to stop the further publication of adequate accounts of the work of the Survey; a prohibition of which the effects remain to this day. For the Annual Reports which were eventually issued (but not till 1856) are poor things compared with the reports issued by other great surveys, and are but meagre outlines of the work accomplished, though they are better than nothing. Mudge, after 1811, had to content himself with nothing. Lord Mulgrave was the Master General responsible.

Mudge, and the Survey, survived the encounter with the Commissioners, and the work went on. On the 9th September, 1813, he writes :—

" I am very desirous that you should immediately read the review of Major Lambton's Papers in the Asiatic Searches, giving an account of his Trigonometrical operations in India, which review is to be found in the last number of the Edinburgh Castigator; it is undoubtedly done by Playfair, who had us in his eye all the way through, and has ended his critique with the strongest compliment that could have been paid to the Surveyors in this country . . . . Mr. Playfair is a man of great natural sagacity and much acquired information.

" You will now hear with great satisfaction the probability of my returning with you to the North next Spring to finish our operations, for my health is much restored, and though I write by the hand of another, yet I am in many respects better than I have been for some years, and this brings in my mind how happy I am to account myself, that Providence has placed to my hand so able and so firm a friend as you are.......

Royal Arsenal,

22nd September, 1813.

DEAR COLBY,

I have written to the Board desiring that orders may be sent to the storekeeper at Fort George to receive the Sector and Apparatus. You, of course, direct your steps due south, and will perhaps arrive at your old

* A slip of Mudge's, it should, of course, be £2708.

† Volume III of the *Account of the Trigonometrical Survey*, published by Faden in 1811.

quarters in the Tower sometime in the middle of October. You are very much wanted, for what with laying down of points, settling of edges, reconciling differences, and setting out new Work, there is abundant to engage you. Mr. Gardner will, of course, come with you . . . . General Hadden was with me yesterday, and also Mrs. Hadden, after putting Brother Martin into his grave. Poor old Gentleman, 97 years after he was born he bid adieu to this World of tears and repentance, and now lies with the mouldering remains of all the Carpulets in Plumstead Church Yard . . . . The public papers will have made you acquainted with the loss of my poor friend Fletcher,* a loss indeed, both to the Public and to his Family, but this comes of Volunteering and looking plump into the Cannon's Mouth. Collyer fell upon the top of the breach killed, his place was directly supplied by Mr. Marshall, who instantly dropped wounded; the third, Capt. Rhodes, immediately repaired to the spot and was also instantly killed, a fourth then mounted the breach and happily survived; really I think hereafter the Corps of Engineers should be looked upon as belonging to *Undertakers* as well as to Carpenters and Joiners, and have the Death's Head and bones upon their Buttons by way of a *Memento Mori*. It is a nice Corps for Promotion, but excessively selfish, for it has absorbed all that once belonged to the Artillery."

In the same year, 1813, Wordsworth wrote a poem on the subject of one of Mudge's experiences on the mountain of Black Comb in Cumberland. "Written with a slate pencil on a stone, on the side of the Mountain of Black Comb—

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

Know . . . .
That on the summit whither thou art bound
A geographic Labourer pitched his tent,
With books supplied and instruments of art,
To measure height and distance; lonely task,
Week after week pursued!

....Once, while there he plied his studious work,
Within that canvas Dwelling, colours, lines,
And the whole surface of the outspread map,
Became invisible . . . . .total gloom
In which he sate alone, with unclosed eyes
Upon the blinded mountain's silent top!"

* Sir Richard Fletcher, killed on 31st August, 1813, at San Sebastian. He had married Mudge's sister, Elizabeth.

The Beginnings of the Geological Survey.—Mudge, writing to Colby on the 16th May, 1814, says,

"On Friday I received a letter from Col. Chapman, grounded on a very good and scientific Representation to the Master General, desiring to know whether or not a Mineralogical and Geological Surveyor would not be exceedingly useful to me, as affording means of making those observations in those branches of human knowledge that might help to account for those extraordinary Anomalies which have of late so inconveniently hung round our operations. The Master General at the same time desiring to be informed whether, if such were my opinion, Dr. McCulloch would not be a very good person for the place. My answer was, as you may suppose it was, affirmative all the way through, and I do in consequence expect to have Dr. McCulloch's appointment nominated to me before the present week shall finish its course."

The idea was, that Dr. MacCulloch (as his name is usually spelt), should be able to point out where and what abnormal deflections of the plumbline were likely to occur; with a view to avoiding stations for the zenith sector where large deflections might be expected. The zenith sector observations being required for the determination of the meridian curvatures, which were themselves required in the construction of the one-inch map.

John MacCulloch was born in 1773, in Guernsey, and studied medicine in Edinburgh. In 1811 he gave up his practice and devoted himself to the geological investigation of Scotland. In May, 1814, he was appointed geologist to the Trigonometrical Survey. In 1826 he was instructed by the Treasury to prepare a geological map of Scotland. "This large undertaking was completed in 1834. There were, however, no detailed topographical maps of Scotland available at that time, and MacCulloch had to enter the geological colours on the meagre topographical basis of the Arrowsmith map. MacCulloch's map was published posthumously in 1840."* A competent observer, Mr. J. Jardine, writing to Colby in December, 1819, expresses his astonishment at the extent of MacCulloch's work and its accuracy. "No person but a man of iron like yourself could have gone over such an extent of rugged country with so much minute accuracy."

MacCulloch's death occurred in 1835, and was caused by a carriage accident.

Lyell, in an address to the Geological Society of the 19th February, 1836, says, "The map of Scotland, by Dr. MacCulloch, which has been so long and impatiently expected, is at length on the eve of publication. But at the moment when I can announce this

* Zittel's *History of Geology and Palæontology*, translated by M. Ogilvie-Gordon, p. 113. The writer is indebted to Mr. J. A. Howe, of the Geological Survey, for this reference.

welcome intelligence, we have to deplore the sudden loss of this distinguished philosopher." Lyell speaks of a want of condensation and clearness in MacCulloch's style and " a disposition to neglect or speak slightingly of the labours of others." MacCulloch seems to have been troubled with continual ill-health, and this made him difficult to get on with. His work, is, however, of importance in the history of geology, and Lyell said that he received more instruction from MacCulloch's labours in geology than he had from those of any then-living geologist.

The rest of the early history of official geology in this country may be briefly summarized. MacCulloch himself wrote *Memoirs to H. M. Treasury respecting a Geological Survey of Scotland*, the forwarding letter being dated July, 28, 1834. These memoirs were published by Arrowsmith after MacCulloch's death. The writer says that the Board of Ordnance gave him originally two principal tasks; one being to discover a mountain more suitable for the determination of the density of the Earth than Schiehallien, and the other the geological investigation of probable attractions of the plumb-bob. There were no accurate maps of Scotland in his day, and he says, with reference to the one-inch Ordnance map of England " It would require but a small geologist indeed to lay down the rocks of any part of England on the Ordnance maps; he is to be envied on whom such a duty may hereafter fall." He also talks about " the geographical surveyors of that splendid work."

In the spring of 1835, the Master General and Board of Ordnance appointed a committee, composed of Lyell, Buckland and Sedgwick, to report upon the desirability of a Geological Survey of England. "The enlightened views of the Board of Ordnance were warmly seconded by the present Chancellor of the Exchequer, and a grant was obtained from the Treasury to defray the additional expense which will be incurred in colouring geologically the Ordnance county maps." But, for some years before this was sanctioned, H. T. De la Beche had been mapping, at his own expense, the geological structure of Devon and Cornwall. He applied to the Government for recognition and assistance, and his application was warmly supported by Colby, who had long encouraged the Ordnance Surveyors to keep a record of geological observations. De la Beche represented that his work would be much more efficiently carried out if joined with the Trigonometrical Survey. The sum allowed for the Geological Survey was £300 a year, most of the expenses still falling on De la Beche. A room was assigned to him for the collection of geological specimens in Craig's Court, Charing Cross—an address once very familiar to R.A. and R.E. officers—and De la Beche was appointed Director of the infant museum—with no salary.

In 1845 the geological staff, which had meanwhile been increased, was transferred from the Board of Ordnance to the office of Woods and Forests, and, thereafter, the only connection between the Geological Survey and the Ordnance Survey was that the latter continued to print, colour and publish, the maps of the former. De la Beche remained in charge of the Geological Survey until 1855, when he died, and was succeeded by Sir Roderick Murchison.

The friend and biographer of Sir Roderick, the late Sir Archibald Geikie, who was Director of the Geological Survey from 1881 to 1901, wrote in his recently published autobiography*: "During the first ten years of its existence, [1835-1845], the Geological Survey was a branch of the Board of Ordnance. Its officers wore a dark blue official uniform. But a tight-fitting, well buttoned frock coat could only be an inconvenient garment for the rough scrambling and climbing life of a field-geologist. It was accordingly at once discarded when the Survey in 1845 was placed under the office of Woods and Forests."

One would like to know who insisted upon the dark blue frock coat. It does not seem the sort of thing that Colby was likely to do. Some of the brass buttons that adorned the coat, bearing a device of crossed hammers, are still in existence.

Don Rodriguez.—There is a wearisome small business which must be recorded, because it occupied a good deal of Mudge's time and exercised his patience, but in itself was a matter of little importance. Don J. Rodriguez was permitted to publish, in the *Philosophical Transactions* of 1812, a paper in which he explained the anomalies in Mudge's arc from Dunnose to Clifton as being caused by errors in the latitudes derived from Ramsden's zenith sector. Mudge was convinced that this was not the true explanation. But some scientific men accepted the Don's view and Mudge was naturally concerned to defend the accuracy of his work. In his letter to Colby of the 16th May, 1814, he writes :—" I should have derived infinite satisfaction from the Zenith Sector being this year used instead of the Circular Instrument, and am sure I cannot see why it should not be so used, for I should in that case be enabled the sooner to put up the Zenith Sector on Arbury Hill, which I have promised to do, and certainly will do, not indeed to please Don Rodriguez, for he at length has given up, but to vindicate the memory of Ramsden and ourselves. The Reviewers, you will find, have, I am sure, without my knowing anything about it, made their *amende honorable* and the Honorable Society are likewise concerned that they have given any Countenance to Don Rodriguez."

It does not appear that Arbury Hill was ever, as a fact, revisited for the purpose. But there are three stations in the triangulation of the United Kingdom at which observations for latitude were taken

* *A Long Life's Work.* Sir Archibald Geikie, O.M., K.C.B., F.R.S. p. 47.

with Ramsden's zenith sector, and forty years afterwards with Airy's zenith sector. These three stations are: Dunnose, Cowhythe and Balta. The difference between the resulting latitudes were found to be: 0".01, 0".11, and 0".09—an ample vindication of the excellence of Ramsden's instrument. And there we may leave the matter.

The Work of the Survey from 1810 to 1820.—During these years the triangulation was pushed on into Scotland, the observations being made by Colby and Gardner. Thus we find that, in 1814, Colby observed from 10 stations in Scotland; in the latter part of 1815 the observations were chiefly carried out by Gardner, because Colby was then called to the Tower. There are records of the Scottish triangulation being carried on by these two in the years 1816 to 1819 inclusive.

The zenith sector was set up at Kellie Law in 1813, at Cowhythe in the same year, and at Balta in 1817, Colby and Gardner being the observers.

In 1817, also, Colby and Gardner measured a base at Belhelvie, near Aberdeen. Its length was 26,515.65 feet of Ramsden's scale, or 26517.53 feet of the final Ordnance standard (O_1). As tested by the connection with the later triangulation, reduced by Clarke, the discrepancy was about 1 in 110,000. This base was measured with Ramsden's two 100-ft. chains and one 50-ft. chain.

The detail survey went on in England. "Surveyors belonging to the corps of Surveyors and Draughtsmen were now employed in various parts of the country, by permission of the Chief Engineer (Inspector General of Fortifications), who was the official head of the corps, and they received, besides their military pay as warrant officers, 32s. 6d. per square mile, for all the work they surveyed and plotted on a scale of two inches to the mile. These plots were reduced at the Map Office to plans on a scale of one inch to a mile and traces from these prepared for the use of the engravers."* Before Mudge's death in April, 1820, substantial progress had been made in the production of the one-inch map. 37 sheets had been printed, with regular sheet-lines, ignoring the county boundaries. The sheets varied in length from east to west, the largest being 35 inches long; from north to south they measured 23 inches. The area covered was the whole of the South of England, up to a line running roughly through Bath, Oxford, Hertford and Ipswich. The sheet covering Pembrokeshire was also printed. And of course, many sheets were in the hands of the engravers.

* *Memoirs of Major-General Colby.* By Lt.-Col. Portlock, R.E., F.R.S.

Some more letters from Mudge:—

Royal Arsenal,
16th May, 1814.

We have had so much trouble here with shewing the lions to one Duchess, that the trouble to shew them to two Emperors and one King, if it be determined by the Rules of Common Arithmetic, I look for it as certain that Bedlam will be well stocked.

Royal Arsenal,
14th August, 1815.

. . .of Dr. McCulloch I know nothing and have in fact heard as little as I know—your sentiments on our Union with his proceedings are precisely the same as mine. Mr. Hyett has completed his second Survey of the St. Alban's District, and certainly the result would augur that we have blamed him beyond his deserts. Mr. Yeakell seems to break [up] with great rapidity both as his strength of Eye and general health is concerned. . . . I find it necessary to look very close into his work. . . .

Royal Arsenal,
September 21st, 1815.

On account of the advanced season of the year and still more on account of my long continued indisposition . . I beg you will *immediately* close your operations and return to London.

Royal Arsenal,
27th January, 1816.

. . . .When I get Mr. Crocker's Edge, Mr. Budgen's plan, and Mr. Stanley's plan, the whole should be sent to the office, or rather taken there by myself that a fair view of the whole transaction may be laid before the General [*i.e.*, the I.G.F.].

5th February, 1816.

. . . .I want to cut off the surveying attendants on the Surveyors and that as quickly as possible.

29th February, 1816.

I . . .was informed that the Austrian Arch Dukes wanted to see everything connected with the Survey, therefore let Mr. Yeakel look out all such plans as it may be proper to show them not neglecting the Isle of Wight and Kent plans. . . . Tomorrow I go to Addiscombe on particular business.

Royal Military Academy,
2nd September, 1816.

. . . .It is my desire not to have more of the public money in my Hands than is actually wanted. . . I believe . . that I have more difficulties thrown in my way as to the progress of the map making by Ignorance, Avarice, and Cupidity than you have by the intervention of Mountains, Morasses with all the local difficulties peculiar to Scotland put together. . . It will, however, please you in understanding that the Work is most highly approved of and esteemed as exceedingly accurate.

10th September, 1816.

I do not imagine under all the difficulties which seem to attend the Northern Survey that the Business of another station can be achieved this year, and if so the conclusion of your operations will be found on Cairnsmuir.

Royal Arsenal,
24th December, 1816.

I wrote M. Biot yesterday, and sent him a sketch of the Triangles Mr. Gardner did for me with some but not many observations touching the best way of proceeding next Year. I dare say I shall hear from him in reply and now I beg you will be so good as to get Mr. Gardner to do for me as quickly as he possibly can another Tracing of the Triangles with the Meridian running up from Dunnose as well as Black Down, and I shall be very glad if I can be supplied with it this week. I came downstairs for the first time to-Day consoling myself with my good luck in not being prisoner to my Bedroom longer than I have been. . . I have sent my son [Lieut. Richard Mudge] to Shrewsbury to look after Mr. Stevens' Work.

West European Arc of Meridian.—In the year 1816 the project of extending northwards the European Arc of Meridian, which already stretched the whole length of France, and had been continued into Spain, was discussed on both sides of the Channel. Roy's cross-Channel connection amply sufficed for the purpose of joining the two national surveys, and the chief matter which required decision was the selection of the terminal point of the arc in Great Britain. At first the French were inclined to support Yarmouth (in Norfolk), as suited for the purpose; but eventually better counsels prevailed, and the obvious scheme of using the triangulation of Great Britain to its fullest extent was adopted, and the terminal point was fixed in the Shetland Islands.

Sometime early in 1816, Arago wrote thus to Mudge:—

"La lettre que vous m'avez fait l'honneur de m'écrire a beaucoup ajouté aux regrèts que j'avais déjà de ne vous avoir pas été présenté le jour de mon voyage à Woolwich. J'avais le plus grand désir de m'entretenir avec vous de la belle entreprise que vous dirigez avec tout de succès . . . . Le seul moyen de me dédommager sera, Monsieur, de me permettre de vous communiquer par ecrit quelques idées qui ont été souvant discutées dans le Bureau de longitudes de Paris, sur la liaison qu'on peut établir entre vos mesúres et celles que nous avons executées en France et en Espagne.

On the 19th October, 1816, Arago again writes to Mudge:—

J'ai reçu la lettre que vous m'avez fait l'honneur de m'écrire et dès aujourd'hui je vais mettre votre obligeance à contribution; je vous demanderais Si Yarmouth est déjà lié a la chaine principale de vos triangles et s'il est entré dans votre plan de faire mesurer la latitude de cette station avec assez de soin pour qu'on puisse en faire le point de départ d'une Ligne méridienne qui se terminerait à Formentera. M. Laplace, qui m'a chargé de vous presenter des complimens, tiendrait beaucoup a l'exécution de ce projet; il verrait dans l'arc compris entre Yarmouth et Formentera, le moyen de trouver avec une extrême précision la Valeur D'un dégrée de Latitude pour le 45me dégré. Cette opération aurait cet avantage précieux d'appartenir également a l'Angleterre et à la France et servirait, peut-être, un jour à établir un systeme uniforme de Poids et Mesures."

Arago goes on to say that the Institute had elected Mudge " un de ses correspondans dans la Section d'Astronomie." Laplace, on the 21st March, 1817, made a speech in the Chambre des Pairs on the subject of the measurement of the West European Arc; in this speech he alluded to Mudge as follows: Le Colonel Mudge, qui lève avec autant d'habilite que de zèle les plans de l'Angleterre et de l'Ecosse, doit se réunir aux savants français et concourir avec eux au prolongement de notre méridienne.

Jean Baptiste Biot was the Frenchman selected to work with Mudge and Colby; Arago, unfortunately, was not able to come over to England at a suitable time. Biot (1774-1862), was a friend of Laplace and Arago, a distinguished member of the French Institute, and a man of all-round attainments. But he and Colby did not manage to hit it off. Biot was ten years older than Colby, and it is possible that he did not realise that the latter had for many years been in effective charge of the operations of the survey. Biot arrived in England in May 1817, and was hospitably received. On the 20th of that month, Mudge writes :—" I have been travelling in a chaise with M. Biot, who speaks English as imperfectly as I do French." Mudge had resolved to take charge of the work, but alas! ill-health prevented his getting further than Edinburgh. He writes from Leith on the 7th June, 1817, to Colby, who was then at Aberdeen:—

" I came here with M. Biot upwards of a fortnight since and have been busily occupied in erecting an observatory, preparing for the clock, and adjusting the Circle of repetition... I am chained up here something like a wild beast against my will, finding it impossible to leave M. Biot, whom I perceive to be a very able man and a very diligent observer. ... Dr. Gregory will come out for the holidays and perhaps be at Aberdeen towards the end of the month. Mr. Thomas, Commander of H.M.B. Investigator, goes round to Aberdeen tomorrow to have an interview with you."

Ultimately, the scheme agreed to was, that Colby, Gregory and Gardner should take Ramsden's zenith sector to some station in the Shetland Islands and observe for latitude; that Biot, accompanied by Richard Mudge, should observe a latitude with the French repeating instrument at the same station, and should also take pendulum observations for the determination of gravity; that the British survey should connect the Shetland station with the British triangulation, through the Orkneys and Foula.

A letter from Laplace to Mudge has been preserved. It runs as follows :—

Paris, le 4 juillet, 1817.

MONSIEUR,

Je commence par vous remercier de la bienveillance avec laquelle vous avez acceuilli mon idée de joindre Yarmouth à la méridienne de France, en voulant bien coöperer vous même à cette jonction.

Mais je vois par votre lettre qu'en étendent jusqu'aux isles Shetland vos operations, et vous rapprochant ainsi de cette meridienne, vous croyez que l'on peut sans erreur sensible joindre votre arc de meridien au notre et qu'alors la station de Yarmouth devient inutile; je pense entierement comme vous, Monsieur, et je suis persuadé que l'extension de l'arc du meridien jusqu'au soixantième dégré de latitude est plus que suffisante pour compenser l'inconvenant qui pourrait resulter d'une petite dissemblance des meridiens aussi voisins. . . .

Je me felicite, Monsieur, de l'occasion que m'offre cette circonstance pour vous témoigner toute ma reconnaissance, et l'estime particulière que vos travaux importans m'ont depuis longtemps inspirée.

Well, the execution of this scheme was largely spoilt by the fact that Colby and Biot could not agree; Mudge not being there to take charge and compose differences. Portlock says that "Dr. Gregory attached himself to Captain Colby; and whilst the latter disliked and distrusted Biot, he, Biot, detested Dr. Gregory. Don Rodriguez, who had been so severely attacked by Dr. Gregory, had been the associate and friend of Biot in the triangulation of France and Spain." Richard Mudge in after years said that "it was fated that an eternal frost should separate Colby and Biot."

In the end Colby set up his instruments at Balta, and Biot his instruments on Unst. Mudge writes to Colby, "One great disadvantage attending your removal from M. Biot is that a comparison cannot be made between the results of observations. . . . . with the sector and circle of repetition; this is a very great misfortune"; and again, "I have never ceased to deplore, with the keenest recollection, the happiness that I thought before me nipped in the bud, and I sent home, as it were, invalided."

There is no need to go into the details of the operations; they must not be looked upon as wasted, but as somewhat injured by the want of co-operation. The coolness between Colby and Biot never extended to Arago, nor did it affect further co-operation. In November, 1817, Arago and Humboldt, accompanied by Biot, came to England with two pendulums, which were swung at Greenwich in the presence of Pond, the Astronomer Royal. Arago, Humboldt, Biot and Colby all met at Mudge's house in the Arsenal during the same month. Late in 1818, Mudge and Colby took Ramsden's sector to Dunkirk and observed a latitude with it, at the request of Arago and Biot; but "it is certain that the desire of Colonel Mudge, to bring the sector and repeating circle into direct comparison with each other, was not even gratified at Dunkirk." No blame, with regard to the Shetland affair, was ever attached, by anyone, to Mudge, who remained on friendly terms with all concerned.

Let us end this story of the Shetland work on a more cheerful note:—

Captain A. Thomas, R.N., to Colby, H.M.B. Investigator, Balta Sound, 26th August, 1817.

"I have sent you by the Jolly Boat two gallons of rum and thirty pounds of Ship Biscuit, now in return you will be so good as to send me on board the same man that was on Yell and Fetlar with me, and to-morrow evening the staff will be on Ronas Hill; and should there be any westing in the wind the day after tomorrow, the staff will be on Faul Isle. . ."

Progress of the Work from 1818 to 1820.

Mudge to Colby, April 25, 1818.

"I have a great deal to do one way or the other, so that I shall not be at the Tower until towards the end of the week, but if you will take a run down we can arrange anything that may appear pressing to you. I attended Council of Royal Society on Thursday, on business closely connected with the Survey, of which I can say nothing more at present excepting that the Pendulum is to be carried along our arch under Captain Kater."

Royal Arsenal, Woolwich,
1st May, 1818.

. . ." I was yesterday at the Committee Somerset House, when it was determined that Captain Kater should go on the Meridional Line from Dunnose to Shetland, visiting the two extremities of the Arc and three intermediate stations, and Edinburgh one of them."

Royal Military Academy,
1st September, 1818.

"The account you give of your operations is very satisfactory, and we have another proof, if another proof were wanted, of your zeal and activity. When the state of the Work shall be known to the public they will have a just means of estimating your talents which will receive their deserved reward. The Frome sheet is struck off with the Hills finished. I have been all over that quarter with the Map in my Hand and find the work excellently done. Sir Rd. Hoare, to whom I gave a proof for correction, is delighted with the work and particularly with the antiquities, to which all the persons employed on the Survey of that Quarter have paid particular attention. . . . . The Admiralty, with Mr. Croker, took down the Hampshire Survey when they settled in the South the new Telegraph line. Mr. Croker told Captain Hurd that without it they could have done nothing. Faden also says that the reputation of the Work increases daily."

In the same letter he points out to Colby the necessity of accepting the French offer to take the sector to Dunkirk.

"I do say that tho' you have no reason whatever to be pleased with Biot, and God knows I have just as little, yet I trust you will see with me the actual necessity of our concluding the work of this year in France; I feel that by so doing I shall conclude my labours honourably. . . . Captain Thomas in the Investigator will take us to Dunkirk."

14th September, 1818.

..." I am to-morrow to be at the Admiralty with Mr. Croker, and am truly happy in finding we are firmly supported in that quarter.... The work of reduction, the deadly work of reduction, is going on swimmingly. [The Ordnance estimates were being reduced and the Artillery cut down]. ... I am, thank God, perfectly well and just off a journey of 260 miles. P.S.—Mr. Gardner must go over with us."

Royal Arsenal,
21st February, 1819.

" The Duke [of Wellington] has postponed for a little time any consideration of the Scotch Survey, but proposed, when his present business is off his hands, to see whether it cannot be carried on less expensively than the way we propose." The Duke had also complained of imperfections in the one-inch sheet containing Strathfieldsaye and Mudge says, " It is my intention to battle this matter inch by inch. To all appearances I shall

See a great deal more of
His Grace than will be
pleasing.

I am quite depressed under all these considerations and mean without delay to collate all the Field Work in hand, that the vessel may be under proper Trim when the Storm comes on. Of the little time I have before me I must make all the use I can. My opinion is that the Quarter-Master-General's Department and Arrowsmiths are at the bottom of the whole of it."

That is the last letter preserved in the Colby collection from this old chief of the Survey. He had now not much more than a year to live. He died, as stated above, on the 17th April, 1820.

Robert Dawson, who had worked under Mudge since 1802, and knew him well, wrote to Colby on hearing the news:—

" Alas! the connection of 18 years is dissolved and we are left in sorrow and reflection. The General's kind and amiable disposition, his mildness of temper, gentleness of command, and many marks of attachment and regard given to me particularly, and evidently always ready for his Friends, have created and nourished a Love for him in my heart, which will ever be the first impulse with which I shall cherish his memory."

Portlock, who was a cadet when Mudge was Lieut-Governor of the R.M. Academy, says in his memoir, " The present writer, when at the Academy, enjoyed the occasional privilege of visiting at his house, and whilst participating in the friendly hospitality which he bestowed upon his young friends, and which was always distinguished by a warmth and simplicity which made them feel quite at home, even with the Lieutenant-Governor, had ample opportunity of witnessing and appreciating that never-ceasing enthusiasm for his favourite science which he felt in his own heart, and desired on every occasion to instil into the minds and hearts of his young guests."

QUANTITY OF WATER IN CONCRETE

The January, 1925, issue of *Concrete and Constructional Engineering* calls attention to the fact, that the strength of concrete depends as much on the quantity of water as it does on the quantity of cement. Too little water in concrete has the effect that the particles of sand and ballast are not sufficiently well lubricated to slip into place in such a way as to get a concrete of maximum density. The particles remain touching on points, with considerable air voids, and form a relatively porous concrete, and if the lack of water is carried to excess there may even be insufficient water to develop the full chemical action of which the cement is capable. In the same way an excess of water evaporates, and its place is taken by air, so that once more the concrete is left relatively porous with the particles touching on points instead of over their whole area. It is quite clear that the densest concrete will be the strongest, and this has been proved by numerous experiments. We print below a table prepared by Dr. Oscar Faber, O.B.E., D.Sc., M.Inst. C.E., showing the quantity of water which he uses for different concretes. He gives the following formula:—"Take 28 per cent. by weight of the cement and add 4 per cent. by weight of the sand and ballast. This gives the weight of water (at 10 lbs. to the gallon) required to give a good working mix when the sand and ballast are dry and are of non-absorbent materials." The extra amount of water required for absorbent materials is best found by weighing, say, 8 c.f., of the material both dry and after it has been thoroughly soaked in water. The difference in weight should be added to the amount calculated for non-absorbent materials.

QUANTITY OF WATER TO GIVE BEST RESULTS FOR REINFORCED CONCRETE WITH DRY NON-ABSORBENT MATERIALS.

Mix.	Weight of Materials. Lb. per bag of cement.			Volume of Materials. Cu. ft. per bag of cement.			Lb. per bag of cement.			Water per bag of cemnt. Galls.	Water per cu yd. of sand and ballast
	Cement	Sand	Ballast.	Cemnt.	Sand.	Ballast.	28% Cement	4% Sand and Ballast	Total.		
1	2	3	4	5	6	7	8	9	10	11	12
1, 4, 8	200	800	1.600	2.22	8.88	17.77	56	96	152	15.2	15.4
1, 3, 6	200	600	1.200	2.22	6.66	13.33	56	72	128	12.8	17.3
1, 2, 4	200	400	800	2.22	4.44	8.88	56	48	104	10.4	21.1
1, 1½, 3	200	300	600	2.22	3.33	6.66	56	36	92	9.2	24.9
1, 1, 2	200	200	400	2.22	2.22	4.44	56	24	80	8.0	32.4

NOTES.

(1) With absorbent materials, add enough water to provide for full absorption.

(2) When materials are wet, reduce water, but not below that quantity given in Column 8.

(3) Cement, sand, and ballast are taken as weighing 90 lb. per cu. ft.

(4) Cement should always be measured by weight.

THE CHEMICAL WEAPON.

Précis of an Article by "Talin" in *Voina i Mir*, No. 13.

By LIEUT.-COLONEL A. H. BELL, D.S.O., O.B.E., R.E.

The Editor, M. Kolossovski, in a short preface, writes — A characteristic of modern military literature is the rare and grudging discussion allotted to the most important and essential questions. All nations are secretly and silently preparing tactical and technical surprises for their future enemies. The fact that the author of the article is a man of deep erudition, with a wide experience of war and a thorough knowledge of facts, makes his article of considerable value both from a scientific and a practical point of view.

If the war had continued till 1919, by which time the mass production of gas would have been developed and gas bombs would have been used by aircraft, the whole aspect of affairs would have been completely changed. As it is, many people are sceptical about the extensive use of poison gas, and think that its use hitherto has not justified expectations. The war of the future will be as different from the last, as the latter was from the Crusades. The characteristic of the new weapon is the extensiveness of its action as compared to the linear action of ordinary projectiles. The power of this new weapon depends on the quantities in which it can be produced. There have been many fantastic rumours about discoveries of new gases possessing the most improbable qualities, such, for example, as Lewisite, yet when it was tested in European laboratories, it proved to be by no means so terrible as Americans had made out. Even if the ideal war gas were discovered, an antidote to it would surely be found, as it has been to other gases. At the present time there is a defence against all war gases. Modern gas-masks possess powerful absorbers which retain all poison gas, partly by mechanical means, partly by the aid of chemical reactions. But against the use of gases in large quantities this form of defence is insufficient, as the duration of its effectiveness is limited. A zone 50-70 kilometres wide poisoned with yperite* is almost impassible to a soldier even though equipped with a gas mask

* Yperite is $\beta\beta^1$ dichlor diethyl sulphide $(CH_2ClCH_2)_2S$, or mustard gas.

and anti-yperite clothing. A man may have to live in such an area from two to four days, but the ordinary absorber is efficient for several hours only; all water and food would be poisoned, horses and transport animals would suffer in an even greater degree than man, moreover, during marches defence against aircraft would be necessary. Only gas-proof trains and tanks could move over the area in safety.

A saturation of one part of air by a millionth part of yperite is sufficiently strong for military purposes. On this basis about seven tons of yperite would be required to saturate an area of 50 sq. kilometres to a height of 20 metres. Germany, at the end of the war, using the complicated method of Meyer, was producing 1,000 tons of yperite per month. America, using Gouthrie's perfected method, will be able to turn out 300 tons per day. The quantity of lachrimatory gas required for infecting large areas would be considerably less, as a weaker mixture is effective.

In the late war poison gas did not occupy a dominating position because countries were not in a position to use it in large quantities and because the means of spreading it were primitive. The use of gas cylinders was a clumsy method, which was completely abandoned towards the end of the war. It was liable to easy discovery by the enemy, was dependent on winds, and could not be used in connection with persistent gases, which are the most valuable from the military point of view. In future, the use of portable reservoirs of poison gas will be a possibility, such as poison candles, which can be made to any dimensions. They consist of metal envelopes of any form, usually cylindrical, filled with a compressed mixture of any easily inflammable material, such as smokeless powder and one of the arsenic compounds. They give out thick clouds of poisonous smoke. Chemical fougasses will be much used; by their means it will be possible to infect evenly and economically large tracts of deserted territory. Various types of chemical machines will be employed for poisoning abandoned trenches and buildings.

Artillery will use chemical shells almost exclusively. At the end of the war 50-60 per cent. of German shells were filled with chemicals. Most of the gases used will be persistent, such as yperite, lewisite, various arsenic compounds and several kinds of lachrimatory gas.

Chemical shells filled with persistent gases will have the bursting properties of common shell; the action of yperite is much increased when forming part of the charge of a shell. There will be no sense in using ordinary common shell or shrapnel, as chemical shell will combine the ordinary bursting effect with poisonous action. In shrapnel the chemical materials will fill the interstices between the balls. Poison gas will be used by all types of combatants, tanks will use smoke as screens; the Navy will use smoke and also poisonous gases, which will penetrate through the ventilating system of a vessel and choke the crew.

In all modern armies special gas and bomb-throwing units have been introduced, with special gas-throwing weapons, such as Stokes mortars; in the future war portable projectors will play a large part.

But poison gas will be most frequently and effectively employed from aircraft. Aeroplanes carrying loads of five to ten tons will bombard areas deep in the enemy's rear. The aero-chemical weapon annihilates all the old conceptions of war. The front used to be looked upon as defending what lay behind; all efforts of the enemy were directed towards the breaking of this protective line. Now-a-days the front line will have scarcely any significance. The limits of the battlefield will be extended indefinitely, depending only on the range of aeroplanes. A clear distinction between the army and the peaceful inhabitants will disappear, as every citizen will be under the threat of attack. Poison gas will be the principal weapon of attack for aeroplanes against the army, the fleet and the civil population, as the value of the results will be greater than those obtainable by any other form of load. In open places the effect of gas lasts from two to ten days, and in towns from six to thirty days. According to calculations a two ton yperite bomb will affect an area of 140,000 square metres. When it is required to make large areas of land impassable, in order, for example, to cut off the retreat of the enemy, to defend the flanks, or to prevent pursuit, aeroplanes will scatter bombs of small calibre, according to a pre-arranged plan, a certain number of bombs to a certain area. For such purposes persistent gases only would be used.

The country most advantageously situated for chemical warfare is that with a highly developed chemical industry, large cadres of chemical personnel and up-to-date aviation factories. From this point of view, Germany had a crushing superiority in the last war, but was unable to make use of her advantages owing to the strategical, tactical and technical mistakes she made in the use of gas. Her chemical industry appears to be now based on an *Interessen-Gemenischaft* a trust embodying the whole of the dye companies. The United States towards the end of the war developed their industry with great energy. In the Edgewood Arsenal a whole war-chemical town grew up. In spite of the Washington Conference, this arsenal is still fully equipped and ready—a fact which the Americans make no attempt to conceal. Very shortly after the declaration of war the Edgewood Arsenal could produce 100 tons of yperite per day—using all their factories probably 300 tons a day could now be produced—whereas at the end of the war Germany could produce only 40 tons per day of yperite and 3,000 tons per month of gases of all kinds. But the chemical activity of America is not confined to yperite. In the event of mobilisation there would come under the immediate control of the Edgewood Arsenal a number of important chemical factories, such as the Electro-Chemical Co., Oldbury (phosgene); Midland factories (tear gas); Charleston W. factories (raw material for yperite); factories in Buffalo (yperite), Croyland (lewisite, arsenic compounds); Kingsport (tear gas); Stamford (chloropicrin); Hastings-on-Hudson (yperite), and so on. The production of poison gas in the United States would reach fantastic figures.

Serious steps are being taken in England, but with far less success than in America. Research work of a high order is being carried on, and great success has been obtained in investigating the qualities of yperite and in the methods of producing it. One such process has been the obtaining by Gouthrie's method of a stable form of yperite approximating in purity to that obtained by the much more complicated German process (Meyer's). As is well known the Germans were unable to turn out sufficient yperite to keep the front supplied. The allies produced yperite by a much simpler process, the action of ethylene on chloric sulphur. The advantages of the German production were that the yperite was considerably cleaner, more powerful, more difficult to detect, being almost without smell, and far more stable. The resources of England generally are a long way behind those of America, her dye industries being in a decadent condition, notwithstanding subsidies from the Government.

A new war-chemical star is rising on the European horizon—France. Before the war her chemical industries were weak, but now having confiscated the German chemical factories in Alsace and made use of a number of chemical secrets obtained as a result of control, she can consider herself the strongest war chemical power on the Continent. Her lack of experienced chemical personnel is made up for by the work of foreign chemists. The chief organising centre is the *Compagnie naturale des matières colorantes et produits chimiques*, with factories at Villers St. Paul and at Oisel. To this company are united the *Compagnie Parisienne de couleur d'aniline* and *Manufacture Lyonnaise de matières colorantes.* Another large French chemical centre is *Société anonyme de matières colorantes et produits chimiques de Saint-Denis*, with a capital of 60 million francs. Others are *Société Alsacienne de produits chimiques*, and *Société chimique de la grande Paroisse.* These factories are already in a position to satisfy 80 per cent. of the French demands in dyes, and in the event of war would be converted into centres for the preparation of poison gas.

The comparatively inconsiderable production of poison gas in the late war is partly explained by the lack of means for utilising it. There were times when there were not sufficient shells available for filling; the use on a large scale of gas projectors, chemical fougasses, poison candles and huge aeroplane bombs will completely change this aspect of affairs. It will no longer be necessary to scatter whole mines of expensive metal over the battlefield, thousands of tons of poison gas will be distributed by much cheaper methods.

The most important materials required for the production of poison gas are chlorine, bromine, arsenic and sulphur. Chlorine is a property of all the chief poison gases: phosgene, superpalite, chloropicrin, yperite, lewisite. Peace production is much smaller than war requirements; more extensive uses for chlorine in peace time are being sought; experiments are being made in the use of chlorine for the production of cellulose, and if these are successful the question of the use of the surplus chlorine would be solved. Bromine enters into the composition of the majority of lachrimatory gases, but most countries are entirely deficient of the means of obtaining it. To get bromine from the ashes of seaweeds or from the water of salt lakes is a complicated and expensive process. Arsenic was not used in poison gas before 1917, but in the last part of the war, first aliphatic and then aromatic arsenics were in use. The latter can be reduced to a particulate state by means of a strong bursting charge, and possess greater power of penetration through the filter of a gas mask than the aliphatic.

Sulphur is a component part of the most important war gas, yperite. All countries are trying to improve the mass production of yperite in case of war, but most of them are not in the fortunate position of Italy and the United States. Owing to a lack of sulphur Germany was unable to produce yperite in the quantities desired.

It is unlikely that there will be a wide use of cyanide compounds in the next war, as experience has not given positive results.

Chemical and dye industries as organised in peace time are far from satisfying military demands in explosives and poison gases; only a few of the four or five hundred materials produced in dye factories are of value for military purposes. In France in 1922 the year's production of dyes hardly amounted to 8,000 tons, whilst during the war France produced about 25,000 tons of poison gas. Germany used to produce 125,000 tons of dyes per year.

For defence against gas careful preparation of all inhabited points and of the whole population is indispensable in view of the use of long distance aeroplane bombers and gas sprinklers and of huge dirigibles capable of transporting tons of poison gas at a time. The problem is two-fold—individual defence and collective defence. As regards the first, anti-gas methods have been evolved on much the same lines in all countries. In the perfect gas mask the following points are aimed at:—

(*a*) Reduction of the harmful space (that between the skin and the material of the mask in which part of the carbonic acid exhaled is retained).
(*b*) Increase of field of vision.
(*c*) Firm adherence to the face.
(*d*) Lightness.
(*e*) Impermeability to all kinds of poison gas.
(*f*) Reliable valves.
(*g*) Easiness of putting on.

The most important part of the mask is the absorber which is enclosed in a respiratory box (container). It usually consists of three parts, specially prepared charcoal, some chemically active material, such as hyposulphite of soda or permanganate of potash, and a filter (generally made of felt). The charcoal absorbs nearly all the poison, the chemical reacts on the remains of the gas, the filter serves to retain the smoke, *i.e.*, the fine solid particles which pass through the first two parts of the absorber. Not all " smoke " can be stopped by the filter; absorbers must be perfected so as to be of universal application, but the contents must not be so dense as to be an obstacle to breathing.

In addition to masks, anti-gas clothes are necessary to protect the skin from the action of lewisite and yperite, and wearing them involves loss of efficiency in the soldier. In the last war the gases used were mostly of volatile varieties; persistent gases which will be used in future wars will cause gas masks to wear out much more quickly. Moreover, large numbers of civilians must be provided with them, so that the numbers to be manufactured will run into hundreds of millions. Gas refuges, provided with filtering and ventilating systems, were constructed during the last war, but had the disadvantage of being immobile. In the future wars gas refuges in the form of folding tents, made of impermeable material and provided with ventilators and filters will be used. The latter can be improvised from earth or sawdust saturated with lubricating oil or other sticky liquid.

Gas attacks will for the most part be directed on large towns, industrial centres, railway junctions, harbours, fortresses, etc. It must not be supposed that as soon as war is declared all the large towns will be at once destroyed and the inhabitants poisoned, active defence by aeroplanes would beat off an attack for a considerable time, nevertheless it must be admitted that in modern war the inhabited industrial centres will be under the immediate threat of destruction and poisoning. Anti-gas defence must, therefore, be employed not only at the front, but throughout the country. Every person immediately necessary to the Army (and after them the remaining inhabitants) must be supplied with individual means of defence. Gas refuges must be ready on a large scale. The supply of food and ammunition, etc., to the Army will have to be specially safeguarded, trains will have to be provided with ventilating and filtering arrangements. Individual protective measures could not be used by young children and old people, nor by invalids with weak respiration; this mass of people would be defenceless unless anti-gas buildings were prepared for them beforehand. In future any large building it is proposed to construct in a town liable to attack, will have to be regarded from a new point of view, that of suitability for use as a gas refuge. A system of neutralisation of poison gas by anti-gas liquids will have to be arranged; oxidisers, chloride of lime and permanganate of potash are the most useful. The expenditure will be very great, as 20 kilograms of chloride of lime are required to neutralise one kilogram of yperite. Mechanical means will also be used, such as spreading charcoal or ashes in the streets, lighting bonfires, and by small explosives.

To sum up: "In view of the mass production of poison gas and the perfected technique of aviation, in the war of the future every citizen will become a soldier and every foot of territory a front."

NOTE.—Mr. J. B. S. Haldane, in his little book "Callinicus" (Kegan Paul, price 2/6) divides poisonous substances into four classes according to their effect on men:—

(1). Gases and vapours which are poisonous when breathed, but have no effect on the skin, such as chlorine and phosgene.

(2). Those which irritate the eyes but are only poisonous in very high concentrations.

(3). Poisonous smokes, mostly arsenic compounds; in small amounts they cause sneezing, in larger quantities they cause pain of an acute kind in the head and chest. They penetrate respirators.

(4). Blistering gases, which are poisonous when breathed and cause blisters on the skin. Only one such gas, dichlorethyl sulphide or mustard gas, was used during the war. It is called "yperite" by the French and Russians.

NOTES ON THE DESIGN OF T BEAMS IN REINFORCED CONCRETE.

By CAPT. W. A. FITZG. KERRICH, D.S.O., M.C., R.E.

NOTE: All symbols used have the same meaning as in the Reinforced Concrete Manual issued by the S.M.E., and page references are to the Manual.

(1) T beams in reinforced concrete are of two kinds; those in which the neutral axis is inside the slab, and those in which the neutral axis is outside the slab.

The former class are designed by rectangular beam formulae, the latter by T beam formulae.

Calculations with T beam formulae are very much more laborious than calculations with rectangular beam formulae.

The object of these notes is to show that, even when the neutral axis falls outside the slab, rectangular beam formulae may be used so long as the " equal strength ratio " is not exceeded.

(2) Since a complete set of graphs are given in the S.M.E. Manual, which practically eliminate the use of all formulae for R.C. calculations, it may seem of little interest to investigate the matter.

It must be remembered, however, that these graphs are only made possible by assigning fixed values to certain factors in the problem, viz.:—

$m=15$
t (safe working)=16,000 lbs./in^2
c (safe working)=600 lbs./in^2

These are the values assigned to them by the L.C.C. regulations, and are generally accepted in civil practice in this country.

The constant advance in the strength and reliability of the materials used in reinforced concrete may at any time invalidate one or other of them, and render useless the whole or portions of the graphs.

In support of the above contention the following may be cited.

1. *R.E. Journal*, September, 1924. Report on the International Cement Congress. It is here argued that certain aluminous cement concretes have a safe working stress of 1,300 to 1,400 lbs./in^2.

2. *Concrete and Constructional Engineering*, September, 1924. The Modulus of Elasticity in compression of Concrete. According to this article the value of the modulus is 5.46×10^6. This would give a value for m of approximately 5.5.

(3) T beams in which the steel is the ruling factor, i.e., those in which the steel is stressed up to the maximum safe intensity under full load, but the concrete is not, are calculated from the following formulae (see pp. 51-53).

$$B = t\ A_t\ (d - y)$$

$$\text{where } y = \frac{d_s}{3}\left(\frac{3n - 2\ d_s}{2n - d_s}\right)$$

$$\text{where } n = \frac{2\ r\ m\ d^2 + d_s^2}{2\ (r\ m\ d + d_s)}$$

Whether the steel or the concrete is the ruling factor is easily determined from the formula on p. 54 for the equal strength ratio.

$$r' = .0375 - .052\ s_1.$$

For a rectangular beam of the same breadth and total depth the formulae are (see pp. 16-17).

$$B = t\ A_t\ (d - \frac{n}{3})$$

$$\text{where } n = m\ r\ d\left(\sqrt{1 + \frac{2}{m\ r}} - 1\right)$$

The problem usually met with in practice is, knowing the load to be carried, to find the dimensions of the beam, and the amount of reinforcement necessary for the purpose. This can only be done by trial and error if no graphs are available, and the process is laborious. If it is possible to use the rectangular beam formulae in the place of the T beam formulae, i.e., to calculate a T beam as if it were a rectangular beam of the same width and total depth, a lot of time and calculation will be saved.

As soon as the value of m has been decided on, a graph plotting $\frac{n}{d}$ against r is easily got out (Graph No. 1 in the Manual), and the rectangular beam formulae are then obviously very simple. A series of such curves would be necessary for the T beam formulae, since in calculating n an independent factor (d_s) is introduced.

In the Manual, two sets of graphs (3a and 3b) are all that are required for rectangular beams, whereas seven (9a — 9g) are necessary for T beams.

(4) By comparing the two formulae for the value of B it is obvious that the percentage of error involved in using rectangular for T beam formulae is

$$\frac{\frac{n}{3} - y}{d - y} \times 100$$ where n has its rectangular beam value.

The values of n and y however, depend on so many variables that the expression is too complicated for mathematical analysis; and it has been found necessary to fall back on numerical examples.

In Table A (see next page) the smallest depth of slab used in practice d=3″ has been taken. The percentage of error has then been worked out for varying effective depths of beam from 18″ to 30″ the latter being as deep as the beam is likely to be with a 3″ slab.

Different amounts of reinforcements have also been calculated for.

The following deductions can be drawn from the table:

(*a*) That the error is *always on the safe side* since $\frac{n}{3}$ is always greater than y.

(*b*) That the error increases with the amount of steel used, up to the equal strength ratio, when the formulae are no longer applicable.

(*c*) That the error increases as the depth of the beam increases in comparison with the depth of the slab.

The maximum error in the table is 4.28% and it is hardly likely that a T beam will be found in practice in which the conditions are more unfavourable, since the equal strength ratio has been reached, and

$$s_1 = \frac{d_s}{d} = 0.10$$

(5) In view of the many assumptions and approximations made in reinforced concrete calculations (for example b_s is arrived at from purely empirical formulae, see p. 49) it would appear that such a small percentage as this might be neglected, and all the T beams in which the steel is the ruling factor be calculated as if they were rectangular.

Even if results arrived at by this method are not considered to be sufficiently accurate, the limits within which it will then be necessary to do trial and error calculations with the T beam formulae will be very small.

(6) T beams in which the concrete is the ruling factor must be calculated by T beam formulae.

They generally occur when headroom is limited, and are not often met with in practice. As will be obvious from the graphs in the Manual a large increase in the amount of steel used only gives a small increase in the strength of the beam, and they are not, therefore, usually economical.

TABLE A. FOR A T-BEAM WITH A 3 INCH SLAB.

$$\% \text{ error} = \frac{\frac{n}{3} \text{ (for rectangular beam)} - y \text{ (for T beam)}}{d - y} \times 100$$

r	d=18 s₁=.167				d=22. s₁=.136				d=26. s₁=.115				d=30. s₁=.100			
	$\frac{r^1}{r}$	n/3	y	Error %	$\frac{r^1}{r}$	n/3	y	Error %	$\frac{r^1}{r}$	n/3	y	Error %	$\frac{r^1}{r}$	n/3	y	Error %
.001		N.A.	in slab		.0073	1.17	1.13	0.19	.0087	1.38	1.23	0.66	.01	1.59	1.30	1.01
.0015	.009	1.14	1.12	0.12	.011	1.39	1.24	0.72	.013	1.65	1.31	1.38	.015	1.90	1.36	1.89
.002	.012	1.30	1.20	0.60	.0147	1.58	1.30	1.35	.0173	1.87	1.35	2.11	.02	2.16	1.39	2.69
.0025	.015	1.43	1.25	1.07	.0183	1.75	1.33	2.03	.0217	2.07	1.38	2.64	.025	2.39	1.40	3.44
.003	.018	1.55	1.29	1.55	.022	1.89	1.35	2.61	.026	2.24	1.39	3.45	.03	2.58	1.41	4.07
.00323													.0323*	2.67	1.42	4.28
.0035	.021	1.65	1.31	2.04	.0262	2.02	1.37	3.15	.0303	2.38	1.40	4.02				
.00362									.0314*	2.42	1.40	4.14				
.004	.024	1.75	1.33	2.52	.0293*	2.13	1.38	3.63								
.00413						2.16	1.38	3.78								
.0045	.027	1.84	1.34	3.00												
.00481	.0289*	1.88	1.35	3.18												

* Equal strength ratio. $r^1 = .0375 - .052\, s_1$

ARTHUR FFOLLIOTT GARRETT PRIZE ESSAY, 1924.

"*MODERN SCHEME OF WATER SUPPLY FOR A LARGE CANTONMENT OR TOWN WITH A POPULATION OF ABOUT* 20,000 *INHABITANTS IN A TROPICAL OR SEMI-TROPICAL COUNTRY.*"

By "SIGMA" (MAJOR A. P. SAYER, D.S.O., R.E.).

SECTION I.—INTRODUCTION.

THAT oft quoted person "the man in the street," essentially a town dweller, does not usually concern himself with how he gets his water. All he knows is that it comes in pipes and that he can get what he wants by turning on a tap. Occasionally he finds there is something beyond his control affecting it; he is called on to pay a water rate bill, or he finds an excavation by men "doing something to the mains."

To his more isolated country cousin water supply is a matter of personal labour. He is concerned with the source of supply and the labour of getting water from it. A combination of these two view-points would provide the rudiments of a supply scheme. Between them they give the source, the means of getting water from it, and its distribution. The quality, however, is not questioned, and that is the most important consideration in a modern scheme.

It is axiomatic that a pure and ample water supply is one of the greatest factors in the prevention of disease. In preparing and working such a scheme the pathologist and the engineer must proceed hand in hand.

Town life involves an unnatural density of population and that of itself is apt to breed disease and help its spread. If the natural resources permitted each individual to obtain his own supply independently, the health of the community would be at the mercy of individual carelessness. Efficient control can only be exercised over a limited number of sources of supply, the points most accessible to contamination, and proper purification can only be assured when the whole supply is treated in bulk.

The necessity for medical control is obvious under any conditions, but it becomes insistent in a town with a mixed population in a tropical or semi-tropical climate. There, individual resistance to disease is usually lower and the conditions are more favourable to its spread.

In designing a project for a modern water supply under these conditions the doctor must fix the standard of purity for drinking purposes and must advise on the quantity and degree of distribution.

The engineer has to provide the water, bring it to the required purity standard and deliver it to the consumers in the necessary quantities, all at a minimum cost.

Each case will depend on local conditions. No two places are exactly similar, and the term "tropical or semi-tropical" covers wide variations.

It is not possible, therefore, to define a system suitable for all such places. All that can be done here is to review the chief components of a modern scheme and the forms they may take.

From that, and from the study of existing systems in similar places, it should be possible to develop a suitable modern scheme for any particular place.

The following points of such a system will be dealt with :—

Source of supply.
Bulk supply.
Purification.
Distribution.
Control.

II.—THE SOURCE OF SUPPLY.

Water occurs in various forms, its natural cycle being from the the sea by evaporation to the air ; from the air by deposit as dew or by falling as rain, snow, etc. back to the sea or on to the ground surface ; thence, by flow along the surface or percolation through it, back to the sea. Occasionally a break from the cycle occurs when the surface flow or percolation collects the water in some position whence it has no natural outlet. Any of these stages may be utilised for obtaining a supply. The practicable sources for supplying a town are :—(*a*) The sea, (*b*) rain, (*c*) springs, streams, rivers, etc., (*d*) shallow wells, (*e*) deep wells.

The Sea.—As a source of supply, provides an unlimited quantity of water at small cost to coast towns, but the water is unfit for domestic or industrial use without treatment. The only satisfactory method of making it suitable for such use is by the costly process of distillation or condensation. The water thus obtained is somewhat dull and unpalatable, but is in its purest form. Owing to its high cost the supply of such water must be strictly limited. This source of supply, therefore, would only be adopted where no other could be used. Aden may be cited as an example of the use of this source of supply. There, the long periods without rainfall and the absence of wells and surface water give no alternative. In addition, in many sea ports condensation of sea water is used for marine and industrial purposes, and in some cases these plants form a reserve or stand-by for use in the event of failure of the normal source.

Apart from the requirements for domestic and industrial purposes coastal towns have in the sea a cheap and unlimited supply from which to draw for any purpose for which purity is not essential.

Such include fire protection, water borne sewage disposal, drain flushing, road watering and such like sanitary uses. This source of supply should, therefore, be investigated in a coastal town :

(1) For domestic and industrial purposes when no other source is possible.

(2) For protection and sanitary purposes in all cases.

Rainwater.—As a direct source of supply, is seldom used for a town. It is frequently made use of for individual purposes by collection from roofs of buildings, as the water is soft and usually free from impurities. Such collection is, however, a source of danger in tropical and semi-tropical places on account of the encouragement to mosquito breeding. Individual collection and storage should be deprecated owing to the difficulty of control.

In many places, however, this source will repay consideration when dealing with a communal system.

The conditions that are necessary are :—

(1) A fairly steady annual rainfall.

(2) A convenient area for use as a catchment, that can be protected from fouling.

(3) Ample accommodation for suitable storage reservoirs.

If any of the following conditions are also present the cost of a supply system based on this source would be greatly reduced :—

(4) The rainfall is spread over a large part of the year.

(5) The catchment area is situated on a slope with an impervious surface or one that can be easily made one.

(6) The catchment area is at such a height that it can supply reservoirs situated at a sufficient height to eliminate or reduce pumping for distribution.

With regard to these conditions No. 4 reduces the storage capacity required. No. 5 reduces loss by percolation and evaporation ; it also permits of simple cleaning of the area by using the first rains to flush it and run to waste. No. 6 provides a gravity supply, the advantage of which is obvious.

It should be noted that the length of the maximum dry periods will fix the storage capacity required and the minimum annual rainfall will decide the area of the catchment. Gibraltar is an example of a place where the conditions are generally favourable. Originally individuals were dependent on their own collection, but now the supply under the control of the Sanitary Commissioners is gradually replacing this.

The general system consists of a concreted catchment area high up on the sandy slope on the east side of the Rock. A channel at its foot collects and conveys the water to reservoirs cut inside the Rock itself at a level above the town. Thence it is distributed by gravity, except to certain raised or outlying points.

The cost of such a system depends chiefly on the cost of storage accommodation, and this will usually involve a separate distribution system for sanitary water.

Control of this source of supply is simple and upkeep small.

Streams, Rivers and Lakes.—This is perhaps the most common source of supply. Surface waters are usually soft, but contain many organic impurities, as the natural drainage of the country side is by the streams and rivers. Hill springs and streams are frequently drinkable without treatment. The method of using this source will depend on its form.

Springs should have their surroundings protected and fenced, and the actual outfall should be built up to prevent the water coming in contact with the ground surface. It should be piped to a collecting reservoir, whence it can be pumped as required. The output should be measured at the driest period of the year and calculations based on that minimum. Usually several springs will be required or they may be supplemented by other sources.

Hill Streams should be collected by catchment channels, which will allow excess or storm water to escape. Otherwise they should be treated in the same way as springs and their catchment areas acquired if possible, and villages, dwellings, etc., excluded.

Mussoorie, an Indian hill station, is an example of the use of springs and hill streams. No purification is required, but dispersed pumping and service storage are necessary owing to the number of sources and the grouping of consumers round the various hill tops.

Lake Water gives a simple source to operate and sometimes it is an advantage to form an artificial lake by damming a river or stream. The pump intake must be clear of local contamination so as to get the advantage of diffusion of impurities. The minimum inflow and the seasonal variation in water level in natural lakes must be noted. In artificially constructed or improved lakes weir outfalls steady this level. In such cases it is worth while considering the use of waste power of the outfall.

Naini Tal, another hill station in India, is an example of this. There, a high natural lake with a steep outfall provides the source of supply and the power for pumping as well as for electric lighting, by a hydro-electric plant.

River Water is usually collected from wells or sumps in its banks or bed. In tropical climates large variations in level must be allowed for and in flat country the possibility of changes of bed must be considered. Training works may be necessary, but when possible the pumping station should be situated where changes cannot occur.

As in lakes, points of local contamination must be avoided; the intake should be above a town if possible.

In special cases where no river or other source is available, it may be possible to lead water from a distant river by means of a canal, as is done at Ismailia and Suez, with the fresh water canal from the Nile. Canal water is, however, usually much more liable to contamination than river water.

For any of these sources the question of water rights must be considered and, if necessary, the cost of compensation must be included in the project.

Shallow Wells.—These are the traditional and almost universal sources of supply in the plains of India and other similar places. They are sunk in or near rivers or into water holding strata, that is, in the permeable subsoil immediately below the surface, and are in consequence very liable to contamination from sewage, manuring of fields, etc. They will be steined with masonry or brickwork to prevent caving in. It may be found advantageous to extend their collecting area by means of horizontal adits or galleries below water level. The yield of wells may be ascertained by pumping tests or more simply by recuperation tests. For each well there is a critical output; if this is exceeded the surrounding soil will be disturbed and the well will silt up or may cave in.

For each well there is a "cone of depression," and if the cones of two wells meet, the output of one will be affected by pumping from the other. The wells must, therefore, be dispersed.

This leads to pumping difficulties. Adits must be run below water level to a central sump—a difficult matter; syphons must be arranged—a likely source of trouble; or a suction pipe from a central suction chamber must be led to each well, involving loss of power. Otherwise separate pumps and dispersed power must be applied.

One well and pump per house or group is possible, but this defeats control, the main principle of a modern system. A shallow well source has, therefore, little to recommend it for a town supply.

Deep Wells are distinct from shallow or surface wells in that they pass through a stratum that the local surface water cannot penetrate and tap sources below it.

Owing to the wrinkling of the earth's crust, strata through which water can percolate freely may occur on the ground surface in one place and be carried at considerable depths in others. A stratum such as this, with an impervious layer beneath it to prevent further percolation, and another such layer above it to prevent ingress of surface water, is the source aimed at by a deep well.

In some places the lower impervious strata may form a cup which collects the subsoil water and retains it. Such water is under pressure, or, at least, if the upper retaining layer of impervious stratum is pierced by a tube, the water will rise in it, owing to the hydraulic gradient. The nearer the water reaches to the surface, the less pumping will be required and, therefore, the greater the efficiency of this source of supply.

Some places are fortunate enough to find such wells artesian in action, that is to say, the water rises to or above the ground surface.

The possibility of using such a source of supply depends entirely on the geological formation of the locality and its surroundings. If the geological formation and history is known, well and good. If no previous deep borings have been made the possibility of sinking a trial bore must be considered.

The usual form of these wells is an iron tube with the portion in the strata to be tapped in the form of a strainer, which allows the entry of water, but excludes the sand and gravel that carries it. Its diameter is kept as small as the pumping arrangements will permit, consistent with a good yield. It is sunk in the ground by sinking a boring pipe of larger diameter. This is forced vertically down by pressure while the earth, rock, etc., inside it is broken up and removed. The boring pipe is removed after the strainer and tube, suitably shrouded, have been lowered inside it.

Meerut Cantonment in the U.P. District, India, may be cited as an example of a case of the successful use of this source of supply. There a 10-in. tube well supplies all barracks and cantonments, and the yield has at times reached 35,000 gallons per hour: in this case the depth of the well is only 270 feet.

A similar scheme is being installed in Allahabad Cantonments to replace the doubtful municipal supply. There the tube depth is 300-ft., pumping depth 120-ft., with anticipated yield of $1\frac{1}{2}$ to 2 cusecs per tube.

Points to be remembered in considering this source are :—

(*a*) The water is generally fit for drinking without treatment.

(*b*) The cost of sinking tubes increases considerably with the depth.

(*c*) Pumping costs vary inversely with the approach to artesian effect ; and

(*d*) Above anything else the geological formation must be suitable.

SECTION III.—BULK SUPPLY.

Under this heading the chief requirements between the source of supply and the distribution system will be considered. Such arrangements for purification as may be necessary properly come under this head, but will be dealt with separately.

Pumping Plant.—In nearly every case pumping will be necessary at some stage while dealing with the water in bulk. The type of plant to be used will depend on the conditions of the particular case. This plant has to give long and regular service and the efficiency of the whole system depends on it. It must be realised that the standard of efficiency of the staff in a tropical or semi-tropical place will generally be considerably below that ruling in England; similarly, the standard of supervision may be lower. In any case the expert inspection and advice of the manufacturers will not be available and the time taken to obtain parts for replacements will be long.

For these reasons the plant selected should be of proved reliability and such that no particularly expert supervision is required nor frequent fine adjustment necessary. Sub-divisions or "sets" should be standardised so that spares will serve any "set" and delays of special manufacture will be avoided. Provision must be made for reserve or stand-by plant to prevent interruption of the service and to meet emergencies.

Types of Pumps.—The type most commonly used is the double acting lift and force pump; it is simple in action and simple to maintain.

In some cases centrifugal pumps are more suitable, on account of their compactness and high lift capacity. They require rather more attention and more expert adjustment than the former type. Another form of pump that has developed from the centrifugal pump is the vertical-spindle tube well pump. It consists of a series of vanes or impellers on a shaft working centrally in a tube, either the tube of the well itself or a special tube lowered into the well. Each impeller raises a column of water to the next above. Such a pump needs very careful adjustment and very specially designed bearings.

Another type is the air-lift pump suitable for tube wells, but uneconomical except where one compressor can serve several tubes.

Power Plant.—Steam plant, internal combustion engines, electric motors, or water power may be used; wind power can be used for individual wells, but is too variable for normal use for water supply. The choice is not decided solely by the cost on site of the fuel nor on the cost per H.P. produced. Each type has its particular advantages which must be considered in connection with the particular conditions.

Steam plant is very generally used. It is usually economical for the steam producing plant to be used continuously, and it is, therefore, suitable when one boiler house can supply pumps that can be used alternately.

Internal combustion engines driving pumps direct are suitable for periodical pumping when the pumping points are separated.

Electric motors are convenient for dispersed pumping as the power can be easily distributed though centrally produced and controlled.

Water power for direct pumping may be used occasionally but it is usually better to instal a hydro-electric plant and pump electrically.

Reservoirs.—Some form of storage is required to deal with the water in bulk. Normally open reservoirs for untreated water and a protected "clear water well," with the purification arrangement between, will be provided. The rate of supply will decide the capacity of the former and the rate of consumption that of the latter.

When possible, reservoirs should be excavated, to reduce the thickness of walls required, and floors and walls should be impervious, to avoid percolation losses. They should be large in area rather than deep; an increase in depth means a large increase in capacity, but a loss of head. They should be divided to permit periodical cleaning. In cases where the supply rate falls below the consumption rate during parts of the year, special storage arrangements are necessary. These will usually take the form of impounding reservoirs, and their capacity is fixed by the maximum deficiency for the maximum period, due allowance being made for evaporation and other losses.

SECTION IV.—PURIFICATION.

No natural source produces absolutely pure water: the solids, liquids and gases with which the water has come in contact contaminate it.

The impurities are carried in three forms: suspended, colloidal and dissolved, and may be organic or inorganic. For drinking purposes organic impurities are the chief concern, as these carry harmful bacteria. The salts in solution are usually so diffused as to be harmless, but analysis and medical advice will show if special treatment is necessary. For domestic purposes other than drinking the degree of hardness is of importance, as it is also for boiler feed-water, etc., and industrial use.

The methods of freeing water from impurities can be roughly divided into storage, filtration, chemical treatment and heat treatment. Any of these, or a combination of them, may be used, but the last is impracticable for town supplies.

Storage.—This allows sedimentation, by which suspended matter is deposited, equalization, by which abnormal pollution is diffused, and the time taken to pass through the reservoirs kills the bacteria. It involves rest or slow movement for the water and, therefore, requires large reservoirs.

Filtration.—Mechanically removes the impurities by passing the water through a material that will prohibit the passage of the impurities.

This may be effected by slow flow through graded sand filters, in the upper layers of which a film forms that holds up the finest particles and the majority of bacteria. Rapid or pressure filters are less satisfactory for domestic supply. As a possible development the Hele Shew pressure filter with sheets of water-proof paper under pressure, might be examined as it promises minute filtration in small space.

Chemical Treatment.—May be employed for three purposes: (*a*) to kill bacteria, (*b*) to coagulate suspended matter and in precipitating it to carry with it the bacteria and finest colloidal impurities, and (*c*) to soften the water.

For the first purpose the most generally successful treatment is chlorination.

Some form of mechanical device should be employed, such as a "Chloronome," to treat the water as it flows and to regulate the dose. If too much is added the water tastes and has to be treated with sulphurous acid or other means. For the second, sulphate of alumina is added to the water, and reacting with the carbonates in the water forms the insoluble hydrate of alumina, which is precipitated. This precipitation or coagulation is of assistance in forming the film in the sand filters.

It should be noted that electrical coagulation is a possibility, but at present it is still in the theoretical stage.

For softening, two forms of treatment may be necessary, one for the temporary and one for the permanent hardness. Usually for domestic use treatment of the temporary hardness will be sufficient. The treatment consists of absorbing the carbonic acid held by soluble bicarbonates, thereby producing insoluble carbonates. This can be done by heat or by the addition of slaked lime.

Permanent hardness is chiefly caused by soluble sulphates, which, by treatment with sodium carbonate, are converted into insoluble carbonates.

Each of these processes can be mechanically applied, and some means of automatically regulating the quantities should be used.

The purification necessary will be decided by the result of analysis of the water from the source, and this must be continually watched for variations. The costs must be considered with the scheme as a whole, and sometimes it may be found better to choose the less pure of two sources if the ultimate cost is lower.

SECTION V.—DISTRIBUTION.

The distribution system may take many forms. In its simplest form, which may be called the "village pump" system, each individual obtains his supply from a fixed point and provides his own transport. In the most elaborate form the water is carried to each house by pipes, from which an unlimited supply can be obtained at any time. It may even take the form of a double system, one for domestic water and the other for sanitary and other purposes.

The actual form that a modern system will take for any particular place will depend on several conditions. Firstly, on the standard of living of the consumers; secondly, on the local conditions, topographical and climatic; thirdly, on the capacity of the source of supply and the cost of production.

The chief object to be attained in a modern supply system is a pure and ample domestic supply. Purification has already been dealt with and the second condition can only be complied with fully by providing a continuous supply.

Pressure and Gravity Distribution.—The actual daily consumption will vary with the different seasons of the year and will not be evenly spread over the twenty-four hours. Were the supply taken direct from the pumping station the plant would be over-taxed at some hours and under-worked or partly idle at others. This is uneconomical and raises the running costs. Direct pumping into the distribution system is practicable when periodic supply is given or to supplement a small capacity continuous service at the heavy duty hours.

Whenever possible pumping hours should be limited by the provision of a service reservoir, which can be filled by pumping in a few hours.

Service Reservoir.—From the service reservoir the distribution system will be served continuously by gravity. It should be noted that a gravity supply will probably involve additional outlay, but will give lower running cost. In order to serve all parts of the town the service reservoir must be raised to such a height, either naturally or artificially, as will provide sufficient head to force the water to the furthest or highest point of delivery.

In selecting its site a balance must be arrived at between the following factors; (*a*) length and cost of rising main; (*b*) saving in cost of construction by using a naturally raised site; (*c*) a reduction in cost of the distribution system by siting near the "centre of consumption"; (*d*) other local factors that may affect the site, such as security and accessibility.

The capacity of the service reservoir must be sufficient to ensure a continuous supply during times of maximum consumption. It is advisable, therefore, to allow for at least double the normal requirements. To avoid interruption the reservoir should be divided into compartments, which can be cut off periodically for cleaning

Finally the service reservoir must maintain the purity standard of the water and give no opportunity for contamination, and on this account it must be covered.

Piped Distribution.—As the water to be distributed is under pressure, steel or iron pipes are required to carry it. They also prevent contamination from outside.

They should usually be buried in the ground or otherwise suitably protected.

The pipes will vary in size according to the maximum volume of water they are required to carry. It is more economical to run one large pipe than two smaller ones to carry the same quantity of water. In consequence the distribution system will normally consist of a few radiating mains of large diameter, gradually reducing in size as their duty decreases, with sub-mains, loops and branches of smaller size carrying off supplies at intervals to the delivery points.

The mains should run direct to, and through, the largest centres of consumption. It is advantageous, but not essential, to arrange loop-mains or sub-mains, as they assist the supply to distant branches and enable sections to be isolated for repair without interruption of the service.

Each part of each main and branch must be designed for the maximum duty it has to perform. The governing factors are (*a*) a minimum residual head, (*b*) a minimum supply in gallons per minute, (*c*) a maximum rate of flow in the pipes, (*d*) a capacity of double the normal consumption or a capacity to give the daily supply in a period of from four to twelve hours.

Degree of Distribution.—The more highly educated the classes of a community are, the greater will be their demands on the water supply system, both as to quantity and convenience. As the standard of living increases, the adjective "necessary" grows in its application and gradually covers what was previously classed as desirable or even luxurious. It is obvious, therefore, that the same degree of distribution over the whole supply area is unnecessary. This is particularly so in a tropical or semi-tropical town, where, it may be assumed, there is a mixed European and Native population.

In the Cantonment or small town under discussion, it will usually be found that the classes into which the inhabitants are divided also define the areas occupied. This makes it simple to provide the suitable degree of distribution to each area.

A general class division may be made as follows :—

(*a*) Military, British and Native.

(*b*) European Civilians ; Military Officers should be similarly treated.

(*c*) Natives, divided into upper and lower classes, and perhaps also by religion and caste.

(*a*) *Military—British.*—Owing to the definite routine ordering the life of this class, definite hours of supply can be fixed, making a continuous supply unnecessary. Delivery points are few and are laid down by military regulations. Connections should also be given to married quarters as for corresponding civil grades.

Native.—A still simpler scale of distribution is required, little more than supply to cook houses and bathing places is necessary. For Native Officers' quarters and married families and followers, it is usual to provide standposts from which occupants can draw their supply. In both cases water points will be required for sanitary purposes and will usually be provided in the form of standposts. These can also serve for watering, drain flushing, etc., as required.

(*b*) *European Civilians.*—For this class the highest grade of distribution should be provided. Each house should have a separate connection providing a continuous service.

The internal distribution is a matter for the individual house holder. It should, however, be noted that it is an advantage if such houses are provided with house-service tanks with automatic arrangements for refilling as water is drawn off.

Such tanks must, of course, be properly protected against contamination and mosquito breeding. The advantage gained is in the reduced capacity of the service pipes required; where taps are served direct the capacity should be sufficient to give the whole daily supply in from four to six hours, whereas with the small reserve of the house-service tank eight or twelve hours may be allowed.

Apart from the actual house connection, additional connections to garage, stabling, laundry and servants' quarters will be required, and if water is plentiful a garden connection may also be given. These can take the form of standposts.

For the lower class Europeans a connection should be given to each house, but a house-service tank is usually inadvisable.

Bathrooms and cookhouses should receive a direct supply and usually one standpost for servants' quarters, etc., should suffice.

(*c*) *Natives.*—The upper class natives should be graded for distribution approximately as the lower class of European, though in many cases one delivery point in the house will be found sufficient.

For the lower or menial classes usually congregated in bazaar areas no house connections should be given. A series of standposts should be supplied so that each house is within 100 yards of a supply point.

Sanitary Service. Apart from the domestic supply the distribution system must provide for sanitary requirements, which are communal responsibilities.

They require ample supplies and proper care. Most of them do not require the same standard of purity as for domestic supply, and if the cost of production of the pure water is high the possibility of a separate supply and distribution should be considered.

A double system is costly and should only be adopted when the saving in running cost justifies the increased outlay. When a double system is used particular care must be taken to ensure that the "sanitary" water is not used for domestic consumption. It is a help if such water is sufficiently brackish to be unpleasant to drink.

Sewage Disposal.—No mention has been made so far of this important sanitary question. In the majority of small towns and cantonments in the tropics there is no water-borne system or, at any rate, it has not been developed to the stage of serving each house. If such a system exists provision must be made for a larger allowance of water and, to be possible in a hot dry climate, at least double the quantity required at home must be provided. In preparing the water supply scheme the possibility of the introduction of the system must be enquired into if it does not already exist.

Fire Protection.—A modern water supply system must include provision for fire protection. Hydrants should be provided on the mains, capable of providing a minimum supply of 120 gallons per minute. Important buildings should be served by at least two hydrants each capable of giving this supply at the same time. These hydrants can frequently be combined with service points for sanitary purposes. Generally speaking, the flow required at a hydrant will decide the size of the main, but the pressure will be determined by the normal supply.

Industrial Supply.—A supply will be required for pumping and power stations, and such industrial concerns as are included in the area. If any special form of purification is required it should generally be provided by the consumer. If an extensive industrial supply is required, it will probably be more economical to keep it distinct from the domestic supply.

Finally, it should be noted that increased cost to consumer is not a really effective waste preventer. If, therefore, the supply is costly definite means should be taken to limit the consumption. This can be done by (*a*) limiting the rate of flow in the house connection ; (*b*) limiting the hours of supply.

A more drastic means is to refuse house connections, thereby necessitating daily deliveries by water cart or other means of transport. Aden and Gibraltar have been cited as examples where drinking water is limited and costly ; such limited distribution is used in both cases.

Section VI.—Control.

In a Military Cantonment the construction and control of the water supply rests with the military authorities. Funds will be provided in the military budget and provision will be made for the executive staff. Definite regulations cover such a supply and provide for extensions to non-military consumers.

In the case of a town or cantonment where the military interest is small, the control rests with the local civil authorities, usually an elected or partly elected Board. Such a Board will usually license a Company to provide and maintain the water supply, but it may raise a loan to meet the initial outlay and construct and maintain it as a municipal concern.

In either case, the Board must retain responsibility for fixing the requirements and the purity standard and for medical supervision.

Quantity Required.—This will be determined by the doctor and engineer in consultation with representatives of consumers and such industrial and agricultural interests as may be concerned. The effect of local conditions, including the method of sewage disposal, must be carefully considered and full allowance made for extension.

Normally the total daily consumption for all purposes should not exceed 25 to 30 gallons per head. In detail Europeans should be calculated at 15 to 20, Natives at 5 to 8 and animals at 10 gallons per day. Large houses connected should be allowed from 300 to 500 and small from 200 to 300 gallons. Special allowances should be fixed for sanitary purposes, such as road watering, drain flushing, etc., and for special consumers, such as power plants, farms, laundries, refrigerators, ice and mineral water factories, etc.

Cost of Water.—This will be determined by dividing the annual cost by the quantity used. The annual cost must include fair interest on the capital outlay, possibly provision for repayment of the debt, percentage charges for depreciation and renewal of the various parts of the system, annual running costs of plant, including the pay of the staff employed, maintenance and repairs, both labour and materials, office expenses and the cost of collection of charges, including an allowance for late payments.

Generally speaking, the cost should be calculated so as to make the system self-supporting, but not a profit-earning concern.

Recovery of Cost.—A provision is made in the military budget to cover the cost of water consumed by troops. Certain ranks are not entitled to a free supply of water and the cost is recoverable from the individuals. For those occupying Government quarters, which are more or less of standard sizes, it is simple to fix a flat rate charge according to the quarter occupied. The recovery of this is simple, as it can be charged with the rent.

In the case of other consumers the local authority should determine the method of payment and should be responsible for the recoveries.

In a small town house connections should be metered and the actual consumption should be billed for. Meters involve a certain amount of additional expenditure, and extra staff is required, but they give the only fair means of fixing payment for quantity.

Other methods, such as a water tax on the rateable value of the house, or a " ferrule " rate determined by the size of pipe supplying the house, make no distinction between the careful and the wasteful occupier.

Whatever method is adopted the local authority must make provision to cover the cost of water for general purposes, and that used by the non-taxable portion of the community in addition to the supplies to individuals.

Waste Prevention.—This can only be achieved by constant inspection and immediate repair or replacement of leaks or damaged fittings. All mains and sub-mains should have valves at intervals and every branch should be capable of being cut off by a stop cock. District or area meters are an aid to the detection of undue consumption in any particular part of the system.

SECTION VII.—CONCLUSION.

The foregoing remarks have touched upon some of the main features of a water supply system under certain conditions. They do not define a system in detail nor do they attempt to teach the method by which a project for such a system should be worked out. They are offered simply as a guide to the inexperienced and a reminder of the various matters that require consideration.

If submitted to " the man in the street " or his country cousin, they would probably leave him as ignorant as he was before. However, such people are seldom entrusted with the preparation of a scheme for a modern water supply.

WATER SUPPLY, GIBRALTAR.

By MAJOR H. E. COAD, A.M.INST.C.E., S.R.E.S.

GIBRALTAR possesses no rivers or springs and the population, which numbers about 17,500 civilians and 3,600 naval and military members, depends almost entirely for its potable water supply on rainwater caught on artificial catchments. This supply is supplemented to a very small extent by water from shallow wells and from distillation plants.

Every dwelling-house must by law have its own underground masonry tank. Water is led direct from the roofs to these tanks and is accordingly more or less polluted by droppings of birds and cats and by the dust blown up from the surrounding areas and deposited on the roofs. Many of the roofs are flat and are used for recreation in the evenings and for drying clothes in the daytime and are further contaminated accordingly. Frequently *bacillus coli* is found in 10 cubic centimeters of drinking water or less, but little trouble is caused on this account, the inhabitants, through long use of such water, being immune. The following extract from the Annual Report of the Medical Officer of Health, Gibraltar, for 1907, is of interest in this connection :—

"The drinking water which is mainly derived from rain water collected on roofs and specially prepared areas, is inevitably open to contamination. The result of bacteriological examinations shews that B. Coli, the typical organism of sewage contamination, can be isolated in 10 c.c. of practically every sample of water collected on the Rock, and many specimens contain it in even 1 c.c. It is doubtful in how far one can apply, to a water collected as that in Gibraltar is, the same bacteriological standard which we apply in the case of well or spring water, and this appears to be the view held locally. The typical B. Coli having been found in 10 c.c. of most waters collected from roofs, which have been consumed for years without apparent detriment to health, it has been the custom to pass such waters as " fit " for drinking purposes. Water containing B. Coli in 0.1 c.c. has been condemned, as an inspection of the source of supply has usually shewn distinct evidence of contamination by sewage in these cases. An open mind has been kept as to the presence of B. Coli in 1 c.c. of water, the opinion formed being commonly based on the combined results of the chemical and bacteriological examinations, and on the results of the inspection of the source of supply. Under ordinary circumstances, as in the case of a water supply from a well or spring, the presence of B. Coli in 10 c.c. of water would be considered a sign of definite and serious contamination. The Sanitary Officer comes to the conclusion that " it is evident that, in spite of all precautions, contaminated dust gains access to most of the tanks, and this is not surprising when one considers the physical conditions which obtain in Gibraltar."

Rainwater is not collected from garrison roofs at the end of the dry season until the roofs have been well washed by the autumnal rains, bye passes being provided in the collecting pipes for this end.

The rainfall averages 33 inches per annum and this is spread over eight months, June, July, August and September being generally entirely dry months.

The collection from house roofs is supplemented by large supply and reserve tanks fed from special catchment areas. These are generally remote from crowded districts and are consequently freer from dangers of contamination than the ordinary house roofs. The catchments are of three kinds—(*a*) ordinary rock surfaces stripped of earth and vegetable growths, with cracks and crevices stopped with concrete and cement mortar. About 30 acres of these are used. (*b*) Prepared areas of thin concrete. (*c*) Areas covered with corrugated galvanized steel, supported on small creosoted piles and runners. The latter areas, which cover in all about 35 acres, are situated on the sandy slope on the East side.

Generally these catchments are well fenced to keep out sheep and goats and are provided with silt pits at their lowest points, and also, in the case of the smaller ones, with mosquito-proof gauzes at the entrances to the tanks.

It has been found advisable to cement wash the catchments annually, those of corrugated steel included, both for the sake of cleanliness and for diminution of losses by leakages and evaporation. The latter are very heavy after intermittent showers.

Special provision of adequate spill ways in the channels at the foo of the large catchments has had to be made, since the danger of stoppage of the channels by blown sand, and at times by hail, is great. From such large areas, catches of a million gallons per hour are common, and a stoppage in the collecting channel once resulted in the retaining wall at the foot of one of the catchment areas being swept away.

The reserve tanks vary in capacity from 80,000 gallons to 1,000,000 gallons. These are generally constructed below ground for protection from gunfire. In the case of the supply tanks for the civilian population five tanks, with an aggregate capacity of 7,000,000 gallons, have been made in the heart of the mountain and are absolutely bomb-proof.

No filtration of any sort is practised in Gibraltar, but a period of 15 days is allowed for settlement in the main civilian tanks before the water is used. The average annual collection over the Council catchments is 20,000,000 gallons, of which about 15,000,000 gallons are utilised for domestic purposes, the remainder being diverted into the sanitary water reservoirs. The potable water is piped to points in the town, where it is sold to the inhabitants, who obtain it in buckets and tins, at a cost of 2s. 4d. per 100 gallons. Few of the houses have a direct metered fresh water supply. In years of drought—for example, in 1922, when the rainfall was only 25.8 inches—drinking water is shipped in barges from Algeciras and delivered to the inhabitants. The Military resources are, however, always adequate without such assistance.

The practicability of obtaining a constant supply of potable water from the neighbouring Spanish mountains has been investigated, but owing to the peculiar character of Gibraltar as a fortress, such schemes have up to now been rejected.

A supply of brackish water termed " sanitary water " is installed in every house for use in W.C.s, baths and sinks. Its source is the flat sandy neutral territory, where it overlies the sea water at a depth of about 6 feet. It is obtained by pumping from a large number of shallow wells, from which it is lifted by relays to the top of the Rock. About 240,000,000 gallons are pumped annually. Up to the end of the wet season it approximates in quality to fresh water and becomes more saline as the upper layer of water is used up. It is sold at about 3½d. per 100 gallons.

A third source of supply is from wells on the North Front, which yield about 6,000,000 gallons per annum. This water is sold to the shipping for filling boilers, at 9d. per 100 gallons. It is not potable.

There are many small private wells at various points in the fortress, none of which now yields pure water. They are, however, used by the inhabitants to a small extent.

On the whole, the water supply in Gibraltar is good, the only improvements now contemplated being the extension of the main civil supply tanks and catchments, and a large extension of the direct supply of potable water to the houses.

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

EXPERIMENTAL SECTION (*continued*).

CHAPTER 6.—MESSAGE CARRIERS.

Experiments were not carried out to any great extent by the Experimental Section with Message Carriers till the Spring of 1917.

The first suggestion for keeping communication during a battle was to throw a cable and thus connect up by telephone.

During 1915, the Rocket was suggested for this purpose. Experiments had shown, however, as in the case of apparatus for destroying wire entanglements, that the rocket was an unreliable instrument. Its range and direction were both uncertain, but for communicating messages something reasonably accurate was essential. The "Boxer" rocket threw a line about 400 yards, and the "Schumuly" rocket apparatus could only be relied upon for 250 yards. The latter was also too heavy to carry over open ground, and at 250 yards communication could be maintained by visual signalling.

A series of experiments during the Spring of 1915 showed that the Pain, Schumuly, and Boxer Rockets were all unsuitable for the purpose.

Attention was turned to fitting written messages into projectiles that could be fired from the rifle or the smaller mortars. The Second Army pattern of Message Carrier, fired from the Stokes Mortar, was a cast iron projectile containing flare composition which gave a trail in flight and on the ground; but it invariably buried itself in the ground and could not easily be dug out, and remained too hot to handle for some considerable time. Many inventions on similar lines were submitted to G.H.Q., but only on two patterns were experiments carried out. One type was made in the shape of an arrow, with a hollow stem mounted on a stick fitted on the end of the rifle and fired by a blank round. It was not satisfactory and the range was poor. The other pattern, with its flare and message, was projected from a cup with a rod attached. When fired from the rifle, the projectile left the cup attachment and started the flare burning. Its flight, however, was very erratic and it was unsatisfactory.

In 1917 a pattern was designed in the Fourth Army. This was also on the rocket principle, and was given up owing to its erratic flight.

The chief objects which had to be borne in mind in devising a Message Carrier were :—

(i) That it should be visible in its flight to indicate its arrival and direction to the receiver, and if possible carry a whistle for this purpose.

(ii) That it should be invisible at the beginning of its flight so as not to give away the position of the firer.

(iii) That it should not bury itself too deeply nor remain too hot to handle for taking out the message.

(iv) That it should be fairly accurate, and obtain a range of at least 600 yards.

In the summer of 1917 the M.I.D., sent out a Message Carrying Rocket (the Wynne pattern), which had been experimented with in England and which gave fairly good results. The projectile was about 4 feet long and was propelled on the principle of the rocket, but had vanes at the back on which the gases impinged, causing it to rotate and thereby giving it a much steadier flight. Contrary to usual practice it carried the rocket composition in the head, so that the vanes were carried on the tail. The tail contained light smoke composition, giving a light trail in the air and smoke on the ground, and the nose carried a syren operated by the inrush of air. This projectile marked a great advance in the history of rockets. It obtained a range of 2,500 yards and was accurate to within 200-300 yards. The message was carried in a tin cylinder in the top of the tail, which unscrewed from the head. This rocket was introduced into the service in the early part of 1918 and was much in demand.

At the same time as the Wynne Message Carrier came out, the Geake apparatus for throwing a wire, and also the Geake Message Carrier were demonstrated. The message carrier consisted of a hollow tube with its message and composition in the head. The tube fitted over a spigot about two feet long, in the head of which was a striker. The principle was the same as that used in the Foulis Stick Gun and in the "Granatenwerfer" used by the Germans for bomb throwing, and was the reverse of a gun. Instead of the projectile fitting inside the bore of a barrel, the projectile carried a barrel or tube fitting outside a solid spindle. The charge was carried in the head of the tube, and the striker in the spindle fired it when actuated by a trigger mechanism in the base of the gun. The Geake message carrier travelled about 1,000 yards, but the rocket pattern was the one preferred, as no gun was necessary for firing it, and the range was greater.

The Geake cable thrower, which threw a special telephone wire 350 yards, was on the same principle, but was a much stouter and heavier weapon. It was eventually reproduced almost exactly in the German cable thrower, which was of still stouter construction.

The objection to all cable throwing devices was that the wire was liable to be cut by bursting shell, and nothing could be done to prevent this. An independent message-carrying projectile without a cable was therefore preferred, and at the time the Wynne pattern met the demand.

The Experimental Section carried out experiments in design of a Message Carrier to be fired from the discharger which had been introduced for the Mills Grenade. A French pattern (Plate XIV, Fig. 1) fired from the discharger, was in the form of the ordinary grenade, only without a hole, so that it was fired with a blank round instead of a bulleted round. Its range was only 200 yards, and the projectile in soft ground could not easily be found ; also the smoke emitted was not good, neither was there any indication, except for the smoke trail, of its arrival.

Experiments were continued in England on similar lines to those carried out in France in the winter of 1917, and a fairly hopeful design was arrived at, similar to that illustrated in Plate XIV. Fig. 2. It consisted of a thin tube containing a flare composition and smoke composition with a whistle at the head and three vanes on the back. The end carrying the vanes sat in the discharger, and was propelled by a disc with two clips fitting loosely between the vanes, the disc falling off directly after firing, as soon as it left the rifle, the composition being lit on shock of discharge by a cap fitted in the base end of the tube.

This device, with which considerable experiment was carried out both in France and in England, did not mature until March, 1919, as considerable difficulty arose in manufacture, which could not be got over. A series of trials of the manufacturers' samples were attended by the O.C. Experimental Section during the whole of 1918. Though the weapon could be made in the Experimental Workshops, difficulties arose in bulk supply with the composition owing to the small diameter of the tube. At a final trial in March, 1919, it was decided to use a heavier weapon with a $\frac{5}{8}$ inch tube instead of $\frac{3}{8}$ inch, and to do away with the whistle. The projectile was recommended for introduction into the service with these alterations, the whistle being replaced by a head which splayed out on entering the ground, so that the projectile would sit in the ground and be fairly visible while emitting smoke (sparks for night use) for about $1\frac{1}{2}$-2 minutes. A bright flare was emitted in flight, sufficient to catch the attention of the sentry posted to observe it. This final pattern of projectile is that illustrated on Plate XIV, Fig. 2.

CHAPTER 7.—TRENCH MORTARS.

The first trench mortars that were made in the earliest days of trench warfare were 4 inch and 3.75 inch (or 95 m.m.) diameter bore. Both of these were of local manufacture and were necessarily makeshifts.

The 4 inch had a range of 325-550 yards, firing a 7-lb. shell with a percussion fuze, which was dropped into the mortar and fired by a friction tube. The 3.75 inch had a range of 50-200 yards, firing a jam pot bomb weighing about 2-lbs. with a time fuze lit by explosion of the flash powder propelling the charge. The 95 m.m. mortar is illustrated on Plate XV, Fig. 2.

The Experimental Section was called upon to supplement the supply of ammunition by making up bombs from local materials.

The details given on Plate XV, Fig. 1, show the crudeness of the projectiles. These were made up in the backyard of a farm near St. Omer, and were turned out in large quantities.

In January, 1915, the use of some form of smokeless powder became vitally necessary, in order to conceal the positions of the batteries as far as possible; and the home authorities took up the question of production of mortars with suitable ammunition.

For a time guncotton was used as a propelling charge, which necessitated increased contents of the chamber space below the projectile and reduced range.

March, 1915, saw the first mortars sent out from England, the 1.5 Vickers with 18- and 33-lb. bombs, and the 2 inch Woolwich mortar firing the 50-lb. "football" bomb.

During this period experiments were carried out by the Experimental Section to develop an invention brought out to France by Col. Lewis of the American Army and Lieut. Breeze of the Royal Horse Guards. The invention consisted of firing from a mortar a shell on the principle of the rocket, and considerable experiments were carried out, the mortar and shells being manufactured locally, except for certain parts which had to be obtained from London and Paris. These trials continued for some considerable time and were successful on the whole; but, owing to the great visibility of the trail of the rocket and consequent danger of the battery position being easily located, together with the erratic flight of the projectile, the Rocket Gun was dropped and superseded by the 2 inch Trench Mortar produced at Woolwich.

During these experiments, Lieut. Breeze lost his life owing to a premature burst of one of the rocket shells just as it left the mortar.

Experiments continued for some time more, and, when the rocket principle was dropped, the apparatus was converted into a mortar and experiments were continued on these lines.

The rocket gun itself gave a range of 1,200 yards, and the shell weighed about 36-lbs. with the rocket, and contained 10 lbs. of high explosive; but the rocket had always a tendency to fly with its nose into the wind; and it was never safe to predict, when firing with the wind, the direction in which the shell would go, either away from or back again towards the firer.

The Mortar developed from the rocket gun had a range of about 300 yards, and the same shell was used. The body of the shell was of sheet iron instead of cast iron, so that fragmentation at the best of times was poor, and could not be compared in effect with the 30-lb. "football" bomb, with its ¾ inch cast iron shell forming a sphere about 10 inches in diameter.

In February, 1915, the first Brock Mortar was seen and tested in France, and contained many interesting features. These mortars were of light wire-wound steel pipe construction, and were of varying sizes from 3 inches to 12 inches in diameter. They were set in holes in the ground. The projectile carried its propelling charge on it, which was lit by friction ignition when placed in the mortar, the bomb being propelled after a short interval.

In nearly all cases black powder was used for lack of other explosives.

The advent of the Stokes Mortar in the spring of 1916, and the taking over of mortar production by the Ministry of Munitions put an end to the necessity for further experimental work, with the exception of local trials of fittings and minor details.

The Second Army Workshops developed the 6 inch and 9.45 inch Newton Mortars on principles similar to those of the Stokes, but with a different mounting. The mortar was carried on a heavy wooden base plate well braced, and its barrel directed to the line of fire by three adjustable ties, which held the mortar down on the base plate. The shells were vaned, and the charges placed in bags, between the vanes, in wire cages.

The Stokes, Newton and the 2 inch Woolwich Mortars held the field for the remainder of the war, though their spheres of usefulness became gradually restricted by the changing conditions of warfare.

In the spring of 1918 the Experimental Section was called upon to devise a light mounting for the 3 inch Stokes in anti-tank work, to be divisible into single man loads.

At this stage in the War a portable weapon was required for dealing at close range with possible enemy tanks, and the 3 inch Stokes Mortar was obviously the weapon for the purpose. This mortar was a most portable and highly efficient weapon, throwing an 11-lb. shell to a distance of 850 yards.

Several Divisions had evolved a method of firing the gun when slung over a man's shoulder, the gun being held by two wooden handles clamped to the barrel. In this way the Stokes had followed up Infantry advances, so providing means to engage the enemy rapidly with a heavy shell of great moral effect.

Experiments had been carried out at the G.H.Q. Stokes Mortar School in low angle fire, a wooden stick being used as a ramrod to draw the shell down the barrel, and operated by strings which broke off when the shell reached the base of the mortar and fired. This was only a makeshift, and in ordinary soil the base plate could not prevent the mortar from recoiling considerably at every round, so that the backing of the earth became loosened and would not stand up for continuous fire; and this method was only reliable in fixed and prepared emplacements. A suitable mounting was produced by the Experimental Section in October, 1918, but owing to the Armistice in November, no further action was taken with it in France, the samples with description and drawings being sent to the War Office for further development after the War. This mounting is shown in Plate XVI, and also in Photographs (i), (ii) and (iii). The Bipod was detachable from the main frame, but, when mounted, the whole recoiled together, and carried a spade attachable at different angles according as to whether the mortar was firing at high or low angles. The mounting had a special trigger mechanism attached, and could be fired at angles from 7°-70° with a total traverse of 30°-40°. No part weighed more than 50 lbs. and the whole equipment was mounted on a light carriage, and could be carried as single man loads or on a pack saddle.

The 3 inch Stokes was also developed for anti-aircraft fire and the Experimental Section made all the fittings used as samples for manufacture in England. A separate base plate was made for all-round fire down to angles of elevation of 45°, and a pair of handles on a light iron frame with folding legs was used for operating the mortar, the mirror sight being carried on the same bracket. A pendulum clinometer was developed for this purpose, and various other mirror fittings were evolved.

CHAPTER 8.—CATAPULTS AND GRENADE THROWERS.

The first catapults were taken over to France in February, 1915, and tested by the First and Second Armies. The catapult was made by Messrs. Gamage & Co., to a design prepared at the S.M.E. Chatham, and gave fairly good results. It weighed 43-lbs. and consisted of a tripod carrying a canvas bucket with elastic slings. The trigger was not satisfactory and the whole apparatus was cumbersome and unwieldy to set up and use, and the ranges varied considerably. Still the demand at this time was considerable, and 100 were ordered for trial, and eventually in May, 1915, an establishment of 20 per Division was proposed. Only time bombs were used with this catapult as it was not considered safe to use bombs with percussion fuzes. The range obtained with the double cylinder hand grenade was about 110 yards, and was fairly accurate if the catapult was fixed securely. Longer ranges could be obtained up to 200 yards, with the 2-lb. bomb, but not with accurate results. A drawing of the apparatus is given on Plate XVII.

The West Spring Gun was the next apparatus of this nature to be sent to France for trial, and this arrived during April, 1915. The West Spring Gun threw the Mills Grenade about 200 yards, and could throw a projectile weighing about 7-lbs. up to 80 yards, but it took two men to lift it and was large and cumbersome and generally more unwieldy than the Gamage Catapult. Only a limited number were made and issued for use.

About September, 1915, a French invention appeared which was a considerable improvement on previous patterns, and this type was asked for from England as soon as the Gamage catapult contracts had run out. The French catapult known as the "Sauterelle" weighed 53 lbs. and threw the Mills Grenade 120-150 yards, and the Ball Grenade 180 yards.

Various other catapults were tested during the Winter 1915-16, but none of these offered any great advantages over the patterns in use. Considerable improvements were made from time to time to the "Gamage" and "Sauterelle" catapults on the recommendations from Armies after trial, but during the spring of 1916, the Mills No. 23 grenade was introduced with the rifle cup attachment and except for firing the Ball grenade, the demand for catapults generally ceased.

Many designs for catapults were submitted to G.H.Q. from time to time by various inventors, most of whom were somewhat optimistic in their ideas as to the ranges obtainable from their weapons; and, as the result of experience gained in 1915, further experiments were not carried out. It was generally decided that greater ranges could be obtained from elastic slings than from steel springs, but the elastic was not durable and frequently broke.

Many kinds of grenade throwers were submitted for trial which were on other principles than that of the catapult, and inventions and samples were submitted to G.H.Q. right up to Christmas, 1918, but no grenade thrower ever realised the hopes of its inventor, either as regards rate of fire, weight, mobility or range, nor gave results comparable with those obtained in firing a grenade from the rifle.

A very clever but complicated machine in the form of a Grenade thrower, offered to and accepted for trial by the British Army, was invented by a M. Criez. Four men were required to lift this machine, which threw two Mills bombs about 100 yards. It had two long rotating arms on which the bombs were fixed, and sufficient speed being obtained, the bombs flew off by releasing a mechanism which was actuated by the centrifugal force due to the speed. The machine was highly ingenious and was sent to the War Museum as a relic.

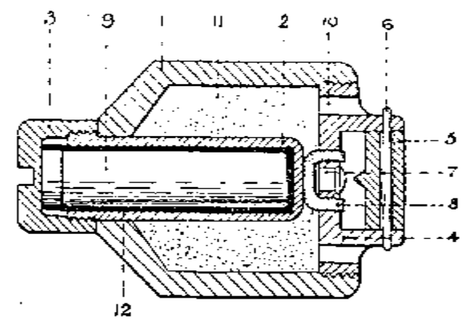
Perhaps the climax in bomb throwers was reached in an invention by a gentleman, who brought to France in July, 1917, a thrower which was carried on the chest. It consisted of four magazines each containing six barrels, and which was clamped on to a breast plate strapped over the shoulders. The grenade thrown was the No. 23 Mills and it reached a range of 90-100 yards. The grenade was held in the right hand and the rod placed into one of the barrels and jerked downwards on to the base of the chamber. This action fired a cap in the chamber, and the grenade was ejected and the safety pin automatically withdrawn by a weight placed in the split ring of the safety pin. By an ingenious design of cap, the apparatus made practically no noise and was flashless. The barrels could also be fitted to be fired from the rifle if desired. Several were sent to Armies and tested, but the device was not considered an improvement on the more simple way of firing from the rifle.

The last machine of its kind for throwing bombs was submitted in January, 1919, by the Canadian Corps. The device, which was made in Army Workshops, was of a highly complicated nature, but of remarkable ingenuity. Bombs weighing 3-lbs. were dropped in at one end of the machine and ejected at the other to a range of about 800 yards at a rapid rate, after going through various evolutions inside the machine. The apparatus weighed about 40-50 lbs., but although highly ingenious, could not compare with the discharger for firing the grenades, and a range of more than 350 yards was not considered necessary for grenade throwing.

Most of these weapons were submitted to the Experimental Section for trial, but no drawings or records were preserved, as the experiments were all of a transitory nature and resulted in no permanent developments.

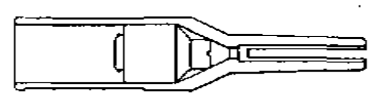
Plate XIV. Fig. 1.

BESSIERE SYSTEM OF MESSAGE-CARRIER PROJECTILE



1.	Body	5	Plunger	9	Case
2.	Holder	6.	Safety wire	10	Holes in Cover
3	Plug	7	Primer	11	Smoke composition
4.	Cover	8	Fuze	12	Asbestos

Position of the projectile when in the blunderbuss V.B



Cartridge DR.

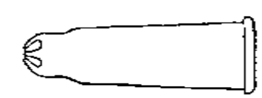
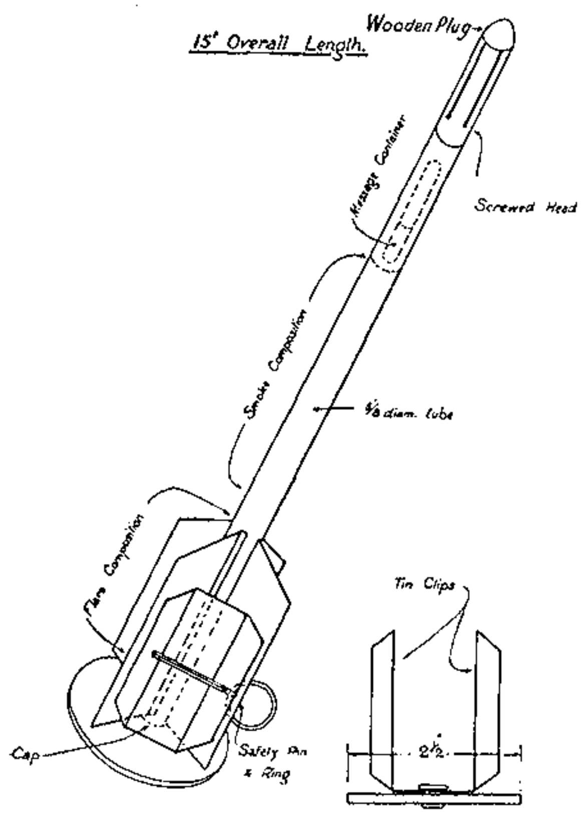


Plate XIV. Fig. 2.

GEAKE MESSAGE CARRIER.

DISCHARGER PATTERN.

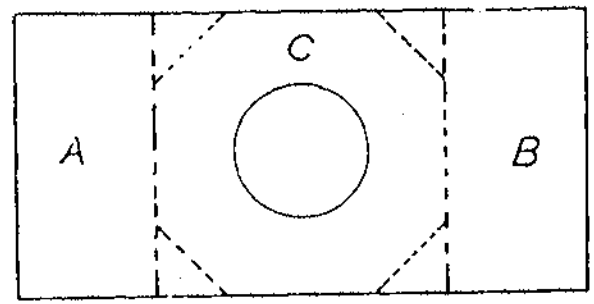


End View of Disc.

90 m/m TRENCH MORTAR BOMB.

MADE AT ARQUES, NOVEMBER, 1914.

15 oz Slab of G.C cut along dotted lines.



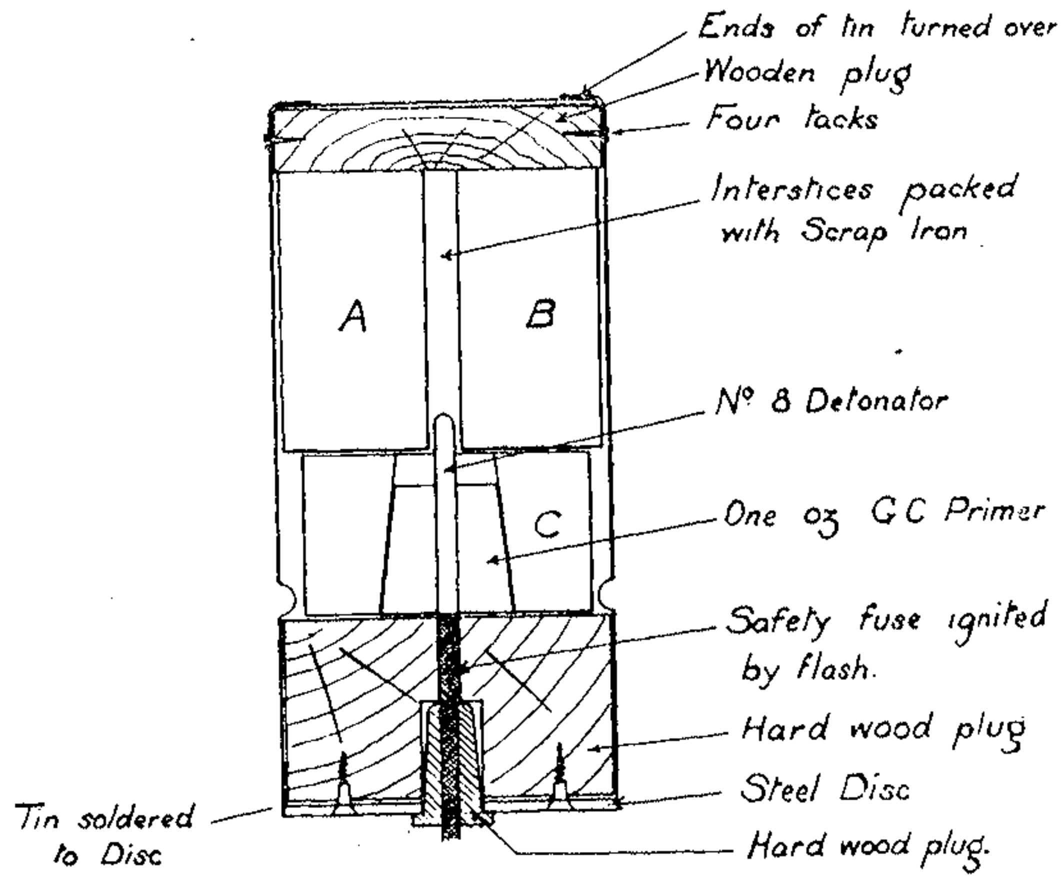
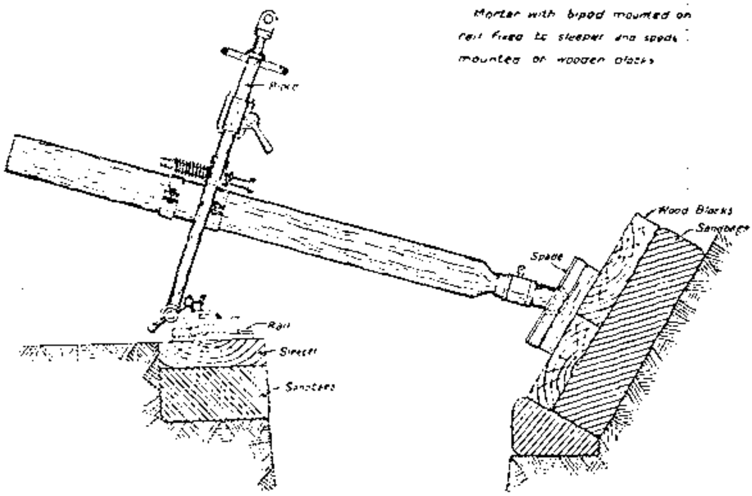


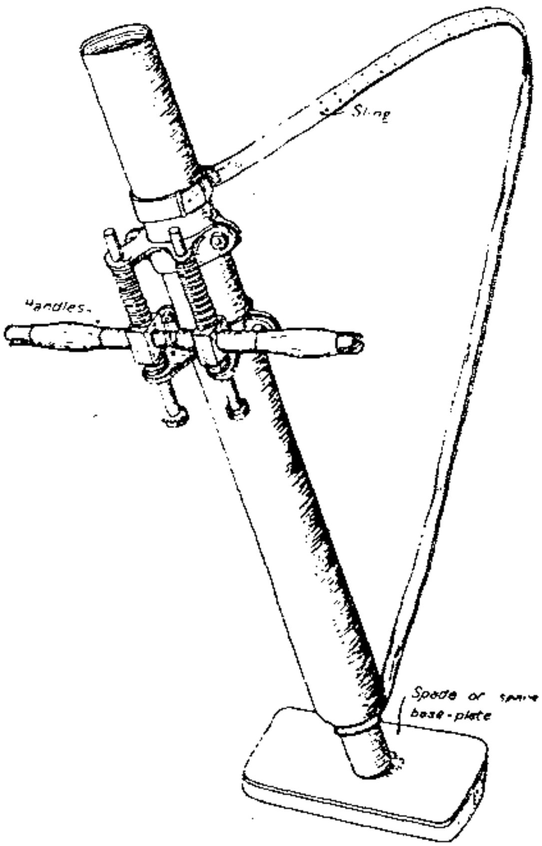
Plate XVI.

3-INCH STOKES' MORTAR

IN TRENCH OR PERMANENT EMPLACEMENT



MORTAR WITH SLING, HANDLES AND SPADE ONLY.



3-INCH STOKES' MORTAR.

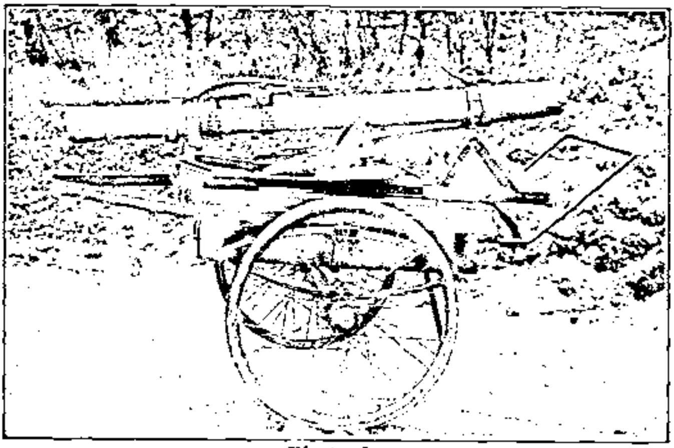


Photo I.

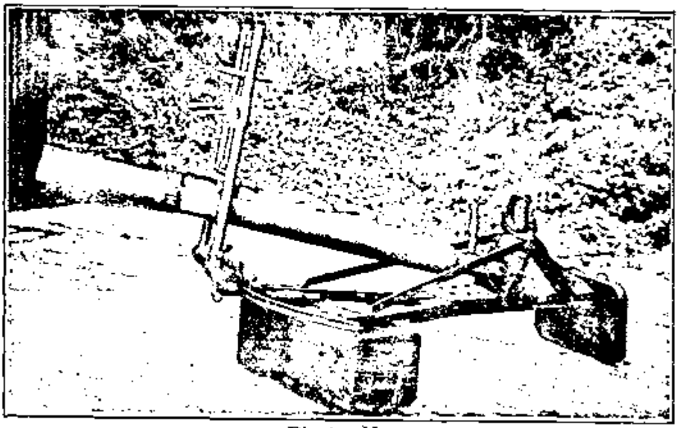


Photo II.

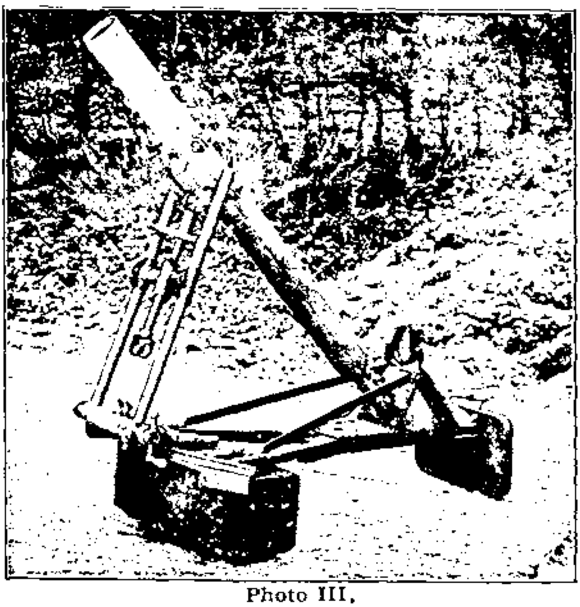
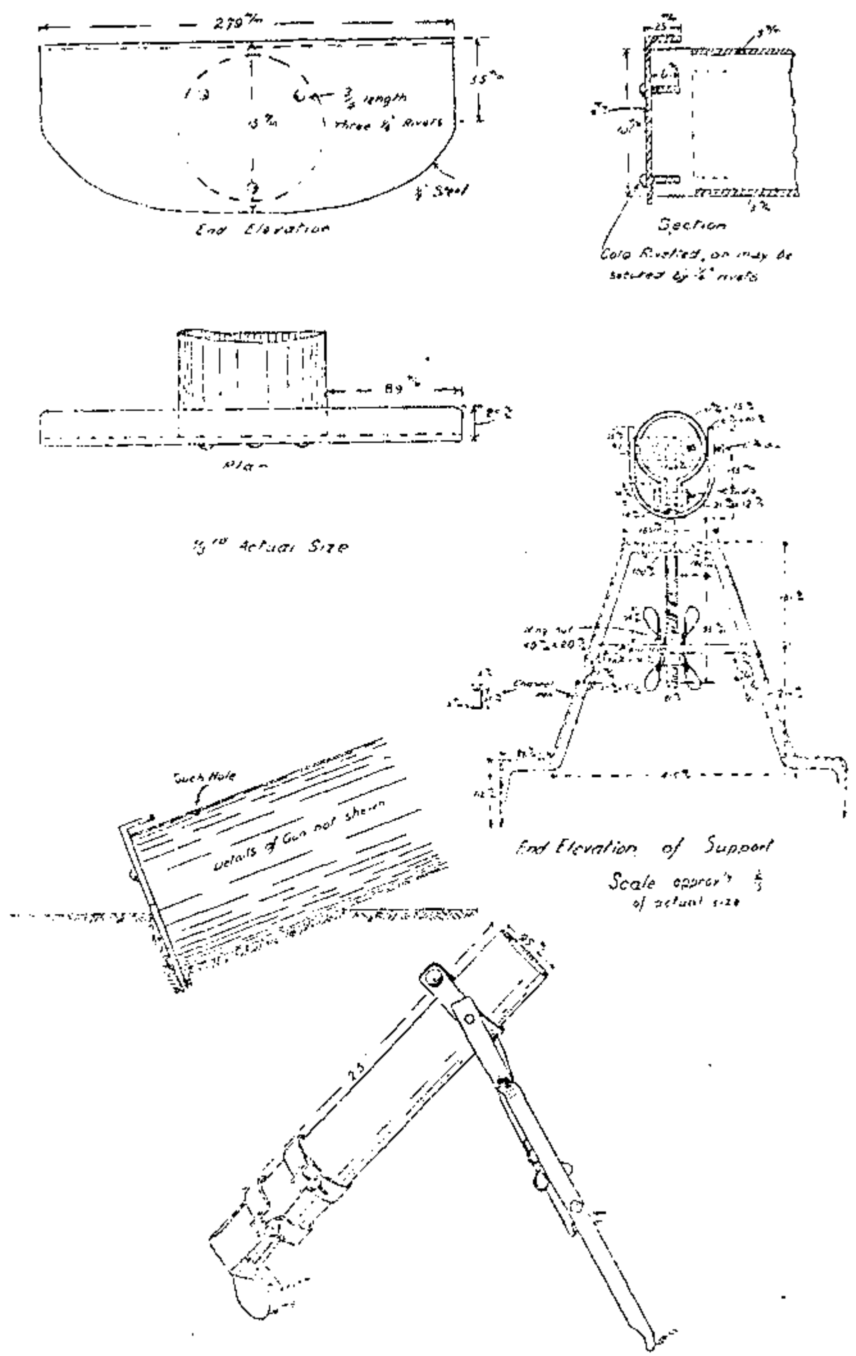


Photo III.

Plate XV. Fig. 1.

INDIAN PATTERN TRENCH MORTAR WITH ALTERNATIVE BASE ATTACHMENTS.



GAMAGE CATAPULT.

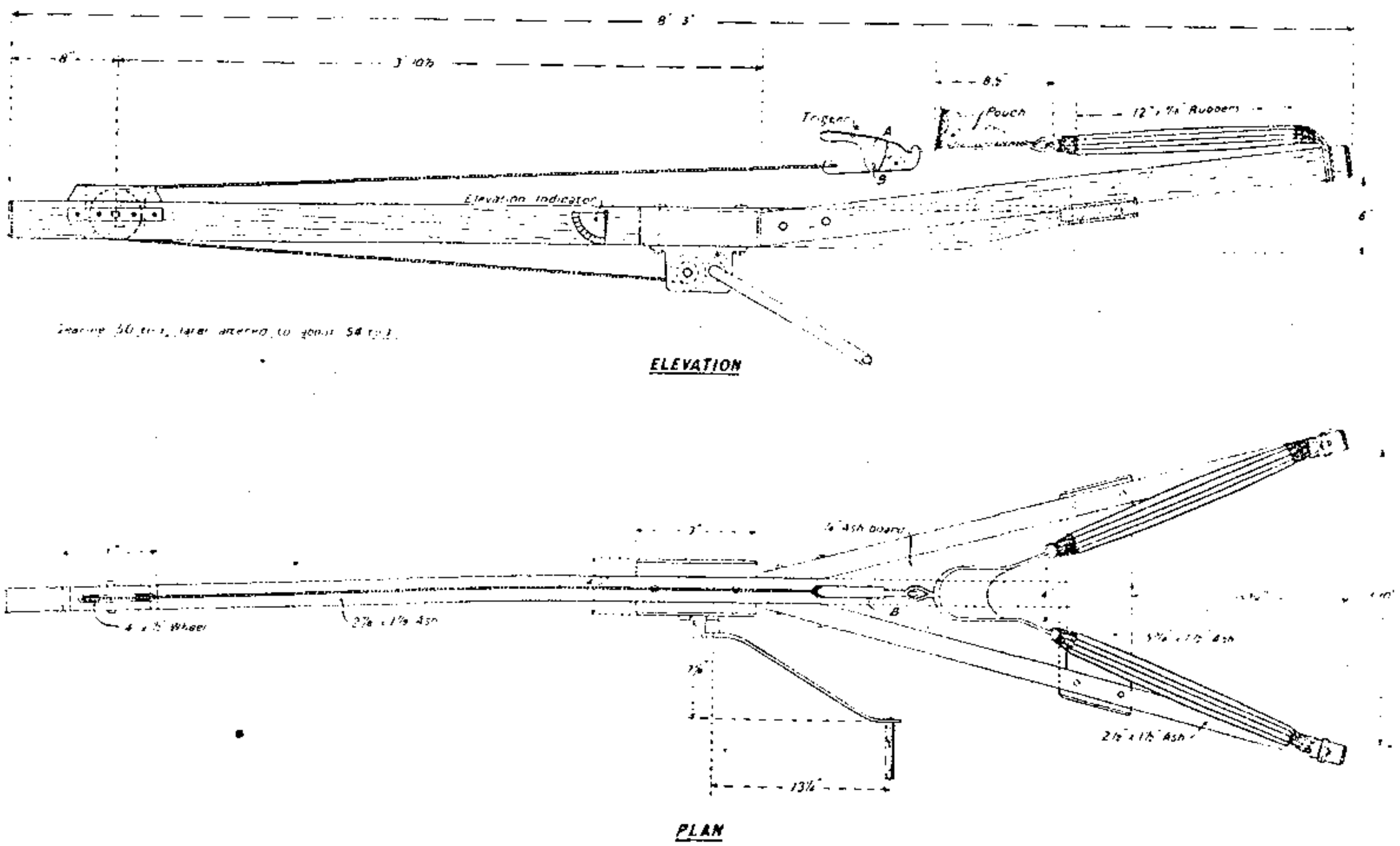


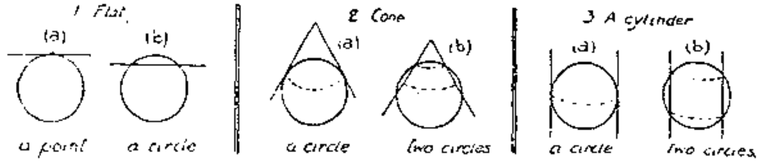
Plate XVII.

SURVEY GRIDS AND MAP REFERENCES.

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

At first sight there seems no justification for writing on so incredibly dull a topic as "grids." It appears, however, that there are still many who really want to know what they are, and what purpose they may be said to serve. The word itself is not very pleasant. It ought not to be necessary to go to the kitchen for an appropriate term for a method of survey, any more than it is really necessary to go to the housemaid for a term by which to label the "ancillary" services. There it is, however, and, anyhow, it conjures up a picture of a lot of lines crossing each other at right angles and forming small squares. But these squares are not necessarily on a map, and with that, we go straight into the heart of the question.

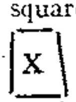
The soldier surveyor of yesterday dealt, generally speaking, with the delimination of frontiers or the mapping, at some smallish scale, of some part of the empire. He was the pioneer who built the first triangulation, and even if he had to have a fair number of points, at any rate he rarely had to think of cadastral or large scale mapping. Frequently did he have to consult the stars for latitude or azimuth, and his calculations were generally, therefore, in terms of latitude and longitude. We have all as young officers learnt to define our trig: points by latitude and longitude. P.Q.R.S. and T. have developed a new significance, and such an elementary thing as the plane rectangular co-ordinate is to most of us an unworthy subterfuge. Yet all surveyors who deal with a close network of triangulation use rectangular co-ordinates which are all "plane" in this respect, that on the map the axes, and, indeed, all x and y lines, are at right angles to each other, although they are not exactly so on the ground. They are, indeed, rectangular on the projection adopted, and here we must digress to touch on this matter of projections in order to see what happens on the ground to the lines which are at right angles on the map. The map itself is, of course, flat. To adapt it as far as possible to the earth we can roll it up into a cylinder or a cone. Suppose we consider it respectively as a plane, a cone and a cylinder, then we can project the sphere on these surfaces in the manner illustrated below :—



It will be observed that the earth (regarded as a sphere) may be any way up compared to the plane, the cylinder and the cone. The flat paper may rest on the north pole, on London or on Timbuctoo, and the cone or the cylinder may be fitted on with equal indifference to geography. It is to be observed that, in general, the areas or belts so represented are confined to comparatively small limits of the earth's surface. In other words, we can represent truly, or nearly so, a belt round the earth either meridionally or longitudinally or at any angle (cases 2 and 3) and alternatively a restricted area (case 1).

Where we consider two circles, as in 2*b* and 3*b*, we must keep them so comparatively close together that the bulge of the earth between them introduces no unallowable errors. Similarly, with 1 (*b*) the circle must be small enough to make it possible to map the ground included.

The subject of projections cannot, of course, be dismissed in a sentence. There are a very large number of projections, and of them some serve a special purpose and some are purely conventional. Broadly speaking, however, the conclusion we have reached is correct, and the squares (or grid) of the projection are sensibly square, too, on the ground, either on one or two circles round the earth or over a restricted and circular area. It is not necessary to *mapping*, of course, that the squares on the map should also be square on the ground. When we are mapping very large areas, such as a continent, it is not possible to make a flat and a curved surface coincide sensibly, and that is why a "grid" as we understand it must be confined to narrowish belts or smallish areas, because for our purposes of survey on the ground the "sensible coincidence" is a necessity. Supposing, for example, that the square A on the map is the graphic representation of a polygon



on the ground. Suppose, too, an observer at the centre of X who takes his (angular) observations to the four corners. It is clear that the various sides of the polygon will not subtend 90° at his point of observation. Two will subtend more and two less. In such a case then measurement differs on the ground and on the map, and without laborious claculation results cannot be plotted on paper.

Consider the projection again. The rectangular co-ordinates on practically any projection are perfectly definite things. Any point properly defined as x and y on projection so and so from such and such an origin can be pegged out on the ground—but the computations are not plane, and each projection indulges in its own variety. If, however, we deal only with a small portion within or near the circles or the restricted area, the odd spherical terms tend to vanish and actually, if the small portion be small enough, they disappear entirely, leaving us only the ordinary plane co-ordinates. This is what we want ; for the term ".small enough " still leaves us an area of, say, 400 sq. miles, so that the surveyor may go out with theodolite or director, may do the simplest calculation, and may plot his results directly on the " grid."

We have to consider here the fact that in serious operations hundreds of points may have to be calculated and plotted every day, and hundreds of air photographs may have to be used in mapping. As regards the computations, the easiest form is certainly the semigraphic employed by a famous computer, O'Farrel, early in the history of the Ordnance Survey, and very popular in both English and French* mapping units in the war. Observations are naturally recorded as bearings and not as angles, and the problems of intersection and resection (with numbers of bearings in either case) predominate. Co-ordinates (and in calculation they must be treated as " plane ") offer the easiest form of record, though, naturally, these " plane " computations are checked here and there on rigorously computed positions. Computations on a " geographical " basis (the graticule of latitude and longitude) may be simplified by tables and approximations, but must include three variables (the differing scales of latitude and longitude and the angle at which meridians converge).

But, of course, we cannot think " universally " in a plane, because the world is round. How large an area can we think of then ? Supposing we take case 1 and consider an area. France could be gridded after the fashion of 1 (*b*) with an outside scale error of one part in 1,040. (We usually think of one part in 2,000 as the limit we would not care to exceed.) But France's military problem, not to put too fine a point on it, is an east and west one. She prefers then to have a grid on the conical idea (as at 2 *b*) so that she may go eastwards, and, as one longitudinal projection will not carry her (within reasonable limits of error) all down her eastern frontier, she has three (and, therefore, two overlaps).

The important parts of Great Britain will go fairly comfortably on one meridional projection. Asia Minor and the Balkans, rather sketchily, on one longitudinal.

* These methods are well described in " Manuel de Topometrie " by Bailland.

Supposing now that we are at war in any area, what has to be done before our grid is ready? In this area there will be some existing maps and consequently some sort of survey, even if only a few latitudes and longitudes. The first thing to do is to choose a projection and grid which will be suitable to the anticipated magnitude and direction of operations. The second is to convert all survey data to terms of the projection chosen. We are, then, ready to carry on fresh intensive and rapid surveys. There is a good deal of preliminary computation to do in most cases, and the more fortunate we might be in finding data the more computation is involved. Our expedition to Italy in 1917 was a case in point (for the Italians did not use a grid).

So far we have not touched the matter of reference on a map. It is not, indeed, absolutely necessary that there should be any direct connection. It is possible to think of a gun as being x' and y' on the grid projection and at M 35 *d* 34 on the map. This is, of course, what we did on the western front (there was a connection in this case, but an obscure one).

Purely and simply as a system of reference our system on the Western Front was a very good one, and had the great merit of causing considerable bewilderment for a time to the Germans. But it is, of course, a great simplification to combine the "grid" and the "reference" if you can. We intend to do so. But here we come up against a very prevalent and quite mistaken idea—namely, that the adoption of a grid on a new projection *ipso facto* makes all existing maps obsolete. Nothing of the kind. In Italy, for example, we had a map on a polyhedric projection overprinted with the grid of a Lambert orthomorphic projection. The explanation is simple. The "squares" and "lines" of a grid on any suitable projection may be identified on the ground. We might even trench or spitlock them out. They would not, of course, be *quite* square, but sensibly so if we are near our circles, and they will be quite definite in relation to any detail. They can thus be mapped at will on any other projection. It would, of course, be quite possible, if this second projection were a badly distorted one, to have the grid lines, as plotted on it, sensibly curved, and the squares far from square. In practice, however, this does not occur on topographical maps at the scales we use for military purposes. One may say that all topographical maps are nearly, if not quite, sensibly and plottably correct (if the original survey was correct).

We deal then in three things—two projections and the earth's surface—all sensibly coinciding (in the restricted area we consider) and on all three will the "grid" be sensibly correct at our scale. One might, then, ask, why introduce a new grid projection if the existing map projection is sensibly the same graphically. The answer is that we have to be much more precise than measurement on a map will permit of. Many projections, sensibly accurate on paper at some such scale as one inch to the mile, are inaccurate enough to make quite unallowable differences between *angles* computed from the projection co-ordinates (treated as plane) and angles measured on the ground. Such was the case with the 1/80,000 of France (on Bonne's projection).

Just one final word on this projection question for those who know something of the subject. An "orthomorphic" projection is one which has the property of showing angles true all round any one particular point (if the rays are not too long). This is a most important factor in maintaining a close connection between field measurement and computed result. We like orthomorphic projections, therefore, even if they are not absolutely essential. The United States grid is an exception, for it is arranged on the polyconic projection used there for mapping (there are seven overlapping meridional strips), whereas France, Germany and ourselves use orthomorphic grids for preference.

Supposing, however, that the problem confronting us consisted merely of some small war or minor operation with little artillery and less survey method. Any system of reference would do. It is easy enough to evolve a good one, and one which will deal not only with the narrow belts and small areas necessary to the introduction of a military grid, but one which would be of universal application.

Such a system could not, however, be founded on lines at right angles or squares, and, therefore, could not lend itself (at any rate, in high latitude) to the use of co-ordinate cards.

In conclusion, let us dispose of one or two questions about the grid which have from time to time, arisen.

The Name. The French were the first to use the grid as a basis for reference. They used a form of reference somewhat like our present form. This system was modified by us in Italy, and modified once again by inter-allied agreement in 1918. Since then we have modified it a third time and the French have returned to their original form. Our grid is not, therefore, French or Allied. Again, the word Lambert is often used. The distinguished old Geodesist, who evolved the projection which we used for our first grid (but do not use in England), would turn in his grave at the thought of using plane co-ordinates on his projection—and, in any case, was not concerned in grids. Let us be content to call it the British grid.

The Origin. Certain enthusiasts have chased the origin of numbers on our grid to its ultimate home in the Atlantic, and are perturbed apparently at its forlorn and undefended position. Thoughts of Coast defence, of perhaps a mixed detachment, seem to have been entertained. The real and important origin for surveyors must always be more or less central, however, and the "false" origin may be anywhere so long only as we remain in one of the quadrants formed by the axes (in order not to change sign). There is no theoretical reason for remaining always in the N.E. quadrant (with co-ordinates increasing to the east and north). In Malaya, for example, it would be more convenient to increase west and north, and even in England a false origin up Iceland way, so that co-ordinates increased south and east, would perhaps be more convenient. But we must make some concession to precedent and tradition—and so far, then, we have arranged matters so that the false origin lies west and south.

The Size of Square. For general purposes of reference it is a matter of indifference what unit is employed. We want a square of a suitable size, of course, not too large to forbid decimal division by eye, and not too small to necessitate obscuring the map with lines. But whether it be metres, yards or even parasangs matters little.

It may be possible for a tank to pursue its unflinching path along a grid line. For most of us it is not possible, and we do not, therefore, measure distances along them. For the surveyor, either of the Corps or of the Regiment, it is important that the unit should be that employed in the survey of the country. In other words, for the grid we must have a convenient survey unit, for reference the point is immaterial.

A FERRY IN NORTHERN IRAQ.

Mules and stores leaving shore. Disembarkation point is just under Quwair village, visible on right.

Mules disembarking.

A FERRY IN NORTHERN IRAQ.

By MAJOR R. HAMILTON, O.B.E., R.E.

IN March, 1923, a column of infantry, pack artillery and sappers set out from Mosul for Southern Kurdistan, the sapper unit concerned being No. 63 Field Company, Q.V.O. Madras Sappers and Miners. The chief engineering operation that had to be performed was the ferrying of the force across the Greater Zab River at Quwair on the way to Erbil, and of this operation it is proposed to give a brief description.

The Greater Zab is the largest tributary of the Tigris, taking its rise in the mountains between Lakes Van and Urumiah. Like the Tigris itself in its upper reaches, the river bed is a wide uneven stretch of shingle, over which the river normally wanders in one or more channels. In the case of flood, caused by rain or melting snow in the hills, these channels expand, covering more and more of the shingle. The highest floods are liable to occur in the early spring, when the two causes are combined, a heavy fall of "warm" rain greatly increasing its own volume of water by the accumulated snow which it falls upon and melts.

As luck would have it, such an occurrence took place just as the column reached the river. There had been heavy rain for some days and the whole expanse of shingle was covered from bank to bank, so that one looked out upon an unbroken stretch of half-a-mile or so of brown, roaring, icy cold torrent. Getting the column to the other side did not promise to be easy.

The craft available were as follows :—

(1) Four boats from local ferries.

One was a large unwieldy boat which would take two or three vehicles, but was not considered safe to work in high flood. The other three were for animals, with blunt bows cut down almost to water level, over which animals are walked in and out. Each would take six or seven horses or mules, but they were in very bad condition and generally only one or at the most two were available for work.

(2) A fleet of some 21 boats brought from Mosul. These were of the type seen in the photographs and were of exceedingly primitive construction. They had to be relied on, however, for most of the work.

(3) Four bays of light bridge with the Sapper Company (British pattern pontoons and superstructure).

(4) Two motor launches which arrived after the first two days.

(5) A "kilik" or skin raft obtained towards the end of the operation.

The boats had to be towed a long distance up stream on each bank in order to make their landing point on the other side, the "round trip" taking from 1½ to 2 hours.

Besides men and stores there were some 1,640 horses and mules and 68 vehicles, mostly G.S. and Ambulance waggons, to be got across.

Men and stores offered little difficulty. Each Mosul boat could take about 20 fully equipped men or an equivalent weight of stores. The launches, when they arrived, were also used for this.

The difficult problem was to ferry the animals and vehicles in a reasonable time.

Of the animals, about 900 to 1,000 were small pack mules, and it was considered too risky to try to make them swim such a long distance. The ferry boats could only deal with a few animals and were reserved mainly for horses. The only method for the small mules was to take them in the boats from Mosul. Accordingly piers were built of sandbags and brushwood to a height just above gunwale level, and the boats brought alongside; brushwood was strewn on the bottom of the boats to form a cushion. Mules were then brought along the piers and made to jump in. It was found that four could be got into a boat, standing side by side athwart the boat.

The whole proceeding was viewed by the boatmen with the deepest gloom and, indeed, to see mules alighting on the boat floor with sickening crashes and then doing their best to kick out the sides, or jump out again (which latter they often succeeded in doing) made one wonder how long these very flimsy craft would survive. A small mercy was the fact that the mules almost always quieted down when well away from shore. Still a passage by "cattle-boat" was never a really dull experience.

Leaks, of course, began almost at once, and after the first day or two a number of boats were always out of action and under repair. Only one actually sank in midstream and that very fortunately on a shingle bank in shallow water so that men and mules were safely rescued. The transport of animals never stopped, however, and about 300 a day were ferried by this means without losing any, and the transport of men, stores and ration sheep went on at the same time. The light draught waggon mules and most of those of the Pack Battery were too large to travel in the Mosul boats without great likelihood of capsizing and it was evident that they would have to be swum. This operation was not begun till two or three days after the ordinary ferrying had been in progress;

the water level had subsided a little and an island appeared which could be reached from the near bank by fording; this island was made the starting point, thus shortening the journey somewhat. There was still a distance of several hundred yards to be swum, however, and this combined with the swiftness of the current prevented any chance of letting animals swim free. They had to be swum from boats and the great necessity was to get a good start.

The following method was evolved. A place where the bank shelved steeply was chosen, so that the mules could be launched more or less directly into water out of their depth. A boat was held bow outwards at right angles to the current by a rope from the bow to the shore upstream. Mules (or horses) were taken in threes; they were brought to the edge of the bank upstream of the boat, and their drivers, one to a mule, got into the boat, holding the head ropes, which had to be specially long ones. A 3-in. rope was passed behind the mules' hindquarters and when all was ready this rope was pulled forward and the mules were driven and pushed into the water; the rope to the bow was let go the instant the mules were in, and the boat started off.

If there were any hitch in getting the mules properly into deep water they would hold back the boat, the bow would swing downstream at once and everything would have to start again. Sometimes the mules would all combine to turn and swim for the near bank, in which case they always defeated the rowers and brought the boat ignominiously back a long distance downstream. Generally speaking, however, the method worked quite well. Four mules died, owing to the drivers holding the head ropes so tight that the mules could not swim freely and were completely exhausted by the time they reached the other side.

To turn to the vehicles. These were taken (*a*) by the big ferry boat, (*b*) by an ordinary pontoon raft, and (*c*) by *kilik*. The last is worthy of remark. The two *kilik* men arrived one morning with an unostentatious little bundle of only 100 goat skins and some thin poles, twine, etc. By evening they had blown out their skins and made their raft, which, after decking with a few chesses, was found fully capable of taking an empty G.S. wagon. On the Tigris very large rafts are made on the same principle. Thirty-one vehicles were ferried in a day by these various means, though this was at the end of the operation when the water had dropped considerably.

A remark may be made about towing the various craft. The Arab boatmen were always supplemented by military fatigue parties, but even so, towing by hand against the heavy current was slow and laborious. It was found that much time could be saved by using the wagon mules for towing. Special rope had to be provided, as the local towing ropes could seldom stand the strain! Also the speed of the boat relative to the water had to be carefully watched, the large ferry boat being swamped and sunk on one occasion by being pulled too fast. It took a considerable time to salve.

No accidents to personnel occurred in the actual process of ferrying, but there were two mishaps to sapper parties, one while engaged in trying to get a cable across a very rapid channel and the other in trying to salve the pontoon lost on the first occasion. A British Officer and some 18 sappers altogether were immersed and carried away a long distance downstream on the two occasions, but all kept afloat and were eventually rescued (though in a half frozen state), except, unfortunately, one sapper, who completely disappeared.

NOTES ON CEMENT CONCRETE WORK IN THE FIELD.

By LT.-COL. D. K. EDGAR, D.S.O., R.E.

THE use of cement concrete in constructional engineering is extending year by year, and, with the improvement which is taking place in the manufacture of cement and the production of rapid hardening cements, it is safe to say that its importance will increase.

It is recognised that full value of cement concrete cannot be obtained without intelligent supervision during mixing and placing, and that the best results are obtained by trained gangs of men well organised and drilled in their duties. Concrete can be laid by unskilled and unexperienced labour, but the results obtained are not as consistent, nor is the work as economically carried out.

From a military standpoint concrete has assumed great importance, and will become more important when a supply of slow setting, rapid hardening, cement can be assured.

To obtain the best results from a cement it must be slow setting; for it is quite conceivable that under certain conditions a period of an hour or more may elapse between mixing and placing the concrete. It must be rapid hardening, in order that the concrete may be taken into use within a day or two of placing.

There are certain brands of cement on the market which claim the above attributes, and there is very little doubt that an ample supply of suitable cements will be forthcoming in future. Good cement being assured, how can the best use be made of it?

Intelligent supervision is essential, and men must be trained in peace time for this duty. Supervision does not mean only the ability to see that the correct amounts of material are measured out and mixed, but it should include the recognition of suitable aggregates for concrete, the knowledge of the dangers involved in the use of dirty or unsuitable sand and stone, and the capacity for organising the labour and the supply of the raw materials.

Trained gangs can be obtained on service by keeping the same units on concrete work. In April, 1918, two Post Construction Companies were lent by the Director-General of Transportation to the Engineer-in-Chief for concrete work, and later on in the same year five Transportation Works Companies were formed for the purpose of erecting standard concrete block pill boxes, and other reinforced concrete work. The evolution and design of these concrete block pill boxes is interesting, but cannot be described in detail here. It will be sufficient to say that they were built of perforated concrete blocks, made in a central factory and shipped with the necessary reinforcement to the site of the works. The concrete blocks were threaded on to vertical rods and were so arranged that a horizontal bond was given. The whole was then grouted up and produced a more or less monolithic blockhouse.

The obvious disadvantage of this method of construction is that for a given thickness of wall, its strength is not equal to that of mass concrete, and, to produce an equal strength would require a greater thickness, and, therefore, more material and transport. Much work was done during the war with mass concrete *in situ*, with excellent results, but such difficulties were encountered that for rapid erection of M.G. emplacements the block concrete system was evolved.

The difficulties met with are tabulated below, and suggestions made of how they might be overcome without resorting to the block type of construction :—

(*a*) Great difficulty in transporting the material to forward sites ;
(*b*) Necessity for keeping the various ingredients (aggregate, sand and cement) clean and in good condition—cement especially suffering from the inevitable exposure to damp ;
(*c*) Delay during construction in erecting shuttering and strutting, and waste in striking on completion. Timber could rarely be used more than once, and there was always a shortage ;
(*d*) Length of time required for setting and maturing ;
(*e*) If reinforced, great difficulty in placing and fixing reinforcement under trench conditions—often by night ;
(*f*) Difficulties of concealment—concrete became very obvious if earth or other covering was destroyed by shell-fire. During construction it was not easy to conceal the materials, mixing boards especially showing up to aerial observation ;
(*g*) Lack of practical experience in the work on the part of the majority of engineers.

In all cases material will have to be brought forward by rail or mechanical transport, and, provided that the walls of the structure can be made thinner with reinforced mass concrete than with concrete blocks, the gross tonnage to be transported will be less. Material in its raw state is more easily handled than concrete blocks, and damage due to careless handling is avoided.

With slow setting cement it is unnecessary to mix the concrete actually on the site of work, and materials can be collected and camouflaged at any convenient spot. If possible, a battery of mechanical mixers should be installed, and the mix distributed by Decauville to the works, which apparently was the system whereby many of the German defences were prepared. If this is not feasible a mechanical mixer mounted on a caterpillar truck, accompanied by sufficient raw material for a night's supply, could carry out work at the spots not served by Decauville.

The point being that it is no more difficult to transport the raw material to site than it would be to transport completed blocks.

Even if materials have to be man-handled, the mixed concrete (gauged with a minimum amount of water) or the raw sand, aggregate or cement could be packed in sandbags and made up into one man loads for transport.

The second difficulty, especially as regards cement, is more serious. Any rough flooring (or tarpaulins) is sufficient to keep the sand and aggregate clean if stacked on muddy ground, and it is unnecessary to protect it from the weather. With regard to cement, sufficient protection for a few days can be given by tarpaulins above and below the stack. Such stacks of materials should not be difficult to screen from observation, and present no more difficulties than stacks of concrete blocks.

With regard to shuttering, good workshops and preparation will go far to solve this difficulty. There is a means, however, of incorporating the block system with the concrete *in situ* and dispensing with the shuttering. It is a common practice in concrete work to build 4½-in. brick skin walls, and after every foot of walling to fill in with concrete, the walls being bonded every fourth course into the concrete by headers. By substituting for the bricks suitable pre-moulded concrete blocks, which will take the necessary reinforcement rods, it should be possible to dispense with the shuttering. It appears, however, that in the majority of situations, suitably designed panel shuttering should be better, and with a well-trained gang the time spent on erection and the wastage when removing should be reduced to a minimum.

In a pamphlet recently issued by a foreign power it was stated that such shuttering could be used four or five times over. The planking on the interior walls might well be left in position, fixed to dovetailed battens embedded in the concrete. If this is decided upon it will only be necessary to remove the interior struts, and will avoid the necessity of taking large panels through a tortuous opening. Some of the advantages of a wooden lining compared to a concrete surface are obvious, but one which might escape notice is the protection given to the occupants from injury from flaking concrete dislodged by the concussion from a direct hit.

The support of a heavy roof during the laying of the concrete is a problem. Wooden shuttering well strutted, similar to that for the inside walls, would do, but probably the most simple method is by shallow and broad R.S.J.'s, spaced about 6-in. apart flange to flange, the intervening spaces filled in by planks resting on the lower flanges; the R.S.J.'s being built into the roof.

The time taken for setting and maturing of the concrete should not cause any difficulty in future with the use of rapid hardening cements. Reinforcement is essential if the bulk of the concrete is to be reduced. During the late war the figures adopted for the thickness of concrete required to resist an 8-in. shell were, for plain concrete, 5-ft. and, for reinforced concrete, $3\frac{1}{4}$ ft. Owing to the greater strength of the present-day concrete, it is probable that these figures can be reduced, but the proportion between plain and reinforced concrete will remain much the same.

If reinforcement is used, all bars must be cut to length and bent as required before being sent to the work. Templates should be prepared for the accurate and rapid spacing of the rods, and the amount of work required to be done on the site reduced to a minimum. Drill and practice in placing the reinforcements, combined with complete preparation of material, will do much to overcome the inherent difficulties. It should not be more difficult to conceal concrete work than many other engineering works which have been successfully camouflaged. After a pill box is completed it should be immune from anything except a direct hit by a heavy shell or bomb. It is during construction that the greatest difficulty will occur. The quicker the work can be carried out, the less chance there is of discovery. Mixing concrete by hand on mixing boards is a slow and cumbersome method, and will seldom have to be resorted to if concrete mixers are available. There are many suitable batch mixers on the market at present, and it is reasonable to assume that sufficient for all purposes will be obtainable on service. Light mobile mixers mounted on their own caterpillar trucks would be suitable for forward areas, while larger ones will be required forther in the rear.

Since the war much attention has been paid to the use of concrete and much experience has been gained, but experience under service conditions is difficult to obtain in peace time. Concrete is an expensive material to expend, and any peace time jobs requiring concrete work must be carried out under peace time conditions, and not as on service. At the front, much of the concrete work will have to be carried out in darkness, and it is well-nigh impossible to do this on a peace time job.

If a standard reinforced concrete machine gun emplacement were approved, much could be done towards the training of the supervising concreter in this class of work. The shuttering could be prepared and fixed by night; a proportion of the reinforcing bars cut and bent to shape and fixed in position by night; and, finally, batches of gravel and sand could be mixed and placed between the shuttering without destroying the value of the material.

It is not only pill boxes which will be constructed of reinforced concrete, but this important service has been used to illustrate the lines on which concrete work may proceed in war. Three things are necessary for effective and efficient work—(*a*) Standardization of designs, whether for roads, pill boxes, dug-outs, culverts, or bridges, etc. ; (*b*) Good equipment and organisation for producing masses of concrete quickly where required ; (*c*) Trained men who know their jobs.

Much of the information regarding the concrete work in late war was obtained from an article on *Work in the Field under the E.-in-C., B.E.F.—Concrete Defence Works and Factories*, which has been written as a part of the series, *The Work of the Royal Engineers in the European War*, 1914-19. It is hoped that the publication of this article will not detract from its interest when it is eventually published.

SOME REFLECTIONS ON FRONTIER WARFARE.

By L.D.G.

When the increase of power and mobility that science has given to the Army is realised, and then when one reads of the vast increase in the cost of defending the nation's frontiers, it is difficult not to wonder what is wrong. If we allow that our opponents' armament has improved to the extent of the difference between the *jezail* and the modern rifle, how is it that with motor cars, aeroplanes, light and heavy machine guns, hand grenades and artillery we have not made frontier warfare a much easier business?

One idea to be set forth in these notes is that some modern developments are, in this type of fighting, an actual handicap, as at present used, and that others are not adequately employed.

In what might be described as the pre-scientific days of frontier fighting the forces employed were in numbers not dissimilar from the expeditions of the last few years—if anything they were less. The armament was poor on both sides with, say, a five to three advantage to us. Discipline was, of course, excellent. Movement was not much slower than to-day. The opposition was good, but it has learnt a certain amount, though not much compared with what the British forces have, or should have, learnt. The results were very similar to those recently achieved at a far greater cost in money and a similar cost in life.

From the above must we assume that frontier fighting has not developed in the last fifty years? If we make this assumption, the question then arises, why has it not developed, and what can be done about it?

The reason that appears first is that as new weapons have been invented they have been immediately introduced on the frontier without a thought of whether they give a return of power commensurate with the extra trouble and hindrance to movement they involve. In other words, the old maxim that success in frontier fighting is measured by the speed at which certain (sure) movements can be made, has been forgotten and the ratio between the mobility of the opposition and that of ourselves has not materially altered. Hence, for our success we still pay as high a price as ever.

In order to study the factors that affect mobility, and to evolve an idea of frontier fighting, which it is hoped may lead to an improvement on present methods, let us re-state some axioms:—

(*a*) A force against normal tribal opposition can defend itself, and provided with food and ammunition, it is independent of L. of C.

(*b*) For any given standard of mobility the safety of a force as a whole is inversely proportional to the amount of transport required to maintain it.

(*c*) The cost of a force is proportional to the amount of transport required to maintain it.

(*d*) The effectiveness of a force is proportional to the square of its safe speed.

(It will be realised that the only novelty in the above axioms is the wording. They are in all text books.)

We are, therefore, met with the task of:—

(1) Increasing mobility.

(2) Decreasing transport.

(3) Decreasing cost.

If we can reduce transport, much will be achieved. The force will be able to move quicker and, therefore, will be more effective and safer. The cost will be less, and few, if any, geographical barriers will prevent its arrival.

The transport carries rations (men and animals—the latter a very, very heavy item) and ammunition forward and casualties backward. The quantity eaten by the man cannot be reduced by any serious amount, though the leisurely progress of grazing herds may be a serious slowing factor to a force. The number of animals required to be maintained with a force can, however, be reduced.

The amount of ammunition to be carried is the next point. In view of the difficulty of dealing with this point and all it involves without coming into conflict with many official *obiter dicta*, let us look for a moment at the bare necessities of a force. Our modern rifle has lost the, say, 20 per cent. advantage that our former weapons held over the *jezail*. The Lewis gun, however, more than replaces this. Is the machine gun, then, necessary? If it is, can the Lewis gun be dispensed with in this type of warfare? Both are ammunition eaters of a high order even when used with the minimum wastage of effort. The machine gun has, of course, long range but heavy weight, it is not a quick weapon in hills, though its power is prodigious.

The Lewis gun, on the other hand, is light, but is heavy enough to require a mule for normal transport. It is a quick weapon even in hills and its fire power is, for the majority of cases that arise, more than adequate. Before, however, ruling the machine gun out for an ideal frontier column and realising that it is a factor which most commanders will be very loth to discard, is it not possible that, anyway, its daylight role might be performed by another agency—the aeroplane? In operations in Kurdistan with a column of levies whose equipment of machine guns was, according to most ideas, inadequate (though their knowledge of mountain warfare was good) a system of employing aeroplanes in this connection was evolved. Each section had with it three strips of white calico. When it was about to picket a hill it put these out at its base in the form of an arrow pointing upwards. One of the aeroplanes that was co-operating with the column then machine gunned the top of the hill in question and thus was able to provide covering fire. On the arrival of the picket at the hill top three white strips were put in a triangle signifying that that hill was held. Just before retiring the strips were changed into the form of an arrow pointing downwards and an aeroplane then flew low over the place to tackle any opposition that tried to rush. This worked excellently, and the lack of active opposition, though not absence of opponents, was considered a measure of their dislike of low-flying machines.

The machine gun, therefore, may be given wings and eliminated from our ground force, and with it vanish many mules.

And now for the man's load. Most of those who have attempted a running climb of a considerable height will agree that a pair of shoes and a *topee* constitute the ideal kit. Between the ideal, however, and the present outfit is it not possible that a mean may be found? Rifle, bayonet, water-bottle and ammunition are unchallenged necessities.

The present form of ammunition boot is heavy, and it is possible that a form of shoe like the Richachatar might be adapted for service use. Climate must count to a large extent, and the question of shorts *v.* trousers is debatable. Tunic and jersey are necessities; and possibly a clean shirt and socks. Ground sheet and overcoat are a heavy handicap to mobility, though essential at nights. Blankets and tents for suitable native troops are not essential for periods up to two months—this is experience, not theory—even with bad weather (rain and slight frosts). The omission of blankets removes the necessity for a quantity of transport. The carrying of overcoats and ground sheets not on the man improves his mobility enormously. The transport required, however, is heavy. It is possible that a compromise might be arrived at and that the overcoats, etc., of only those troops on very active climbing employment need be provided for.

But these considerations, though important, are secondary compared with the elimination as far as possible of the forward cartage of food and ammunition on pack animals. A striking force of 7,000 men and 1,000 animals will require about $24\frac{1}{2}$ tons a day.

allowing for an expenditure of 200,000 rounds S.A.A. and 600 rounds of 3.7 Howitzer.

These figures will be criticised as including an undue expenditure of ammunition and too few animals. The second point will be dealt with shortly. If this expenditure of ammunition is excessive so much the better.

To carry 24½ tons requires about 350 animals (at 2 maunds each) and, allowing for a much lower expenditure of ammunition, it is clear that loads for at least 300 animals must be with the column per day. These in turn require feeding, and so the game goes on. Is there no better way of supplying troops in difficult country than the inefficient pack animal? Good roads would make supply by armoured lorries or caterpillar vehicles, in most cases, possible. Roads, however, are usually not available and, anyway, cannot be counted on. The remaining possibility is the air.

Rationing by aeroplanes in bad country is almost impossible. It has been tried several times—once recently,—but never with any real success. The remaining method is the airship. The type of airship required does not at the moment exist, as the types so far built have been evolved with different ends in view. That such a type is a perfectly practicable and cheap proposition has been stated by experts in this branch of air work. Its journeyings would be at night, when heat did not cause bad atmospheric disturbances and navigation would be comparatively safe. The size suggested is a useful dead load of 5 tons, speed 35-50 m.p.h. No great performance is required, though ease of manipulation and adequate engine power are essential. One original machine of this type can, it is understood, be constructed for about £50,000, or about the cost of four Vickers-Vernon troop carriers, a figure which would be reduced on duplication of orders.

It is realised that difficulties would be encountered and risks be run by the crew. But in man-power units it means risking, say, two or three crews of five against all the equivalent personnel of convoys and pickets, and, in addition, a saving in cost, direct and indirect. The former (direct saving) on cartage costs, including the guarding of convoys, for which must be allowed 400 men per mile (Waziristan figures) and the latter (indirect saving) on the extra speed, and so the smaller time required for a striking force to reach the seat of the trouble, and, therefore, the increased chance of localising it. (Approximate comparative cost figures are attached, Appendix A.).

To sum up. We have at our disposal weapons which have increased our striking power enormously. Inability to use these means that we are not reducing the costs of frontier warfare—in men and material—rather they are increasing. With the present need for economy, to fail to " make the best use of the Army allowed us by the State"* is unwise. With budget cuts, to maintain the same power standard we must try labour-saving devices, *i.e.*, we must take advantage of whatever science has done and can do for us.

Note.—It is possible that the introduction of airships might have a far-reaching influence on warfare other than that in mountains. It is interesting to surmise how the power of feeding an Army well ahead of rail head in roadless country would have affected the Palestine campaign. Naturally, their employment in such circumstances introduces other problems, such as local air-supremacy, and helium resources and supply (though the probability of incendiary bullets may be ruled out against frontier enemies). And, of course, the adoption of such a method, *i.e.*, making a frontier force into a body independent of everything, except the enemy, would involve a certain amount of experiment in reducing establishments of animals and stores to a minimum. No such attempt has been made here, nor would it be profitable, but sufficient, it is hoped, has been said, anyway, to arouse discussion from which possibly good may result.

APPENDIX A.

Data.—Striking force of 7,000 men and 1,000 animals operating with 50 miles L. of C.

L. of C.

Men per mile safety duties, 400 (Waziristan figures). Total men, 20,000.
Daily weight of rations, etc., at 4 lbs. head = 80,000 lbs. = 36 tons.
In cartage units = 26 x 25 = 900 *ton-miles.*

Striking Force of 7,000 men.

Daily requirements	Rations $2\frac{1}{2}$ x 7,000	=	17,500 lbs.
Expended Ammunition	S.A.A. 200,000 at 3 lbs. per cent	=	6,000 ,,
	3.7 How. 600 at 20 lbs. each	=	12,000 ,,
	Forage 1,000 animals at 20 lbs.	=	20,000 ,,
			55,500 ,,
			say $24\frac{1}{2}$ tons.

In cartage units $24\frac{1}{2}$ x 50 = 1,225 ton-miles.

∴ *Daily cartage total* = 2,125 *ton-miles.*

* Major-General Anderson — Lecture on the British Army. Staff College, 1921.

Assume Camel Transport.

Load per camel 400 lbs.

Max. journey per day = 20 miles.

∴ Ton-miles per camel per day = 3.5

∴ Camels required per day = 600.

and as camels take six days for round trip, and allowing for some spare :—

Camels required	=	3,600
Rations for these at 20 lbs a day	=	72,000 lbs.
	=	180 camel loads.

∴ *Allow* 3,800 *camels.*

COSTS.

L. of C. and Supply.	*Per day.*
Pay and maintenance of 20,000 men at £100 per man per year (£80,000 per Battalion per annum in estimates)	£5,500
Pay and maintenance of 3,800 camels at 10*s*. day each (7 Rs. 8 as.)	1,900
Pay and maintenance. Drivers, etc., of camels, 800 ..	175
	£7,575
Allow costs of administration, pensions for killed on L. of C., treatment in hospital for sick on L. of C., etc., etc., 25 per cent.	1,895
	£9,470

For this L. of C., substitute a flight of five airships, first cost £30,000 each, useful load 5 tons, and allow :—

One journey per ship per night for three ships and two journeys for one ship, *i.e.*, one spare ship kept.

Weight required by striking force per day	=		$24\frac{1}{2}$ tons.
First cost of flight	£150,000		
Add for mooring masts, spares, etc. ..	50,000		
			£200,000

	Daily Cost.
Allow depreciation at 50 per cent. per annum ..	£550
Running costs 20*s*. per machine mile ..	500
	£1,050
Add for administration and eventualities 100 per cent.	1,050
	£2,100 per day

With the increased mobility of the column, due to no land L. of C. (incidentally all communications by pick-up message or wireless), the cost of L. of C. would be reduced from £9,470 to £2,100 per day. A not inconsiderable saving. The indirect savings in cost, due to more rapid consummation of the required object and the localising of disturbances, and the reduction in casualties due to increased rapidity of movement, cannot be calculated, but there seems little doubt that they would be considerably larger even than the direct costs.

The cost of other aircraft co-operation is not easy to arrive at. A figure which is official, but is regarded as very high (it includes a portion of everyone's pay and maintenance from the squadron *dhobi* to (probably) the Prime Minister) is £10 per flying hour per machine.

Allow eight machines continuously co-operating with the force for 12 hours a day, *i.e.*, say, half hour out, two hours co-operation, and half-hour back to re-fill, overlapping, gives 18 hours flying for a 12 hours' co-operation, *i.e.*, 144 machine flying hours, if eight machines are required.

Cost = 144 x 10	=	£1,440 per day
Cost of Air L. of C.	=	2,100
Total daily Air cost	=	£3,540

From this must be deducted the cost of maintenance of machine gunners with the column, but even allowing this, a saving of £6,000 a day should be made.

THE SIEGES OF ALEXANDER THE GREAT.

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

1. THE ENGINEERING SKILL OF ALEXANDER.

Military history provides the student with many examples of specialist generals, great infantry or cavalry leaders, great artillerists or engineers, but the few really great soldiers who have risen to be captains of the first rank, have to all the qualities of these specialists added a general grasp of war which has enabled them to use all the means at their disposal as an artist uses his tools. Amongst these great captains none have excelled or even approached Alexander. Whatever he does, he leads by a long length; whether it is as a commander of infantry, or cavalry, or as a besieger of fortresses and cities. In all branches of war, his genius is supreme, and the greater the difficulties, the more eager is he to accept their challenge.

In days when battles were won not by fire power but by assault, to defeat an enemy who occupied a defended camp or fortified town was always a difficult operation, as difficult as was the storming of trenches during the first three years of the Great War of 1914-1918. Yet, no fortress defeated Alexander, and some of the fortresses of antiquity were such as would have struck consternation into Vauban. The walls of Carthage were of terrific strength; in its hey-day Babylon was surrounded by a bastioned wall, reputed to have been 300 feet high and 70 feet thick; Ecbatana possessed seven walls, and lesser cities of importance stout ramparts.

The main sieges undertaken by Alexander fall into two groups—the coastal fortresses and the mountain strongholds. The first includes Miletus, Halicarnassus, Tyre and Gaza, the second, the Sogdian rock, and the rocks of Chorienses and Aornus. Besides these two groups, he also besieged Thebes, and, when in Scythia, Cyropolis, which he took in the same manner as Cyrus took Babylon, that is by entering the town by wading along a branch of the river (Jaxartes) which flowed through its fortifications.

2. THE FIRST PHASE OF THE SIEGE OF TYRE.

Of the first group I will only deal with the siege of Tyre, which was not only by far the most difficult siege undertaken by Alexander, but also one of the most extraordinary sieges in history.

The Phoenician cities formed a league much like the Hanseatic league in the Middle Ages. They owed allegiance to the Great King, but were semi-independent, for the Persian monarchy relied largely on their good will for seamen, ships and trade. Between them reigned persistent jealousy and this greatly assisted Alexander in subduing them. On his southwards march from Issus, the first city to surrender to him was Marathus, then Byblus, reputed to be the most ancient city in the world, capitulated and so also did Sidon out of jealousy for Tyre.

As Alexander neared Tyre, at first the Tyrians were undecided whether to admit him or not. If they opened their gates to him, and should he eventually be defeated by Darius, they would have to pay a heavy fine, they were Shemites and they loved the feel of gold.

Alexander asked permission to enter the city in order to worship in the temple of Hercules, but the Tyrians smelt a rat, and suggested that the temple on the mainland would equally well satisfy his devotions. Alexander could not, however, leave this fortress untaken. If he passed it by, the cities north of it would revolt and those south of it refuse to surrender. Further still, Tyre must be his, its occupation was essential to his plan, for without it he could not gain command of the sea.

The Tyrians now point blank refused to open their gates, and this was easy enough to do, seeing that New Tyre was built on an island, about one mile in length, and half a mile from the mainland, on which the old city stood ; further Alexander possessed no fleet.

To an ordinary general, situated as Alexander was, the reduction of Tyre would have appeared an impossible task, even the old city had withstood Nebuchadnezzar for thirteen years. But Alexander was no ordinary general nor was he a Nebuchadnezzar; he was Alexander faced by an island fortress with walls in places 150 feet high, manned by a brave people of intelligence and resourcefulness, holding command of the sea and determined to defend their city until Darius and his millions could once again sweep down on the rear and flank of the Macedonians.

Possessing no fleet, Alexander determined to build a mole from the mainland to the island. He forthwith demolished Old Tyre and, by impressing thousands of its inhabitants, " raised a mole two hundred feet in breadth." (1) The construction of this immense work is interesting. Arrian tells us : " The place is a narrow strait full of pools ; and the part of it near the mainland is shallow water and muddy," but the part near the city itself, where the channel was deepest, was about three fathoms in depth. But there was an abundant supply of stones and wood (2) which they put on the top of the stones. Stakes were fixed down firmly in the mud, which itself served as a cement to the stones to hold firm. (3).

(1) *Diodorus* XVII, IV.

(2) According to *Curtius* IV, 10, the wood came from Lebanon.

(3) " Arrian " II. XVIII.

At first the Tyrians treated the whole proceedings as a joke and asked Alexander " Whether he supposed himself to be stronger than Neptune." Then, as the mole advanced, they grew nervous; one dreamt that Apollo was about to forsake the city, and the others, determining that he should not do so, " fastened his image to the pedestal with golden chains." Having thus regained their courage, they sailed round the mole " and made it impossible in many places for the Macedonians to pour in the material." To counter these attacks, Alexander constructed two wooden towers at the end of the mole and in these he placed his engines of war.

3. The Second Phase of the Siege of Tyre.

Apollo now being quite incapable of leaving the besieged city, and a whale having been washed up against the mole, which the Tyrians imagined was Neptune himself, a series of most astonishing counter-attacks was launched. First " they filled a vessel, which had been used for transporting horses, with dry twigs and other combustible wood, fixed two masts on the prow, and fenced it round in the form of a circle as large as possible, so that it might contain as much chaff and as many torches as possible. Moreover, they placed upon this vessel quantities of pitch, brimstone, and whatever else was calculated to foment a great flame." (1). This fire-ship they launched and set the wooden towers alight, and, under cover of the confusion resulting, they put to sea and attacked the mole.

The devices made use of by the Tyrians are of great interest. Chemical warfare was employed, for we learn that pots of burning sulphur, naphtha and oil were hurled by the catapults on to the Macedonians. Diodorus gives us a graphic description of a form of vesicant attack. He writes:—

> " Another wonderful invention they found out against the Macedonians, whereby they grievously plagued the chiefest of their enemies, which was this: they filled their iron and brazen shields with sand, and heated them in the fire till the sand was scorching hot, which by an engine they threw upon them that were chiefly engaged, whereby they were cruelly tormented; for, the sand getting within their breast-plates and coats of mail, and grievously scorching their flesh, no remedy could be applied for the cure of the malady; so that (though they made most bitter complaints, as men upon the rack) yet there were none who were able to help them, insomuch that they grew mad by the extremity of the torture and died in the height of inexpressible torments." (2).

(1) " Ibid " ii. XIX.

(2) *Diodorus* XVII. IV.

Their protective devices were equally remarkable: "They contrived wheels with many spokes, which, being whirled about by an engine, shattered in pieces some of the darts and arrows, and turned off others, and broke the force of the rest." (1). They made great sacks, or cushions, out of hides, stuffed them with hay and lowered them from the walls to break the force of the rams. They made hooked tridents with which they wrenched away the shields of the attackers and fastened sharp hooks to long poles wherewith they cut the cords of the enemy's engines. "They plucked . . . men in armour off the ramparts with iron instruments called crows—shaped like men's hands—and caught others in whirling fishing nets."

We see here the ideas of many of our modern devices, wire entanglements, bursters, shock-absorbers, flame projectors, gas, toxic smoke and vesicant chemicals, and so well were they used, that Alexander saw that to take the city he must gain command of the sea.

4. The Third Phase of the Siege of Tyre.

The mole was rebuilt and widened, so that more towers could be built on it, and, whilst this work was in progress, Alexander went to Sidon "to collect there all the triremes he could; since it was evident that the successful conclusion of the siege would be much more difficult to attain, so long as the Tyrians retained the superiority at sea." (2).

His efforts were eminently successful. At Sidon he obtained 8 Phoenician ships and 24 from Rhodes, Mallus, Soli, Lycia and Macedonia. Then the kings of Cyprus, hearing of Darius's defeat at Issus, sailed into Sidon with 120 warships. This placed at Alexander's disposal a magnificent fleet of 224 vessels. On these he embarked his Shield Bearing Guards and sailed for Tyre.

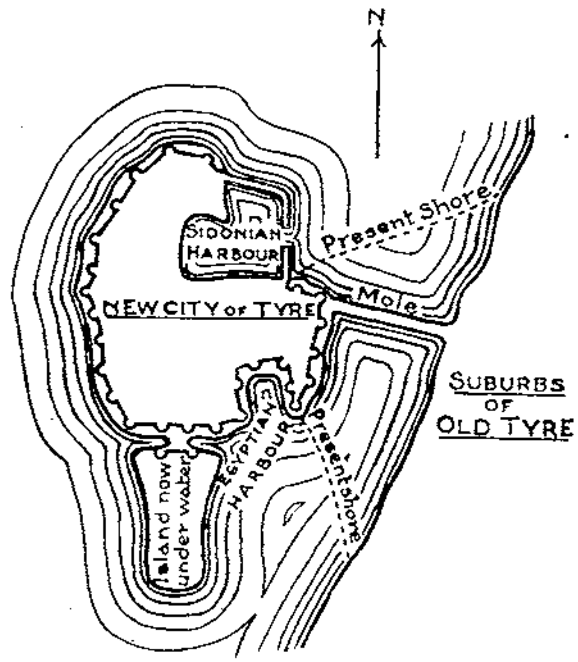
He divided the fleet into two wings, the Cyprians on the right, under his own command, and the Phoenician ships on the left under Craterus.

At first the Tyrians resolved to fight, but when he approached them, "they were surprised to see that he was sailing against them with his fleet in due order," and so thought it wiser not to put to sea. Alexander, thereupon, determined to blockade the two harbours. The Cyprian ships, under their admiral Andromachus, were drawn up outside the Sidonian harbour and the Phoenicians outside the Egyptian harbour.

The reduction of Tyre was now but a matter of time, for, if the assault from the mole proved unsuccessful, starvation must accomplish this work.

(1) *Ibid* XVII iv.

(2) *Arrian* ii. XIX.



PLAN OF TYRE (After Dodge)

5. The Fourth Phase of the Siege of Tyre.

Alexander was not, however, going to wait for starvation to reduce the city. Time, he knew, was the controlling factor, and, if he delayed to take Tyre, Darius might be on him before he could conquer Egypt and gain complete control of the sea and so, if necessary, dispense with his land communications. He constructed, therefore, a number of floating batteries upon which he mounted his rams so as to attack the walls on the flanks of the mole which were "one hundred and fifty feet high, with a breadth in proportion." These walls were protected by large stones sunk in the sea which prevented the floating batteries coming within range. "These stones Alexander determined to drag out of the sea; but this was a work accomplished with great difficulty, since it was performed from ships and not from the firm earth."

To hinder this work, the Tyrians covered a number of their triremes with mail armour and attacked the moorings of Alexander's vessels. Alexander met this manœuvre by placing armoured ships in front of his dredgers. The Tyrians then sent down divers to cut the cables, thereupon Alexander had the cables replaced by chains.

"The Tyrians being now reduced to great straits on all sides, resolved to make an attack on the Cyprian ships, which were moored opposite the harbour turned towards Sidon. For a long time they spread sails across the mouth of the harbour, in order that the manning of the triremes might not be discernible." (1). Under cover of this "screening" they fell upon the Cyprians and drove them back, but Alexander came to their rescue and the Tyrians put back to port.

The new mole was now finished and the great engines erected on it, when it was found that the walls were built on rock and that the work of destruction would be extremely slow. Alexander now determined to force the harbours. This was successfully accomplished, the Egyptian and Sidonian harbours being entered by the Phoenician and Cyprian vessels. Ladders were thrown against the walls, from which the Tyrians were driven by showers of darts and arrows.

At length after a siege of seven months, (2) the city was taken and 8000 Tyrians slaughtered, 2000 later on were executed, and 30,000 sold into slavery. Apollo had proved a false ally and, when Alexander entered his temple, he caused the golden chains to be struck from his limbs and renamed the god Apollo Philaxandrus, that is, the lover of Alexander. (3)

(1) *Ibid* ii, XXI.

(2) Seventeen years after this date, it took Antigonus fifteen months to capture Tyre from Ptolemy. See *Diodorus* XIX. 61.

(3) See *Diodorus* XVII. IV.

Thus ended this memorable siege, in which every type of device that the ingenuity of the human brain could think out was used in attack and defence. Yet in the end, the energy of a single man, one who scorned defeat, triumphs over all material difficulties and, to-day, as an everlasting memorial to his energy, the sea, having long ago washed the sand against the mole, has changed Tyre from an island into a peninsula.

6. THE STORMING OF THE MOUNTAIN STRONGHOLDS.

The storming of the mountain fortresses, which I will now very briefly examine, constitute examples of leadership rather than of generalship. Their chief interest lies in the difficulties they presented and the energy and cunning which was shown by Alexander in overcoming them.

After the rising of the Sogdianians had been suppressed, the whole of their country was reduced to submission except for a few mountain strongholds which were considered impregnable. One of these, known as the Sogdian rock, or rock of Arimazes, was victualed for a long siege by Oxyartes, a Bactrian chieftain.

This stronghold was apparently built on a ledge or flat topped spur, jutting out of the mountain side. When Alexander summoned the barbarians to surrender, they jeered at him saying that to capture the fortress he would have to send "winged soldiers." This at once suggested to him an idea. To assault the rock would prove most costly, to starve its garrison into surrender would take months, why not, therefore, deliver a moral attack on his enemy. He took them at their word, and, choosing the most precipitous side of the mountain, he selected 300 men who were to climb the face of the rock by driving iron pegs into it and by attaching to these ropes of flax.

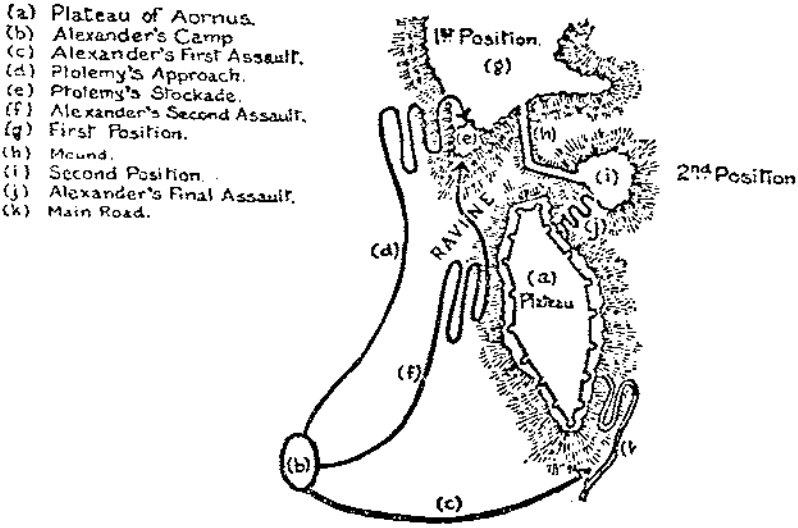
This was done, and, out of the three hundred climbers, two hundred and seventy reached the top. Then he sent a herald to the barbarians saying, as he pointed upwards, "there are my winged soldiers." This resulted in an immediate surrender.

The interesting point to note is the rapidity with which Alexander turns conditions to his advantage. In this case, the decisive point was the superstitious nature of his enemy and he at once attacks it, forcing the surrender of an all but impregnable position at the loss of thirty men. This he was able to do only because he valued conditions rightly.

The last stronghold reduced in the neighbourhood of the Oxus was the rock of Chorienes. It rose from a deep ravine, and was, according to Arrian, some seven miles in circumference and could only be approached by a narrow pathway cut in the rock.

Alexander forced its surrender as follows. First he had a number of ladders made to enable his men to descend into the ravine. Next he built up an extensive crib-work bridge across the ravine so as to reach a level with the top of the rock. When once this work had progressed sufficiently far to enable his missile throwing engines to be brought into play, Choriencs surrendered to him and was rewarded for doing so by being made governor of the surrounding country.

When Alexander marched through the mountains north of the Cabul river, the inhabitants deserted their towns and villages and sought refuge on the rock of Aornus. It has been identified as mount Mahabunn on the right bank of the Indus and some sixty miles north of Attock. On its summit, which was flat, was an extensive area of arable ground and a plentiful supply of water. Tradition related that, when Heracles invaded India, he had failed to take Aornus, this in itself was sufficient reason for Alexander to do so; but take it he must if only to maintain his prestige, for it was his prestige which secured his far-flung line of communications.



ROCK OF AORNUS (After Dodge).

The attack on this stronghold is interesting and it may be followed by means of the diagram (1).

Having selected a lightly equipped force, he placed Ptolemy, son of Lagus, in command of it and sent him to seize the mountain ridge abutting on the rock, but separated from it by a ravine. Once in occupation, Ptolemy was to signal to Alexander who, whilst Ptolemy attacked the rock from the north, would attack it on its southern flank, " so that the Indians, being assailed from both sides at once, might be in perplexity what course to pursue." (2) This attack

(1) Taken from Col. Dodge's "*Alexander,*" Vol. II. p. 529.
(2) *Arrian* IV. XXIX.

failed. The second assault, which was delivered against the western flank of the rock, was equally unsuccessful.

Alexander now changed his plan. First, he united his forces with those of Ptolemy. Next, he constructed a mound from the mountainside to a hill which was on a level with Aornus. The Indians now took alarm and suggested a truce, over the terms of which they argued, as their plan was to gain sufficient time to permit them to secretly leave the rock and seek refuge in the mountains. Alexander, discovering this ruse, at once took advantage of it. He gave the enemy time to begin their retirement, then, from the small hill, he assaulted the plateau and fell upon his enemy when he least expected it. "Thus the rock which had been inexpugnable to Heracles was occupied by Alexander."

7. Alexander Avoids Sieges by means of the Moral Attack.

Since the days of Alexander, the art of siege warfare has changed almost out of recognition, but unless we recognise the difficulties which these sieges entailed, we shall fail to get a true picture of the art of war during this early period. Under the Romans, sieges were frequent, yet not much was added to the art as established by Philip and Alexander. During the Middle Ages, the art, in Western Europe is almost entirely lost, and towns and fortresses are forced to capitulate through starvation or by treachery, and seldom by force of arms Not, until after the Renaissance, does the ancient art of siege warfare re-appear.

To Alexander, sieges were necessary evils, and to limit their number he used terror as a means of overcoming walls. When a city refused submission he never passed it by, and for a definite moral reason—loss of prestige. To paralyse the initiative of a superstitious world, ruled by deities conceived as superior human beings, Alexander always aimed at the super-human—he knocked the gods off their pedestals. There can be little doubt that, in his days, the world in general looked upon him as a god or a heaven-born hero, consequently he was compelled, not only for the sake of vanity but for that of prestige, to overcome all difficulties, and, as each fell victim to his will, his sway over his immense empire, became more sure.

NOTES ON THE ELECTRICAL AND MECHANICAL COURSE.

By LIEUTENANT J. T. GODFREY, R.E.

FROM the number of enquiries he has received on the subject, the writer thinks that a few remarks on the scope and possibilities of the E. and M. course may be of use to others intending to apply for it; and he has included some hints from his own experience for what they are worth, as to how the course may be tackled.

There are four aspects which invite attention :—

1. The type of work.
2. The mode of life.
3. Exercise and social possibilities.
4. Expenses.

Firstly, the type of work. On reporting at the War Office, an officer is allotted a preliminary programme usually extending over about three months. The authorities are very considerate of the individual's convenience, as far as that is possible; and if an early interview can be arranged, say, a month or two before the course starts, even the preliminary programme could probably be adjusted with that end in view.

The course is divided into a number of periods of different lengths, from one to eighteen weeks, and certain subjects to be learnt (*e.g.*, Pumping Machinery) are allotted to each period. As long as the subjects and periods are not radically altered, there is a fairly large choice of individual firms for the various subjects. This choice may be limited by the number of officers already with a particular firm, since usually there are only two vacancies at a time at any one firm.

The types of firms may be roughly classified into the large, the medium, and the small.

Type 1. The large are those which have a number of branches or departments, at which different subjects may be studied all under the one firm, *e.g.*, the General Electric Company, the British Thomson Houston.

Type 2. The medium are those which have a considerable works devoted only to one subject, say, oil engines, but which may possibly extend to two.

Type 3. The small are one-subject firms with less expensive machinery and appliances, or are the geographically distinct branches of a major firm.

A few pros and cons that occur to the writer are tabulated below:—

	Advantages.	Disadvantages.
Type 1.	Large range of subjects. The latest and best methods are in practice. Six to eight months may be spent in one place, so that frequent moves are avoided. Often there is an apprentices' Club with facilities for games.	A great many types of work are in hand which are well outside the range of service requirements, even in the future. Often a very rigid administration! A lot of time can be spent on matters that are of no practical value to an R.E. Officer, but which are very interesting.
Type 2.	In general, the smaller the firm, the better the personal attention to the learner's requirements.	Usually only a short visit, but there is here the advantage of change to keep up interest.
Type 3.	In this type the conditions approach more nearly to those found in the Service and there is better scope for practical work.	No messing amenities for lunch, etc., and as in 2 above.

Throughout the course it is very helpful (1) to know what is *not* required to be learnt of a particular subject, (2) to combine practice and theory; *i.e.*, to look up the subject in text books at the time; and (3) to keep a record of the practical side, workshop tips, and methods of testing and repair. The details of manufacture need not be investigated *deeply*, though works management, modes of supervision, checking and testing are of great value, especially the last; and a good proportion of the officer's time should be spent in the testing departments. Wherever possible, he should apply to the works manager to be sent on installation work, after he has gained a general insight into shop practice.

No period is specially allotted to the study of machine tools, yet they exist in every factory, and the officer should allow himself so much time in every works to learn about them. The general-purpose machines are far more useful than the specialised repetition machines, for military workshops.

The Power Station.—This is a subject to which a considerable time is given. In the writer's opinion it is probably better not

Exercise and Social Possibilities.—Exercise is difficult to get during the week, and after standing up for eight-and-a-half hours one is distinctly foot-weary to start with. During the winter it is next to impossible, except at week-ends, and unless there is a local club for rugger, hockey, or soccer. To reach places where exercise may be obtained some means of transport is very desirable, even the humble bicycle being better than nothing. In the summer conditions improve, and the officer who has a car can always get away for tennis, golf, or fishing and shooting if he makes the necessary arrangements.

Leave is officially six weeks in the year, to be taken at any time that is convenient between subjects.

As regards social life, an officer should either ask to go to a region where he already has friends, or should get from his friends and relations an introduction to a local resident; given that start, the rest follows. The difficulty may often be in finding time to get away, and not in a lack of acquaintances.

If the firm is a large one, the apprentices, who are often Cambridge men, will probably have a cricket club; and if the worst comes to the worst, the fortnight with the Manchester Steam Users' Association, spent on boiler inspection, is equivalent to a fortnight's climbing in a tropical climate.

Expenses are very much in the officer's own hands; he may live very cheaply, or as expensively as his bankers will permit. Full pay and allowances are drawn.

To conclude with a few general remarks. The choice on the whole lies between a prolonged stay in one of the large towns, London, Manchester, Birmingham, or possibly Glasgow, and a series of fairly frequent moves among the smaller towns, or a mixture of the two. Detailed information about the individual firms can be obtained from a list in the War Office when officers report. It must be remembered that these notes have been written from the experience of a single officer, who cannot know more than a limited number of firms, so that the generalisations expressed may be quite misleading for a particular firm outside his knowledge.

Uniform need not be taken, but the flannel trouser is a very present help; and unless the more stationary type of life is preferred, it is best to travel light.

to go to the largest, since the occasions on which an R.E. Officer will have charge of more than 5,000 K.W. will be rare, and the more usual run is 500 K.W., if that. At the same time it must be admitted that the larger the station the more organised the management usually is. Plenty of time should be allowed for A.C. work, especially distribution, H.T. and L.T., transformers, motors and switchgear: this implies attention to sub-stations and their equipment.

A fact to be remembered is that in military life the reciprocating steam engine is far more common than the turbine, though knowledge of the turbine is essential. In this connection, it is very necessary to know what is the best *equipment* for any given turbine or boiler: for instance, the condensers, pumps, valves, circulating system, and especially the governor gear, are as important as the machine itself, and in the case of the boiler, the feed-pumps, steam mains, stop-valves, safety valves, flue dampers, feed regulators, mechanical stokers, fans, steam traps, and so on, often require more attention than the actual boiler.

The period with the consulting engineers was in the writer's case the most profitable and interesting part of the course: after the shortest of preliminaries, the officer works simply as an engineer of the firm, and gains very valuable experience on large work that is actually in hand.

It is very easy throughout the course to specialise almost unconsciously either on the mechanical or the electrical side: but from the R.E. point of view this very nearly amounts to an offence under Section 40 of the Army Act.

Mode of Life.—On arrival at the works, which should take place early in the day, the first requirement is to ask the manager if he has a list of lodgings, which is usually the case; and the first day can be spent settling in. Hotels are generally expensive, but are often useful till a good lodging has been found. N.B.—Enquire if there is a bath, as baths are sometimes non-existent.

The official works hours are generally 8.30 to 1, 2 to 5.30 or 6.0 in the winter, and half-an-hour earlier in the summer. In the larger firms "clocking-in" is the usual custom.

There are two points in connection with lodgings: (1) One's comfort depends entirely on the qualities of the landlady. (2) Lunch is often provided at the works, with the supervisory staff; and it is as well to find this out from the manager, and arrange accordingly.

Two pairs of overalls are necessary; and in the matter of getting dirt off one's hands, *always* rub in slightly moist soap and get it well under the nails, *before* starting work. If very dirty, wash them with oil first, and then with soft soap and sawdust, or one of the many patent gritty soaps.

HISTORY OF THE 12th COMPANY, ROYAL ENGINEERS.
(Continued).

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

CHAPTER V.

THE SOMME (*See Map 6*).

On the afternoon of the 3rd August, 1916, the Company detrained at Candas-Fienvillers, and, marching *via* Beauval and Arquèves, arrived at billets on the Englebelmer-Martinsart road, the transport and rear Headquarters remaining at Acheux.

The 18th Infantry Brigade had meanwhile taken over a sector from the River Ancre to the southern edge of Beaumont-Hamel. The trenches here, in contrast to those in the Ypres Salient, were deep, wide and dry, with mined dug-outs, and the ground was very chalky.

Work in the New Sector.—Until the 25th the Company was engaged in the construction of mined dug-outs, and the lay out and construction of a new front and support line with strong points, which were afterwards used as assembly trenches by the Naval Division in their attack in November. This latter work, which was mainly carried out by Nos. 2 and 4 Sections (Lieuts. Regnard and Johnson), was of no easy character, having to be carried out close to a vigilant enemy and on an exposed ridge where the hard chalk made silent working an impossibility. The parties were, consequently, night after night subjected to a heavy and accurate trench mortar bombardment which caused heavy casualties and severely shook the men, and would, but for the coolness and judgment of the officers in charge, have had very serious effects.

Whilst in this sector the men were subjected to gas shell bombardments for the first time, and underwent several unpleasant experiences in the neighbourhood of Mesnil and Hamel, the chief centres of this activity.

On August 26th the company were relieved, and, marching *via* Amplier and Gezaincourt, arrived on the 29th at Vignacourt, where they remained for a week for drill and training. Leaving on the 6th September, they marched *via* Rannecourt to Sailly-le-Sec, where they arrived the next day. Three days were spent here prior to moving up into the assembly positions for the attack which was about to come off on the intricate network of trenches known as the Quadrilateral.

Attack on the Quadrilateral.—The assembly positions were reached early on the morning of the 14th, the Company being placed in some disused trenches in front of the Briquetterie, near Montauban. The Division was in the line in front of Guillemont, with the 18th Brigade in reserve, so that, when the attack took place the next day, the Company's work consisted only of road making up into Guillemont.

The attack was only partially successful, the centre of the Division being held up by the Quadrilateral itself, and the 18th Brigade was therefore ordered to carry out a further attack. Accordingly, on the night of the 17th, No. 3 Section taped out an assembly position across the front, and the 1st Battalion West Yorkshire Regiment was led into position.

The attack on the morning of the 18th was entirely successful, and the Quadrilateral was taken, together with nearly 1000 prisoners. As soon as the objectives were reached, Nos. 1 and 2 Sections carried out the construction of strong points on the flanks with but little interference from the enemy, one man only being wounded.

That same day the 6th Division was relieved, and the Company marched back to Meaulté for two days' rest.

Attack on Les Bœufs and Morval.—On September 21st, Nos. 2 and 3 Sections moved up by lorry to the north of Guillemont to prepare a battle Headquarters for the 18th Brigade for an attack on Les Bœufs and Morval, the remainder of the Company bivouacking behind Trones Wood.

During the next three days Brigade Headquarters and assembly trenches were prepared, and, on the night of the 24th, Nos. 3 and 4 Sections (Lieuts. Langley and Johnson), took up positions in the assembly trenches North East of Ginchy, Nos. 1 and 2, under Lieut. Regnard, being held in reserve.

On the morning of the 25th, the 6th Division, with the 16th Brigade on the left and the 18th on the right, attacked in conjunction with the Guards who were on their left. The operation was a great success, all the objectives including the villages of Les Bœufs and Morval, together with several thousand prisoners being taken with but little loss, and an advance of about two miles was achieved.

The sappers, with a carrying party of 25 infantry to each section, advanced with the Rear Lines. No. 4 Section came through the enemy barrage successfully, but No. 3 were less fortunate, losing three men killed, including Sergt. Pellowe, the Section sergeant, and seven wounded, besides about half the carrying party.

On reaching the final objective, No. 3 Section, working on the extreme left with the Guards, and No. 4, with the 16th Brigade, constructed two strong points, each consisting of a machine gun post with supporting rifle pits connected up to the general line, and wired them in on the flanks with French concertina wire strengthened with barbed wire and screw pickets.

Infantry patrols which were now sent out met with little or no resistance and the enemy did not greatly further interfere, so that by nightfall the work was finished and the sections were withdrawn to their bivouacs at Trones Wood. For the gallantry displayed during this operation, Lieut. Langley was awarded the Military Cross, Sergt. Caulfield, of No. 3 Section, the Military Medal, and Sergt. Clark the Distinguished Conduct Medal.

On that and the following evenings, Nos. 1 and 2 Sections under Lieut. Regnard went up to continue further consolidation, and on the night of the 27th the whole Company turned out and erected two belts of wire along the front and support lines, each over 1000 yards in length.

On September 28th, the Company marched back to the Briquetterie at Montauban and thence to Méricourt, stopping a night at Meaulté and Ville sur Ancre on the way. Here five days were spent, resting and refitting after the strenuous days just gone through.

On October 7th, the Company marched up to the Citadel, moving into dug-outs in rear of Longueval the next day. The 18th Infantry Brigade had taken over a part of the line east of Guedecourt, and, during the next three days, the Company was employed on wiring and constructing dug-outs in this Sector.

Attack near Le Transloy.—At 1400 hours on the 12th, the 18th Brigade carried out a small attack on the line north of Le Transloy, but were not very successful, making only very little headway against a determined resistance. No. 1 Section, under the command of 2nd Lieut. G. W. Jack, accompanied the leading waves, and, after capturing several prisoners, assisted in the defence and consolidation of the little ground wrested from the enemy. 2nd Lieut. Jack set a fine example of coolness and courage under very trying circumstances, and was subsequently awarded the Military Cross.

At 0535 hours on the 15th, another attack on the same ground, made by the 2nd Battalion Durham Light Infantry and 11th Battalion Essex Regiment on the left with the Sherwood Foresters on the right, met with but little more success, being held up by machine guns which had been insufficiently dealt with by the artillery. Nos. 2 and 3 Sections (Lieuts. Horne and Langley), came up at dusk to carry out consolidation, and did useful work in forming bombing posts and blocking communication trenches leading to the enemy's lines. Lieut. Horne was unfortunately wounded during the operation.

On the 19th the 6th Division was relieved and that day the Company marched back *via* the Citadel to Méricourt. Whilst here Captain A. Campbell, D.S.O., who had commanded the Company since July, 1915, left to take over the duties of Staff Officer to the Chief Engineer XIV Corps.

Move to Allery.—On October 22nd the dismounted personnel proceeded by train to Allery, the transport moving by march route. Here the Company spent nearly a week, resting, training and refitting.

Move to Bethune Area.—On the 29th the Company moved by rail to Choques, and marched thence to Marles-les-Mines, where they carried out further training until November 5th.

On the 6th the Company was unexpectedly ordered to Mazingarbe, where they relieved the 103rd, 104th and 129th Field Companies of the 24th Division, who were employed in the construction of deep dug-outs. No. 2 Section, under 2nd Lieut. Newland, proceeded to Maroc. The work on the deep dug-outs was continued for three weeks, the men working in continuous shifts of six hours and having an hour's march from and to billets.

Whilst here Capt. A. M. Jackson, M.C., returned to assume command of the Company, and Lieut. Regnard received his captaincy and became second in command.

On November 29th the Company rejoined the 18th Brigade, Headquarters moving to Beuvry, with two forward sections to Cambrin.

The ground in this sector was flat and low lying, somewhat similas to that in the Ypres salient, and consequently great difficulty war experienced in the drainage and upkeep of the trenches. The pressure of this work was often very great, so that at one time nearly all the available men were employed on two main communication trenches and the front line posts, little other work in consequence being done.

A few machine gun and trench mortar emplacements were also constructed, and at Beuvry the rear sections were employed on hutting for the reserve troops.

The Company carried on this work until February, 1917, the Brigade carrying out several raids during the period, for a few of which a German portable searchlight was taken forward by the Company, and used successfully to give a signal for the return of the raiding party.

During this period the recreational facilities were very good, and the close proximity of Bethune, the Divisional Concert Parties there, and the Divisional Cinema at Beuvry, were much appreciated by all ranks.

On February 13th the Company moved back to Garbecque on the Aire-Bethune canal, where an extensive training programme was organized, the dismounted men being practised in drill, musketry and pontooning on the canal, and the mounted section in riding and driving drill, while the afternoons were given over to football, obstacle races and cross country runs.

Loos Area (*See Map* 7).—On the 25th the Company moved to Gonnehem for a further two days' training prior to marching to Bethune on the 28th and on to Les Brébis the next day. Here Headquarters and the Reserve Section were established in the School, while the horses were accommodated in excellent stables a little further up the street. Three sections were sent forward to Loos where they were quartered in cellars, the officers living in a dug-out near the R.E. dump in the centre of the village.

The new sector largely consisted of ground over which the battle of Loos had been fought 17 months before, and was covered with a maze of trenches, many of them disused relics of the earlier fighting.

The Crassier and Loos village were prominent features in the locality, the former being useful for observation purposes, although it formed a barrier to communication with the line to the right. The village was garrisoned by a large number of troops and was a centre of great activity both by day and night, forming a rendezvous for the Brigade working and carrying parties, and was full of dumps of rations, ammunition, bombs and R.E. material.

On their arrival the Company found the line in a deplorable condition, the trenches being unrevetted and the chalk sides having fallen in wholesale after the hard frosts in February. Consequently, one of the forward sections was at first almost entirely used for supervising the infantry working parties engaged in the improvement and reconstruction of the trenches. However, by the middle of April a vast improvement was noticeable and from then onwards little difficulty was experienced in keeping the more important trenches in first class order, thus enabling work to be concentrated on other improvements necessary to the defences.

One interesting piece of work was the construction of a bombing and observation post on a small mound known as the "Hump," which was only 25 yards from the German line. A bank connected the Hump to the front line, and was used to give a covered approach, whilst the post itself was hidden by means of careful siting and camouflage.

During the latter half of March, the remainder of the sappers were concentrated on building-in wooden boxes under the parapet of the front line as emplacements for gas cylinders to be used in an attack in April.

In May, the reconstruction of the pipe line from "Fosse 7" was undertaken and the pipe line carried forward as far as the Reserve Line. A new pumping station was also erected in Loos and a 4" main laid along the Hulluch Road for use during the operations in August.

The men were also constantly engaged in the construction of mined dug-outs and trench mortar emplacements, as well as the upkeep of the cellars in Loos, which required constant attention owing to the frequent bombardments to which the village was subjected.

In April, detachments of 25 men per battalion were attached to the Company, and were invaluable for supplying the unskilled labour necessary for the economical completion of these works.

As this sector was on the fringe of the Spring offensive at Arras, raids and counter-raids became very frequent. Artillery and trench mortar activity consequently increased and Loos became more and more devastated, the troops being gradually withdrawn from the village as the cellars and dug-outs were knocked in.

Major Jackson killed.—During this period casualties were fairly frequent, the greatest loss occurring when Major Jackson was mortally wounded while going round the line on April 27th. He had joined the Company on Mobilization in 1914, and, apart from a short absence in 1916, had served with it continuously till the time of his death, which robbed both officers and men of a fine leader and a friend in adversity.

Lieut. Newland was also wounded on May 25th.

On June 25th another calamity occurred when a cellar containing some of the attached infantry was blown in, burying six men. One of them was recovered alive, though badly gassed, but while the rescue parties were still at work another shell hit and detonated a bomb store in an adjoining house, both buildings being totally demolished. The casualties were serious, 1 N.C.O. and 2 sappers of the Company being wounded, and of the attached infantry 6 were killed and 5 wounded. After this the cellars in Loos were finally evacuated, and the forward sections took up their abode in some dug-outs in a camouflaged trench behind the Lens road.

Captain A. M. Williamson now assumed command and Lieut. G. W. Jack received his captaincy.

On July 14th the Company was withdrawn to Labourse where they were employed for a week in laying on water, putting down concrete horse standings, and erecting huts at the camps and water points.

A long rest.—On the 22nd, the Division being relieved, the Company marched back to Guestreville, where a month was spent, the mornings being occupied with lectures and training in drill, musketry and fieldworks, while the evenings were given over to sports.

On August 9th the Chief Engineer 1st Army inspected the Company. On the same day a highly successful Brigade sports and boxing meeting was held, in which the Company tug of war team, coached by C.S.M. Rouse, reached the final, while Sergt. Dowe distinguished himself at boxing.

Advantage was also taken of the lengthy rest to renovate equipment and wagons, and when the three Field Companies were inspected by the G.O.C. 6th Division on August 22nd, the parade was quite up to peace time standards.

Return to Les Brébis.—On August 23rd the Division returned to the line, the Company taking over from the 8th Field Company R.C.E. Headquarters and Reserve billets were again at Les Brébis, and the forward sections found accommodation in deep dugouts at Harts Corner.

The work, for the first month, consisted of consolidating the newly won position on Hill 70, and, after the division side-stepped to the South on September 21st, another month was spent in preparing for future operations in the Cité St. Auguste area. During nearly the whole period an average of 400 men were employed nightly as working and carrying parties, while the sappers who were not required for their supervision were employed on shelters and machine gun emplacements in the front line, and strengthening and fitting out cellars for use as Advanced Dressing Stations, etc.

The sector was subjected to fairly heavy fire over the whole period, and at first, until the trenches had been dug down to the normal depth, casualties were heavy. Lieut. O. C. H. Osmaston, M.C., was killed in Netley Trench, and Sergt. Clarke, his section sergeant, and two sappers were wounded, on August 26th, while on the 30th, Lieut. Obbard was wounded. Afterwards, however, casualties fell off considerably, and in spite of several enemy raids, preceded by violent bombardments, no untoward events occurred.

Move of the 6th Division.—On October 23rd the Division was withdrawn from the line and the Company marched to Noeux-les-Mines, moving thence by train to Lillers, and marching again to Esquedecques, the transport moving by road. Here they spent four days, refitting, bathing at Lillers, and resting prior to moving South to join the IIIrd Army.

On October 29th the Company marched to Magnicourt-en-Compté, and the next day to Grand Rullecourt. They were then split up, Nos. 1 and 2 sections under 2nd Lieut. Newland remaining at Rullecourt, while on November 1st, Headquarters with Nos. 3 and 4 Sections entrained at Saulty for Fins, the transport having left the day previously by march route.

Rumours of a coming battle had been rife for some time, and during the next three weeks there was great activity, conducted at the same time with much secrecy and concealment. The Sections at Fins, who moved to Queens Cross on November 17th, were occupied in erecting shelters and camouflage, while Nos. 1 and 2 at Grand Rullecourt were carrying out manoeuvres in co-operation with infantry and tanks.

Battle of Cambrai (See Map 8).—On the morning of the 20th, the surprise attack was launched, the 6th Division advancing on the line Villers Plouich—Beaucamps, the 16th Brigade on the right next to the 20th Division, while the 71st Brigade were on the left next to the 51st Division. All went well on the Divisional front, the Hindenburg Line and the village of Ribecourt being captured early, and the 18th Brigade then advanced through the 71st and captured Premy Chapel Ridge. A defensive flank had then to be thrown back on the left towards Flesquières where the 51st Division had been held up.

Nos. 2 and 4 Sections (Lieuts. Newland and Veitch) were attached to the 18th Brigade and moved forward with them at 0800 hours, each having two sections attached Infantry and five pack animals loaded with wire and sandbags. No. 3 (Lieut. Langley) was in Brigade Reserve and No. 1 (Lieut. Vachell) was in Divisional Reserve at Queens Cross.

Nos. 2 and 4 began work on strong points on the defensive flank before noon, and No. 4, on the right, completed its task without incident. No. 2, however, were less fortunate for they were working on an exposed ridge in full view of the enemy in Flesquières and the Beetroot Factory, and consequently soon came under heavy machine gun fire which caused several casualties, among them Lieut. Newland, who was mortally wounded. Owing to this fire and to the loss of the Section Officer, the work was greatly delayed, and the Section was relieved at dusk by No. 3 who completed the task.

Meanwhile, as soon as the advance had got under way, Headquarters and No. 3 Section advanced along the Beaucamps—Ribecourt road, sending forward parties to reconnoitre the German Dumps at Ribecourt Station and on the Grand Ravin rivulet. These Dumps were, however, burning, and not much could be salved.

The road was cleared by the 11th Battalion Leicestershire Regiment (Pioneers), and at midday Lieut. Hall with three pontoon wagons loaded with sandbags, wire and pickets, and with Nos. 2 and 3 Sections' Tool Carts, arrived in Ribecourt, this being the first transport to arrive in the village.

The casualties during the day's fighting had been one officer and one other rank killed, and of the attached Infantry three other ranks killed and three wounded.

Advance held up.—The advance had now been checked, and unfortunately the morning's high hopes had not been realised, and the longed for " break through " had not occurred. The next nine days were therefore spent in consolidating and fortifying the newly won positions. On the 21st another strong point was built on the Premy Chapel Ridge and during the following days a large amount of work was carried out on wiring, trenches and shelters in the Cantaing—Premy Chapel area. During the nights of 27th, 28th and 29th November, first Nos. 2 and 3 Sections and subsequently the whole Company were employed on wiring, the wire and pickets being brought up to the centre of Cantaing Village in wagons and thence carried up to the wiring parties. In spite of the brilliant moonlight, there was little interference from the enemy, and in three nights two belts of wire, each six yards wide and about a mile long, were erected.

German Counter Attacks.—In the early morning of November 30th, the enemy launched heavy counter attacks from the North and East, their object being to pinch off the salient which the advanced troops were holding. The attack on the North failed, but that from the East penetrated our line, and by 9 a.m. Gouzeaucourt was in German hands. The situation at Ribecourt was critical, and the transport at Beaucamps had to beat a hasty retreat under machine gun fire. The Company was at once ordered to " Unseen " Trench off " Argyle Road," and kits were hastily packed and despatched in a commandeered lorry to Metz. The two Tool Carts were man-handled up the Trescault Road until met by their teams near the Hindenburg Line. The Company moved off and found that all transport moving out of Ribecourt was blocked owing to the bridges over the Hindenburg Line having been broken. These were soon repaired by Nos. 1 and 4 Sections, after which the Company proceeded to " Ridge Trench," in the Hindenburg Line, overlooking Couillet Wood, where they came under the orders of Lieut. Colonel Rosher commanding the 14th Battalion Durham Light Infantry.

The remainder of this day and the next were spent here, as a further German attack was expected, and as the trench ran at right angles to the probable line of advance, both parapets had to be manned.

The attack did not develop, however, and the Company returned to their old billets in Ribecourt at 1 a.m. on the 2nd, and going out again that night wired around Cantaing, Nos. 1 and 4 strengthening the front line, and Nos. 2 and 3 the support line.

During the previous day the Germans had attacked from La Folie Wood, but were met by the wire previously erected by the Company and were repulsed.

On the morning of the 3rd December the enemy captured the bridgehead at Marcoing, and in the afternoon the Company was ordered to relieve two companies of the 2nd Battalion Durham Light Infantry in the Hindenburg Support Line. At 8.30 p.m. they relieved the two Outpost Companies of this Battalion, but were moved again in the early morning, and at 5.30 a.m. settled down in a reserve position, after a very tiring night of marching, uncertainty of the situation, and numerous orders and counter-orders. They remained here till 7 p.m. when the men moved off to wire along the new outpost line on the Premy Chapel Ridge. On the 5th they wired the support line, and on this and the previous night put up about two miles of wire in spite of the ground being frozen hard. They then returned to new billets in the Hindenburg Line off the Trescault Road.

On the 6th two derelict tanks in No Man's Land, which were being occupied by enemy posts and snipers, were destroyed with 280 lbs. of guncotton apiece.

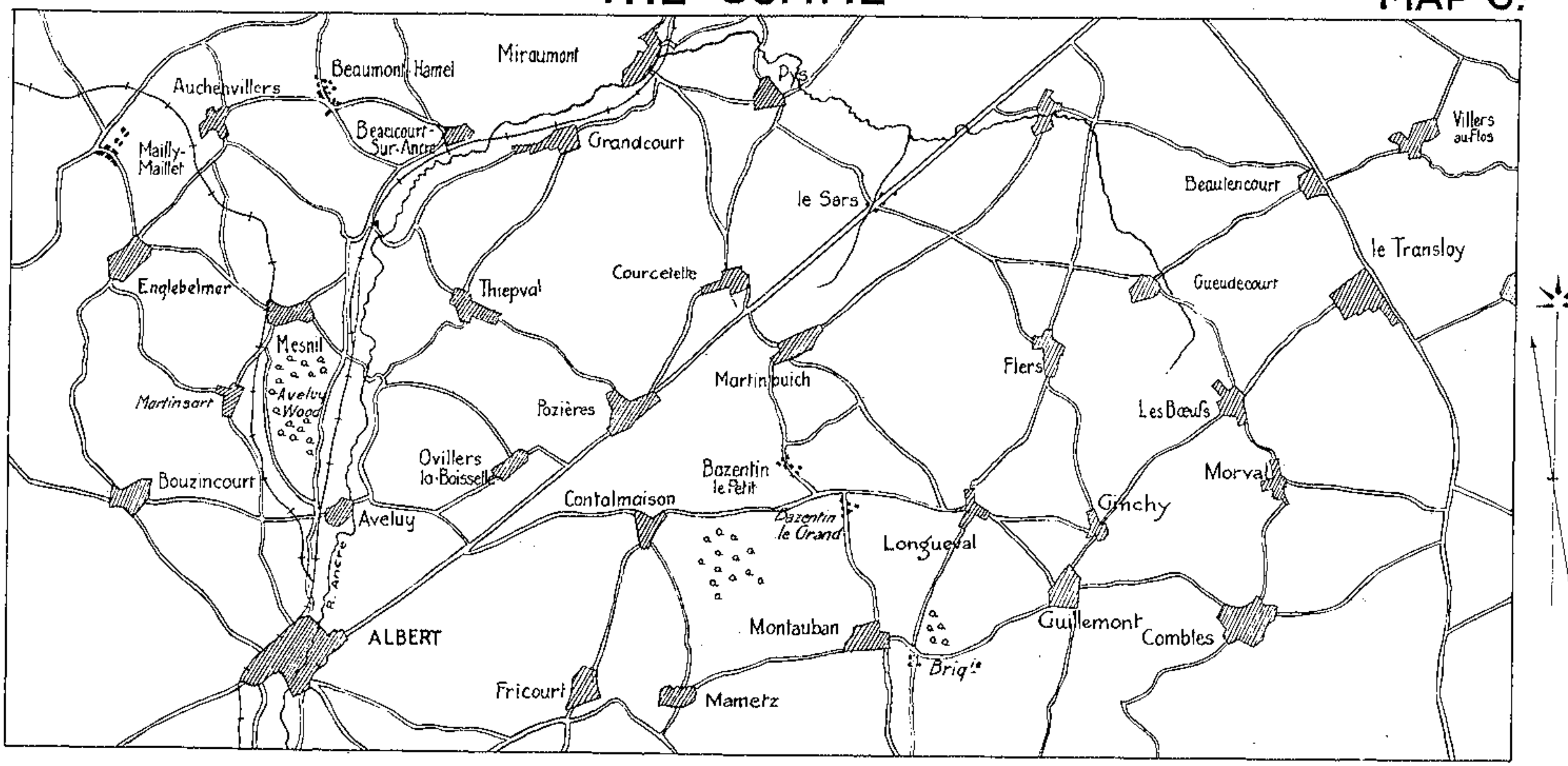
For the next four days work was concentrated on consolidating the new positions which our troops had occupied, and a great deal of work was done every night on the new front line, which was laid out to connect the defences on Premy Chapel Ridge with Flesquières.

6th Division relieved.—On the 11th, having been relieved by the 82nd Company R.E., the Company marched *via* Metz to Etricourt, moving the next day to a rest camp in Hendecourt. It was now hoped that, after the strenuous times just gone through, the men were to have Christmas amidst pleasant surroundings, but it was not to be, for on Christmas Eve they were hurriedly moved to a barren camp in Bapaume to undertake important hutting work.

Louverval Sector.—They remained here until January 19th, 1918, when the work was handed over to the 459th Co. R.E. and the next day they moved into the Line again and took over the Louverval Sector, the dismounted men marching to Laboquiere and the transport to Beugny.

THE SOMME

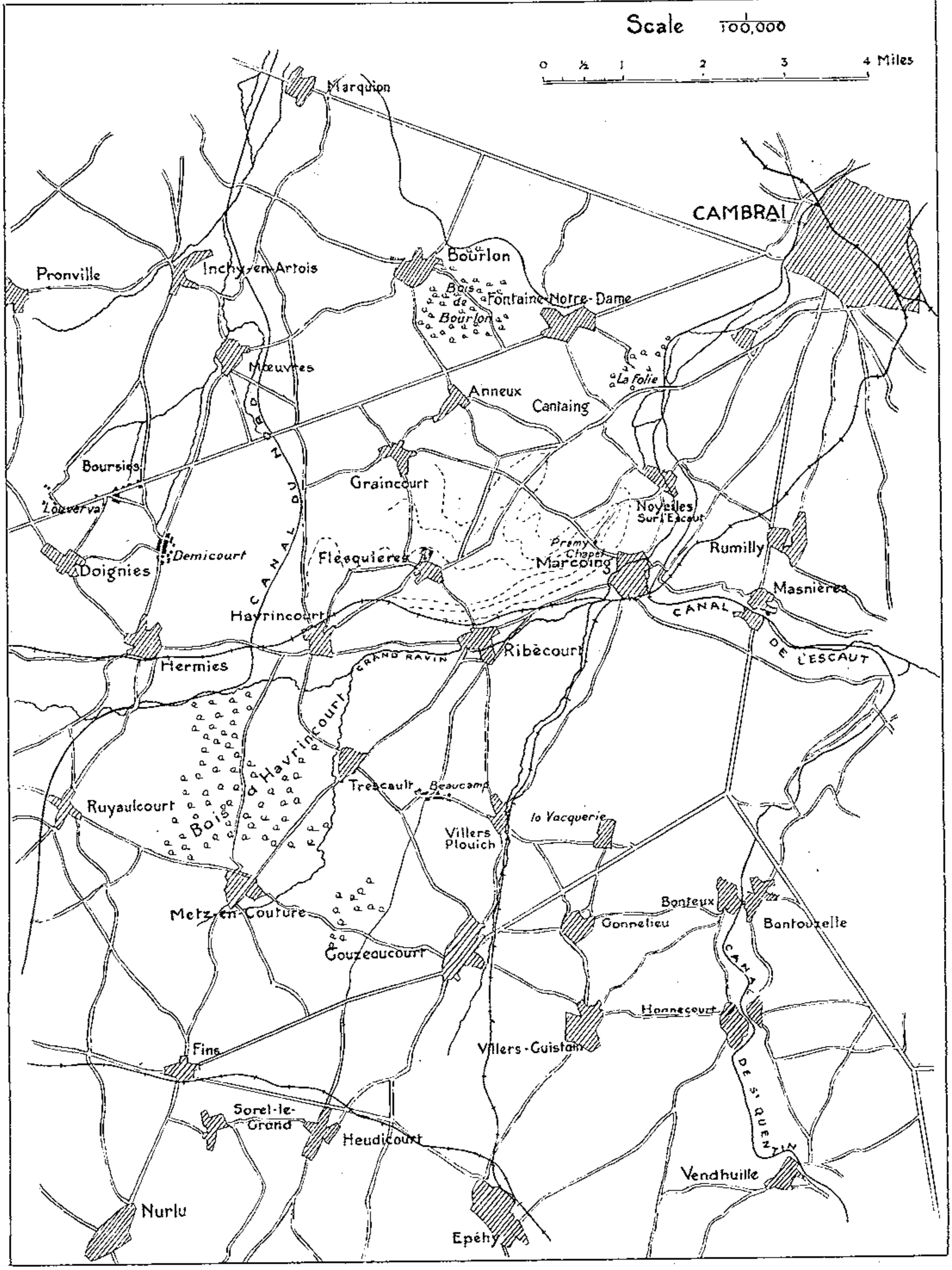
MAP 6.



Scale $\frac{1}{100,000}$

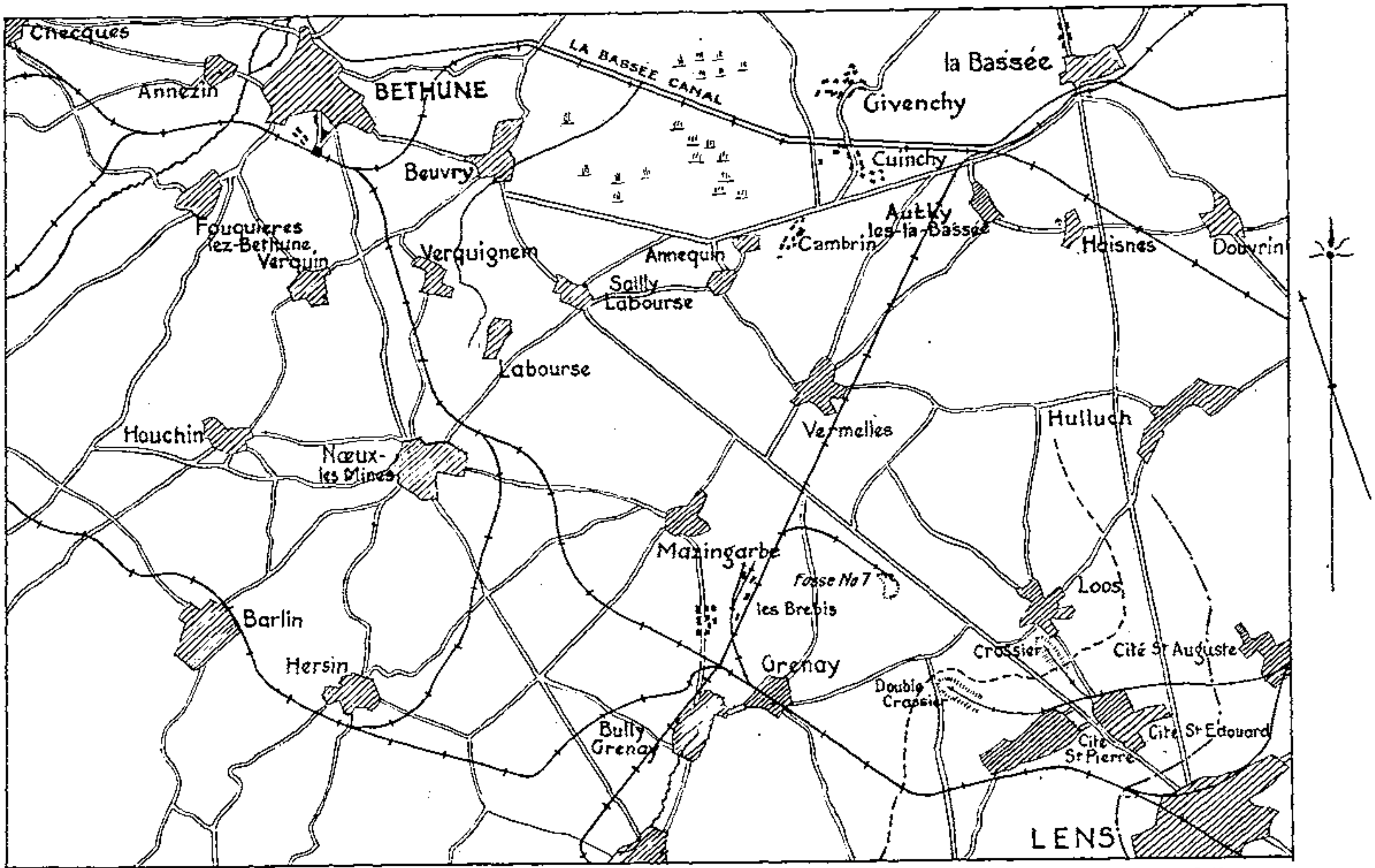
Miles 1 ½ 0 1 2 3 4 Miles

CAMBRAI. MAP 8.



LOOS

MAP 7.



Approximate Front Line prior to August 1917.
after August 16th 1917.

Scale 1/100,000

Miles 1 ½ 0 1 2 3 4 Miles

PROFESSIONAL NOTES.

REINFORCED CONCRETE ROADS.

The writer has recently had the opportunity of seeing some of the concrete road construction that is being carried out in the County of Surrey, and it is thought that a few notes on the subject may be of general interest.

A. The Kingston Bye Pass Road.

(1) *General Description.*—This new road, approximately 10 miles long, is being constructed by the Surrey County Council in order to relieve Kingston and Surbiton of the through traffic on the London-Portsmouth Road. It runs from Beverley Brook to Esher via Tolworth and Hook.

It is proposed that its ultimate width, exclusive of banking, should be 100 feet and the ground for the purpose has already been fenced off; but the carriage way is only being constructed with a width of 30 feet at present. The fencing is of the concrete post and galvanized wire type that is becoming so common.

The subsoil is a stiff sandy clay. All grading is done at least six months in advance before any further work is undertaken. A bed of clinker is then laid down and well rolled to a depth of about three inches. On top of this comes eight inches of concrete in two layers with steel reinforcement. The exact type of surfacing has not yet been decided on, but it will probably be a thin coating of some bituminous material. The road is given a camber of 1/50.

(2) *Details of Concrete.*—The concrete is in two layers of different composition; the bottom layer being six inches of 4:2:1 concrete, and the top layer two inches of 3:1½:1 concrete. Both the coarse material and the sand are washed, screened, and carefully graded: one inch stones are the largest used in the bottom layer and ¾ inch in the top. The placing of the top layer is begun immediately the bottom layer is in position. The ingredients are mechanically mixed in a batch mixer having a capacity of half a cubic yard. The mixer travels on rails at the side of the road, and an overhead girder extends from it across the road to a support running on a rail on the other side. When mixed the concrete is tipped out into a skip, which travels suspended from the girder and deposits the concrete where required.

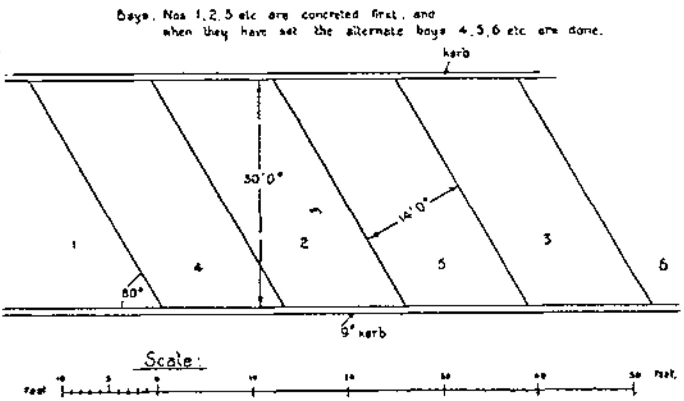
Great stress is laid on cutting down the amount of water used to the minimum compatible with ease in handling. The total amount is stated to be about 25% by weight of the amount of cement used; the actual amount added to each batch mixed depending, of course, on the atmospheric conditions and the amount of water already present in the stone and sand. It is said sometimes not to be necessary to add any water at all. The hardness of the concrete has proved to be extremely satisfactory.

After being deposited from the skip the concrete is spread and rammed. It is levelled off by means of a wooden beam on edge worked backwards and forwards by two men across the top of the shuttering. The beam is shod with steel.

About 24 hours after the concrete has been placed in position the surface is brushed with stiff brooms to remove all scum and laitance. When this has been done a layer of soil is thrown on top and kept damp if necessary by watering for at least 28 days.

The concrete is laid in alternate bays running right across the road and 14 feet wide, at an angle of 60° to the direction of the road. (See *Fig.* I.) The object of the latter is to transfer the weight of

Fig: 1.– Plan of Road.



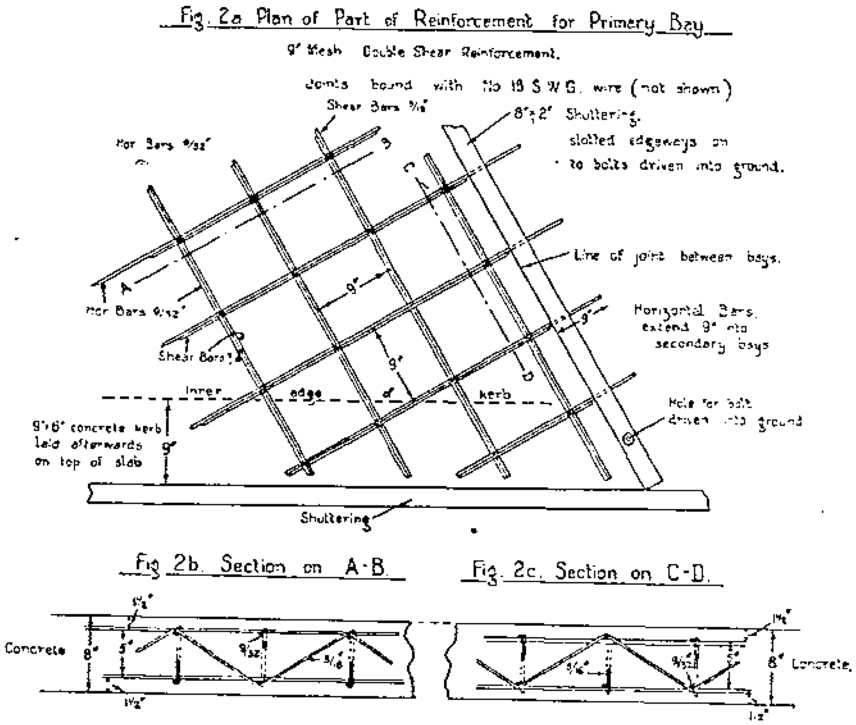
vehicles gradually from one slab to the next; each wheel crossing the joint between two slabs separately, and, also, since the wheel has a definite width, its weight is transferred gradually from one slab to the next. It was also suggested that by this method the expansion of the concrete in the direction of the road is to some extent taken up by a shearing action of one slab against the next, but the argument was not at all clear.

It was observed that in some cases difficulty had been experienced in screeding the intervening bays to the exact level of those first laid down, and it is thought that the slight difference in level may cause vehicles to bump at the joint, and subject the road to undue stresses.

(3) *Details of Reinforcement.*—The type of reinforcement used varies in different parts of the road according to the nature of

the ground. The size of the rods used is determined entirely by practical experience.

The heaviest type is that shown in *Figs.* II. *a*, *b* and *c*. It consists of a double layer reinforcement with shear members. The bottom layer of reinforcement consists of a 9-inch mesh of bars 9/32 inch in diameter laid at right angles to each other. The bars are not interlaced, but are bound where they cross with No. 16 S.W.G. wire.



This reinforcement is placed 1½ inches from the bottom of the concrete. The top layer is exactly similar and is placed 1½ inches from the top of the concrete leaving 5 inches in between the two layers. Here is placed the shear reinforcement consisting of 3/16 inch diameter bars running diagonally from joint to joint of the horizontal reinforcement in both directions.

In places where the subgrade is judged to be stronger, half or all the shear reinforcement is omitted, and ¼-inch bars used, instead of 9/32-inch, in the horizontal reinforcement.

The reinforcement is wired up into mats on the site. It runs continuously through the joints, the horizontal bars sticking out 9 inches on each side of the bars first laid down, and being wired to the reinforcement of the alternate bars when these in turn are concreted.

The reinforcement is kept in its proper position while the concrete is being poured by passing the horizontal members through holes in the shuttering. The latter consists of 8in. boards slotted edgeways on to bolts driven into the ground. The boards are cut along the lines of holes for the reinforcement into three widths of $1\frac{1}{2}$, 5 and $1\frac{1}{2}$ inches respectively, thus enabling the reinforcement to be easily inserted, and the shuttering to be easily removed when the concrete is set.

(4) Mr. J. H. Walker, M.I.C.E., of the Walker-Weston Co., Ltd., who accompanied the writer, had the following comments to make :—

(*a*) While it is undoubtedly essential to prevent the slabs from getting out of level, since if they do so the road quickly gets broken up by the traffic at the joint, to run the reinforcement through the joint destroys the value of the latter as an expansion joint. To provide a proper expansion joint, and prevent the road from cracking under the influence of temperature changes, is the object aimed at in laying the road in alternate bays instead of continuously. Further, in time water is bound to percolate into the joint, even if it is filled up with mastic ,and will eventually destroy the steel. Adjoining slabs can be kept level, without running the steel through them, by "interlocking" the concrete. See *Figs.* 3 *a*, *b* and *c*.

Fig 3a Plan of Suggested Interlocking Joint.

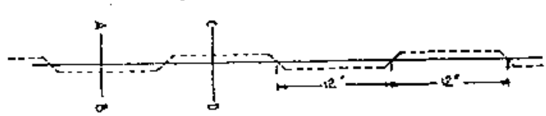
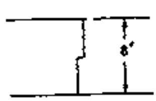


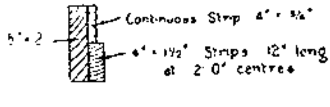
Fig 3b Section on A B

Fig 3c Section on C D



On the upper face of the road the joint is a straight line The lower halves of the two adjoining slabs consist of alternate insets and offsets, locking into one another a distance of $\frac{3}{4}$ inch. The shuttering for this is shown in *Fig.* 3*d*. This is not to be confused with a simple stepped joint, in which the slab which projects at the base is free to sink under the traffic load.

Fig 3d Shuttering for Joint.



(b) There would appear to be no advantages gained in making ¾-inch the limiting size for the aggregate in the upper layer. In his opinion large aggregate up to, say, 2½ inches, is definitely superior, as the larger stones are more firmly fixed in the slab, and are also less likely to crush when a heavy load comes on them.

Improvement of an Old Road.

B. This road is an old waterbound macadam one, with metalling about 9 inches thick, in poor condition. It is being widened to 30 ft. by means of concrete slabs a foot thick on each side. (See

Fig. 4. Improvement of Existing Road.

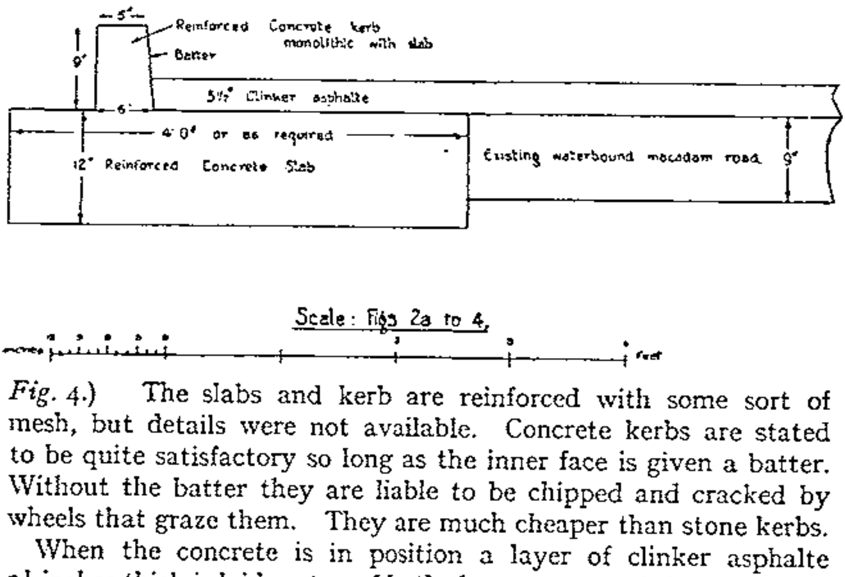


Fig. 4.) The slabs and kerb are reinforced with some sort of mesh, but details were not available. Concrete kerbs are stated to be quite satisfactory so long as the inner face is given a batter. Without the batter they are liable to be chipped and cracked by wheels that graze them. They are much cheaper than stone kerbs.

When the concrete is in position a layer of clinker asphalte 3½ inches thick is laid on top of both the concrete and the macadam. It is expected that the road will then be able to stand the traffic to which a second-class road is subjected.

A very interesting point about this road is that it is being "super-elevated" at the curves, *i.e.*, the road slopes evenly right across from side to side instead of being higher in the middle than at both sides. With ordinary camber, of course, the traffic that should keep to the outside of the curve comes into the middle of the road or even right across, as it is difficult to drive round a curve with the camber against you.

"Super-elevation" obviates this danger and thus also prevents the road from getting more worn in the centre and inside than at the outside, as generally occurs; and there do not appear to be any important disadvantages attached to the method.

W. A. FitzG. K.

WORLD'S SHORTAGE OF LEAD.

There are indications from the technical building journals that a serious shortage in the supply of lead is imminent, and that the price of leaden pipes and fittings will tend to rise again in consequence.

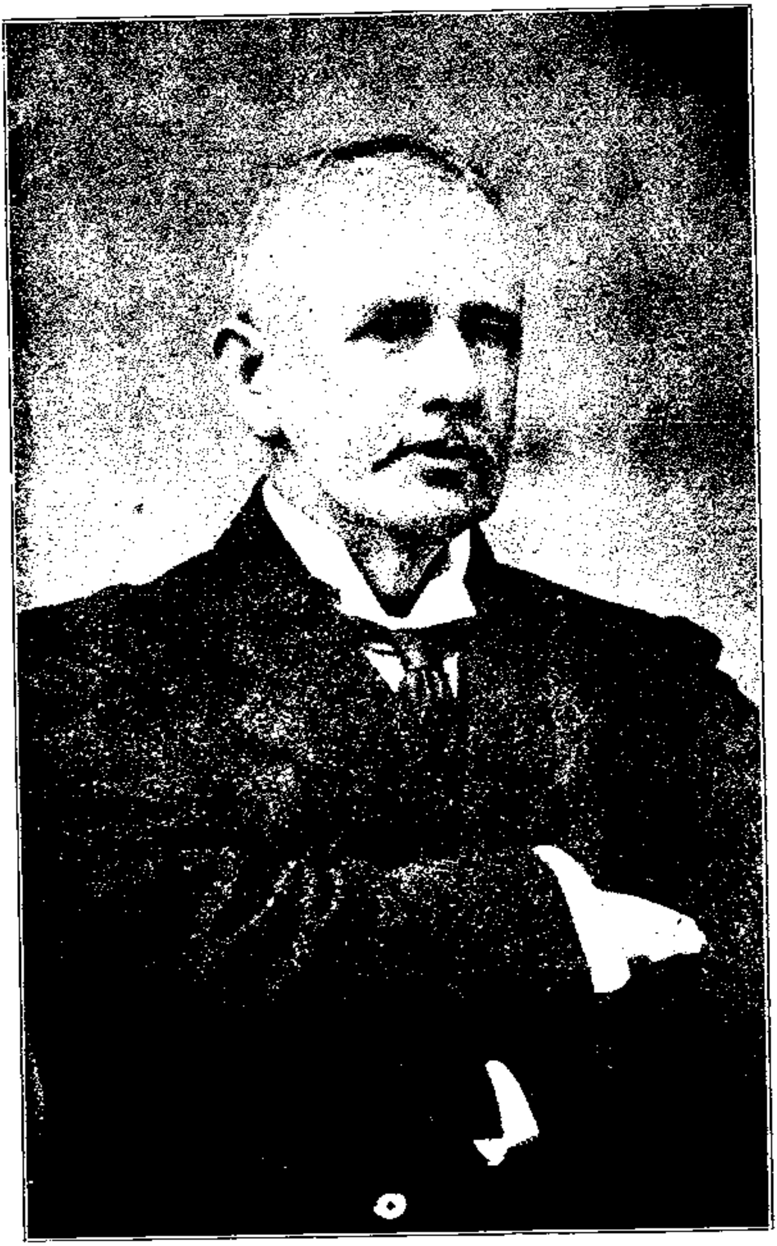
During the period April to August last, lead was selling at approximately £32-£34 per ton. In September the price dropped to £33 15s., but to-day it has reached £48 per ton.

The world's consumption of this metal is now far in excess of production, the demand continuing to expand whilst the supply remains stationary. The output of some of the larger mines seems to be diminishing, and the production of some of the newer fields is only increasing very slowly.

For the year 1923 the United Kingdom made use of 15,700 tons of lead, whereas more recently the consumption has been in the neighbourhood of 22,000 tons. The consumption on the continent has increased in even a larger ratio.

In roof work zinc may be substituted for lead, copper for weatherings, cast iron for weights, iron for pipes; generally speaking the substitutes, except copper, would be cheaper than lead.

D.M.F.H.



Colonel Henry Davison Love.

Photograph by Herbert Norris, Newton Abbot.

MEMOIR.

COLONEL H. D. LOVE.

COLONEL HENRY DAVISON LOVE, R.E. (retired), of Moorlands, Chagford, Devon, who died at Exeter on the 25th October, 1924, at the age of 72, made some important contributions to our knowledge of the establishment of British influence and authority in Southern India. Educated at the Tavistock Grammar School and at Bath, he entered the Royal Military Academy at Woolwich, and was commissioned to the Royal Engineers a few days before completing his 20th year. After a brief period of Home service he was admitted to the Indian establishment, and in 1876 joined the Queen's Own Sappers and Miners at Bangalore. He acted several times as Deputy Consulting Engineer for Railways, Madras, and now and again was on special duty in the Military Department. At the beginning of 1880 he was appointed Principal of the Civil Engineering College at Madras, and held the post until his retirement from the Service 27 years later. A man of great charm, he won the affectionate regard of staff and students, and set them the example of wholehearted study. In addition to many papers on technical subjects, he wrote a manual on hydraulics, published in 1887.

Colonel Love will be best remembered, however, for his non-professional studies, which were directed to Anglo-Indian history. In 1903, at the request of Lord Ampthill, he compiled an illustrated descriptive catalogue of the pictures in Government House and the Banqueting Hall at Madras, which is the only thorough one of its kind in relation to gubernatorial residences in India. His most important work, brought out in 1913, six years after his retirement, was his *Vestiges of Old Madras* in the Indian Record Series. The undertaking was laborious, requiring years of research, and entailing much wearisome copying of old documents; but the labour was well repaid by the three volumes and the separate index (compiled by the author with characteristic care) taking their place as the standard authority on the origins and development of our association with South India down to the beginning of the nineteenth century. The "Vestiges" throw a clear light on the life of the early English settlers; on the appalling political confusion of the country as they found it; on the sufferings of the people, and the benevolent and kindly attitude of the English to them. Subsequently Colonel Love compiled for the Historical Manuscripts Commission a calendar of the papers of Sir Robert Palk, sometime President and Governor of Fort St. George, Madras, covering the period of 1767-

1786. These papers are now deposited in the Exeter Public Library. Colonel Love lost his wife some years ago, but had in his daughter an enthusiastic assistant in his literary work.—(*Extract from the Times of 4th November*, 1924.)

Colonel Love was the elder son of Henry Love, of the English Civil Service, and was born at Beaumaris in the Isle of Anglesey. At Woolwich he became Senior, or, as it was then called, Responsible, Under Officer, and passed out top of his batch, gaining the Pollock medal. In 1879, in Bombay, he married Janet Arnold, daughter of the late Captain William Orcher Lloyd, Royal Artillery, and widow of Lieut. Daniel Leland Litton, Royal Engineers. The *Report on the Palk Manuscripts* was published by H.M. Stationery Office, and reviewed in the *R.E. Journal* in March, 1923. Colonel Love also wrote a *Manual of Applied Mechanics*.

Major-General J. A. Ferrier, C.B., D.S.O., writes: "Love was a fine mathematician and naturally well versed in engineering, especially hydraulics, and conversation with him on any engineering subject was always enlightening. But he was not only an engineer, but a man of culture, with an agile brain capable of assimilating any subject at short notice.

"I consider him one of the most brilliant of my contemporaries, and always deplored the fact that he had been hidden away in a position that brought him so little before the public eye. He and his wife had many friends, most of whom, I fear, have passed away, but those that survive will, I think, share with me in regret for the loss of a friend who was always helpful, thoughtful and kind, and never worried."

One of these friends, the widow of an officer of the Corps, writes: "I never knew such a wonderfully kind, good man—so thorough in everything he undertook; and I know of so many cases when persons left as I was turned to him for advice. . . . . His loss to many can never be filled."

COLONEL F. P. RUNDLE, C.M.G., D.S.O.

FRANK PEVERIL RUNDLE was born at Plymouth on 13th October, 1871. He was a grandson, on the maternal side, of Captain John Edward Davis, R.N., who came of an old naval family going back several generations, and who accompanied Sir James Ross on the *Erebus* and *Terror* expedition to the Antarctic in 1839-43.

Rundle was educated at Mannamead School at Plymouth, and at Charterhouse ("*Hodgsoneites*"). From Charterhouse he passed direct to the "Shop" and got his commission in 1889.

After his two years at Chatham he went to Sheerness as a Submarine Miner, and thence in the same branch to Karachi in 1895.

Colonel F. P. Rundle, C.M.G., D.S.O.

He first saw field service as an attached Officer with a company of Bombay Sappers and Miners with the Malakand Field Force in 1897.

He subsequently served as a Submarine Miner, a Divisional Officer R.E., and a M.W.S. Officer at Bombay, Aden, Harwich, Rangoon, Calcutta and Secunderabad.

East Africa was the theatre which claimed his services during the Great War. Arriving there in May, 1915, he served there practically continuously until after the Armistice. His duties brought him into personal touch with Generals Smuts and Van Deventer, under whom he rose to the position of Chief Engineer. His services were recognised by the awards of a Brevet lieutenant-colonelcy, the decorations of C.M.G. and D.S.O., and several mentions in despatches.

After the Armistice he returned to India and continued to serve there until his retirement in 1923.

He died suddenly in London on March 31st, 1924, from an attack of angina pectoris, probably largely induced by the strain of unceasing work and responsibility throughout the War years in a trying climate.

As regards his activities outside his profession—without being to any extent a betting man—Rundle was a devoted follower of horse racing. At one time a Steward of the West of India Turf Club, he was at the time of his death a subscriber to Newmarket and a member of Epsom, Doncaster, York, Aintree, Windsor, Newbury and other racing clubs.

No man who acquired his friendship has ever had a more staunch, loyal and stouthearted comrade. His downrightness and entire disregard of his own personal loss or gain in adhering to the line which he judged to be the right one, were the outstanding characteristics which probably won for "Bull Rundle" the sobriquet by which he was known to his large circle of friends.

His death has deprived those friends of the genial companionship of a personality which can never be replaced.

BOOKS:

LA BATAILLE DE L'YSER.

Examen critique d'une étude de M. L. MADELIN.

La Bataille de l'Yser (Brussels, Van Sulper), by Colonel C. Merzbach, of the Belgian General Staff and head of the Belgian Historical Section, is a critical examination of the writings of a Frenchman, M. Madelin, on the war, as they affect the Belgians. That he should have cause for complaint is small wonder; M. Madelin's publications have been full of errors and misconceptions as regards the British share in the War, but this is usually the case when civilians write about any war, recent or ancient. M. Madelin gives the French Commanders credit for everything. He says that General Pau went to Antwerp to induce King Albert to withdraw his troops and take the left of the line. As a matter of fact, General Pau never came into Antwerp, but he did come to Belgian Headquarters at Selzaete after the Belgian Army had left Antwerp and was already on the left of the line. It was General Foch, we are told, who suggested flooding the Yser to cover the Belgian troops. Here again, as a matter of fact, General Foch proposed to make the St. Omer-Calais inundation *behind* the Belgians, so that then they would have been cut off. M. Madelin's publications contain discourteous as well as inaccurate statements, *e.g.*, " The Belgian Army was full of courage, but besides being tired out, its soldiers could not have the solidity of our 'old troops,' for our men, who since the 15th August had taken part in so many fights, had already the faces of veterans." Yet, as Colonel Merzbach points out, the Belgians had been fighting since the Germans entered their country on the 4th August. The French author gives all the credit for stopping the Germans on the Yser to the " red breeches " of General Grossetti at Nieuport and the Marines of Admiral Ronarc'h at Dixmude. Colonel Merzbach considers that this kind of thing might be forgiven to a lecturer carried away by his subject, or to a poet relying on his imagination for his facts, but it is not creditable to "an historian by profession, *agregé* (qualified at the highest standard examination) of history and geography, doctor of letters, and candidate for the Academy," and, we might add, one of the regular contributors to the *Revue des Deux Mondes*. No military writer, we feel sure, would make such claims for the French or cast doubt on the extraordinary resistance offered by the small Belgian Army to the gigantic and barbarous forces of the old German Empire.

J.E.E.

THE MILITARY USES OF ASTRONOMY.

By MAJOR F. C. MOLESWORTH, R.E., F.R.A.S. (London: Longmans, Green and Co.) 1924. pp. 112, with diagrams.

MAJOR Molesworth has written an excellent little introduction to the study of astronomy, which can be safely recommended to any one who is beginning the subject. Many of the practical hints will be found of real value to soldiers, if only these hints can be kept in the memory. And that is the real difficulty. An officer has nowadays to learn and remember so much that is essential in the carrying out of his duties, that matters of less, or only occasional, importance must sometimes go to the wall. In his mental equipment he cannot follow the example of the White Knight.

But still there are some elementary astronomical facts that every officer might, perhaps, be expected to have at his disposal, such as rough ways of finding the North, simple methods of determining local time, and so on. These he will find clearly expounded in the book under review. Curiously enough, however, practically nothing is said about sun-dials; though these may often be found of real use, especially in standing camps away from railways and telegraphs. But perhaps the author had in mind the employment of wireless.

Nine men out of ten, when asked to describe the value of elementary astronomy to a soldier, would instance the case of night-marching. Now, there is, in reality, very little to be said on this subject; in this book we find three pages on *Direction by the Stars*, and in the official Manual there are only a few paragraphs. To march by the stars involves no knowledge of the names of the stars, and, indeed, no knowledge of astronomy, except the elementary fact of the earth's rotation. But in night marching the utmost care is required in simple details, and, in any case, one should not expect—except in very favourable circumstances—the rather high degree of accuracy indicated by the author, namely, an error of less than one degree, say, thirty yards in a mile. But in this sort of thing practice makes perfect, and it can be imagined that a specialist in the night-marching of the kind described might get very good results; but, in any case, in important operations an expert would certainly be called in, as happened at Tel-el-Kebir. In this connection Major Molesworth quotes "450 *Miles to Freedom*," which describes the way in which eight officers found their way by azimuth charts.

The book contains some labour-saving sun azimuth and altitude diagrams, and the reviewer was about to say that these alone were worth the cost of the book, when he discovered that there is no price marked.* However, the diagrams may often serve a good purpose, and not only for purely military needs. There is also a chapter on that tricky subject, the Tides. The Bombay chart seems to have been generalised into rather too angular a series, and it may convey a somewhat incorrect impression as to the character of the tide curve; but the matter is not important, as it can be but rarely that a land officer is seriously concerned with tidal matters.

The book, as a whole, can be recommended, even to those who have gone through some period of pleasureable instruction in Astronomy at the S.M.E.

C.F.C.

* The price is 3s. 6d.—Ed., *R.E.J.*

MATHEMATICS FOR TECHNICAL STUDENTS.

By E. R. Verity, B.Sc., A.R.C.Sc., Head of the Department of Mathematics and Mechanics, The Technical College, Sunderland. (London: Longmans, Green & Co.) Price 12s. 6d.

This treatise is mainly devoted to Algebra, commencing with simple equations and up to the binomial, logarithmic theorems, and the graphical solution of cubic equations. There are four chapters on Trigonometry, which subject is dealt with as far as the solution of triangles, two on Projections and Solid Geometry, one on Simple Harmonic Motion, one on Areas and Centroids, one on Moments of Inertia, two on Kinematics; the last six chapters contain an introduction to the Calculus.

The book is very elementary throughout, and though of no use to the serious mathematical student, should appeal to that very wide class which possesses little mathematical knowledge.

No pains have been spared to obtain lucidity, and a great deal of useful information is given in a moderate compass and at a very reasonable price.

Special stress has been laid on graphic methods. There are numerous examples of an instructive and practical character.

J. M. Wade, *Lieut.-Colonel* (B.Sc., London).

SOME ASPECTS OF IMPERIAL COMMUNICATIONS.

By Major A. V. T. Wakely, M.C., R.E. (Sifton Praed.) Price 9s.

Major Wakely has, in the volume under review, brought together much interesting and valuable information relating to Imperial Communications, using the latter term in the wide sense as applying to "means of transport" as well as "means of inter-communication"; the great sea routes, the air routes of the Empire, Imperial railway communications, inland waterways, mechanical transport, sea cables and land lines and wireless inter-communications all receive careful attention, and, in many cases, the information given in the volume has been brought up to date, so as to include the latest developments in the subject under treatment. The volume, which is illustrated and also provided with a number of plates giving information on certain matters in graphic form, should appeal to many classes of readers, but to none more so than those who follow the profession of arms, whether as sailors, soldiers or airmen, to whom all that appertains to the communication services has at all times been a matter of deep concern and importance. The strategical aspect of the several branches of the subject receives considerable attention; *inter alia*, the defence of sea communications, and the strategic aspects and problems of the railways on the North-Western Frontier of India, and of those in Canada and Australasia are discussed, and some of the principles involved in the situations dealt with are clearly stated. Further, in many instances, Major Wakely reviews the essential elements or requirements of particular branches of various communication services; for example, in the case of port organisation, the elements of a port are classified; again, in the case of air routes of the Empire, the requirements of commercial aviation are given; and so on. In this way, the non-expert is put in a position readily to grasp the nature of the problems that have to be dealt with in connection with Imperial Communications, and the volume should, therefore, achieve its purpose, which, the author tells us in his preface, is an endeavour on his part to outline the various problems relating to his subject in language intelligible to non-technical readers. As will be seen from the foregoing statement of the scope of the work, the ground covered in the volume extends over a very wide range; however, in regard to recent progress the matters left untouched in the volume are exceedingly few, the most noticeable, perhaps, being the absence of any mention of the recent advances in the field of multiple telephony; the achievements in the United State of America in this field are very remarkable; for instance, in 1923, a single line between New York and Chicago, a distance—by route—of nearly 1,000 miles, was satisfactorily carrying 85 telephonic and telegraphic communications simultaneously (*vide Journal I.E.E.*, vol. 61, No. 319—June, 1923—at p. 634). The example given here of the progress made certainly relates to American practice, which admittedly leads the way in the telephone field; but mention is made of this achievement as there must be a field in our vast dependencies and colonies, such as India, Canada and Australasia, for a similar utilisation of costly long-distance telephone lines. From the foregoing remark, it must not be assumed that Major Wakely has overlooked important progress in the telegraph field; such is not the case, for on p. 136 of his work, he calls attention to the "interesting development of 'wired wireless'"—of which the American achievement mentioned is but an example—and states that on the route "via Eastern" the cable conductor is not only used for duplex working, but that it is simultaneously utilised for the transmission of a third message by "wired wireless." As another recent development in the telegraphic field, Major Wakely makes a reference to the "loaded" cable laid in September, 1924, by the Western Union Telegraph Company between Fayal (Azores) and New York, the first tests of which showed that in this particular case the increase of the carrying capacity was nearly four-and-a-half-fold as compared with a non-loaded cable between the same points, viz., whereas the normal cable had an output of 75 words, the new "loaded" cable has an output of 340 words (1,700 letters). The loading of cables is not, as a matter of fact, a very recent innovation; it has been in practical use for at least a couple of decades. Originally, one or more layers of soft iron wire or tape were wound spirally over the copper conductor, and in this way the carrying capacity of the circuit could be increased nearly two-fold. Very recently a new alloy, now known as "permalloy," was discovered, and it is found that if instead of winding soft iron wire spirally round the conductor of a submarine cable it is similarly served with a "permalloy" tape, the transmission efficiency of the copper line is very greatly increased; indeed, as the results on the "via Eastern" route given by Major Wakely show, "permalloy" produces results as a "loading" material for cables which are more than two-fold more beneficial than those obtained formerly by the use of soft iron wire or tape. What is a serious slip occurs at p. 139 of the volume: dealing with the problem of wireless transmission, it is rightly stated that signals sent from a transmitting station can be received by any receiving station which is within range, and is properly tuned to the particular transmitting station. The author then proceeds to explain why it is that neighbouring transmitting stations may cause interference with the signals of one another, and states that this is because " the medium used by all stations is the same, viz., the air " ; true, the medium is the same, but whereas sound waves are propagated by means of and through the air, on the other hand, physicists attribute the propagation of radio waves to the existence of an all-pervading ether, and, therefore, scientifically, it would be incorrect to say that the medium through and by means of which radio waves are transmitted is air. In dealing with the question of the Empire Wireless Chain, Major Wakely frankly recognises that he is touching upon a highly controversial subject ; he therefore contents himself, rightly, we think, in simply setting out some of the well-known arguments which have been publicly advanced for and against State-owned Wireless Telegraph Stations being erected in England. One of the chief a guments against State-ownership is in certain well-informed quarters not so delicately stated as by Major Wakely ; the opinion is held in these quarters that the real reason for the failure of a Government Department properly to handle so highly technical an enterprise as the Empire Wireless Chain arises from the fact that the complete control of the scheme is vested in non-technical officials, who do not take the same broad view of their proper sphere of responsibility in the staff organisation as do the financial and administrative officials of a private concern ; consequently, in a Government Department the technical officers have neither the status nor the authority necessary to enable them efficiently to carry out their duties. It is also suggested that hence it is that Government Departments do not succeed in recruiting, and if they do temporarily succeed, then in retaining, in the service of the State, for their technical branches, men of the same eminence in their profession as those who throw in their fortunes with a private firm and make a successful career. Major Wakely has dealt ably with the many problems he discusses in his work, which can be thoroughly recommended to all who take an interest in or are concerned in any way with the subject of Imperial Communications.

W.A.J.O'M.

REGULATION OF RIVERS WITHOUT EMBANKMENTS.

By F. A. LEETE, Imperial Forest Service, India, Chief Conservator of Forests, Burma. (Crosby Lockwood and Son.) Price 30s.

THIS book is an interesting study of the habits of hill torrents discharging into plain , bringing down enormous quantities of silt in suspension, and building up banks for themselves where the silt is precipitated.

That this building up of silt banks does occur when the water spreads over the plains and loses its velocity is well known, but training works to utilise scientifically this great power for reclamation, and to deposit the silt where it will be beneficial, have only recently been undertaken in Burma to a large extent.

The problem in Burma was intimately connected with logging operations, but the results obtained have been beneficial to the country at large, areas have been reclaimed for agriculture and villages safeguarded and protected from floods.

Although logging operations are not usually met with, there are many cases where the problem arises of training silt-laden rivers through flat alluvial plains.

The first chapter of the book gives a summary of the problems presented in the particular case, a brief description of the earlier efforts to control the torrents, and the final solution as worked out.

Chapters VI. and VII. describe in greater detail the methods by which training without artificial embankments is carried out, the intermediate chapters dealing with the problems which had to be solved. The three final chapters deal with Engineering Notes on individual streams, Statistical Data and Extracts from Old Reports, in which is included a Note by Lieut.-Col. (afterwards Sir C. C.) Scott-Moncrieff, R.E., C.S.I., written in May, 1882.

A more correct title for the work would have been " the regulation of rivers without *artificial* embankments," as the regulation is carried out by embankments raised by the streams themselves from their silt-laden waters. In the case of the seven streams dealt with, draining 560 square miles in the hills, the amount of silt brought down has been sufficient to reclaim and raise above flood level 10,000 acres of swamp land, in eight years, and the reclamation is progressing steadily at the rate of 2 sq. miles a year. When it is considered that this swamp land is raised apparently from 10 to 15 ft. in height, some conception of the work done by the streams can be formed.

It is not possible to explain the system in a few words, but all who are confronted with similar problems, either great or small, cannot but be benefited by the perusal of this book.

Apart from the value of the work, the book is most interesting to read, and contains 72 excellent photographs and sufficient maps for reference.

D.K.E.

THE WAR EFFORT OF NEW ZEALAND.

Edited by LIEUT. H. T. B. DREW, N.Z.E.F. (Whitcombe and Tombs, Ltd.) 1923.

THIS book, which is the fourth and last volume of the Official History of New Zealand's effort in the Great War, has been presented to the Corps' Library by the High Commissioner of New Zealand, and contains accounts of the Minor Campaigns, including the occupation of Samoa and the Senussi campaign, in which New Zealanders took part, and reports on the work of the various services and of the work at the Base. An interesting preface, written by the Editor, Lieut. H. T. B. Drew, gives useful statistics of the war effort of New Zealand, both in men and money, and also in supplies of meat and other produce, 160 million pounds' worth of which was shipped to the United Kingdom under the Imperial requisition.

F.E.G.S.

LE COMBAT DE L'INFANTERIE.

(Etude analytique et synthétique d'apres les reglements. Illustrée de cas concréts de la guerre 1914-1918). By COLONEL ALLÉHAUT. (Berger-Levrault) 10 francs.

"ENGINEER officers," says Engineer Training," must understand the methods . . . .employed by the infantry, with which arm they will be most closely associated in battle." Infantry Training is therefore, doubtless, an open book to us all. But experience shows that something more is required to clothe the principles of the Regulations in flesh and blood. The tactics and procedure of infantry are in their essence a psychological study. We must know what they, as men, can and will do before we ask them to do it. Our study will be barren if we cannot give it a human form, and on the human side the Regulations are, perhaps necessarily, incomplete. We need to be able to illustrate and to test them with the touchstone of war experience, by the light of minor episodes of battle. The French army is fortunate in possessing a considerable and increasing literature designed to illustrate their war doctrines with detailed pictures from the late war: a literature which has but a small counterpart in our own military journals. It is therefore with pleasurable anticipation that one opens Colonel Alléhaut's " Le Combat de l'Infanterie," intended, as he tells us, to analyse and explain expressly for the benefit of the other arms the methods of the French infantry and to illustrate their official doctrine with concrete examples from war experience.

Nor, in his First Part—" Liaison morale infanterie-artillerie"—are we in any way disappointed. Colonel Alléhaut adds to a glowing enthusiasm for the French soldier the possession of that lucid yet dramatic style which distinguishes the French military writer. In three vivid pictures he illustrates the essential importance of the closest friendship, collaboration and mutual knowledge between the infantry and the supporting artillery. And he pleads for a less material outlook than is sometimes to be found among artillery commanders. It is the duty of the artillery, he says, to maintain the morale of the infantry by every means in its power. If it cannot hit the enemy, let us at least have the *illusion* of support, let us at least hear the cheerful sound of our own shells passing overhead.

Is it only due to a difference in the psychology of our infantry that his plea finds little, if any, echo in our own Artillery Training?

But if the " First Part " provides an admirably human study, the " Second and Third Parts": " Notions générales," and " Le combat du bataillon et du régiment " are in this respect disappointing. The exposition is complete, clear and logical; but as we proceed we feel the cold breath of regulation, the deadening influence of the *scheme* or diagram. Especially is this the case when Colonel Alléhaut is dealing with the " attack." We ask ourselves: is this true to life? has it been tested in war? will it work? When he deals with the " defence " we are on firmer ground, since the French doctrine, as Colonel Alléhaut presents it, differs little, if at all, from our own. Engineer officers can read this portion of the book with considerable profit; and in the two pictures of defensive battle with which he concludes, one of an improvised front covering Amiens in April, 1918, and the second of a portion of the famous defence of Champagne front in July 15th, 1918, Colonel Alléhaut returns to his earlier form and concludes his study on a high note.

But if the bulk of his book will not greatly assist us to apply our own regulations, cannot we study it with profit as a convenient presentation of the French doctrine? Such a study lies to our hand already in a more convenient form in an able article by Captain Liddell-Hart which appeared in the issue of this Journal for April, 1922, and in a further article by the same author in the September, 1924, number of " The Fighting Forces "; though it must in justice be said that Colonel Alléhaut's interpretation goes some way to meet the criticisms to which the French doctrine was therein subjected.

It is in fact in his reasoned explanation of those differences from our own practice which Captain Liddell-Hart has noticed, that much of the interest of Colonel Alléhaut's presentation lies.

Only one point can be touched on here, but it is one of fundamental difference. The French have been accused of being, in attack, far too thick on the ground; of reverting to the pre-war errors of " building up the firing line " to obtain " superiority of fire " and of " direct reinforcement " of the leading echelon. The " normal " frontage of a *groupe* (consisting of a light automatic *equipe* and a rifle *equipe*, a total of twelve men) in the " échelon de feu " is 55 yards or one man to 4.6 yards. Compare this with our " normal " of two sections " up " on a platoon frontage of 200 yards, or an average of one man to 16.6 yards, and it will be seen that the French can hardly escape from the first of these accusations. Yet their doctrine is based on a logical argument, which runs as follows: In the early stages of a campaign or in open warfare we shall have neither the guns, nor the ammunition, nor the knowledge of the enemy dispositions which will allow the overhead covering weapons completely to ensure the progress of the infantry. Infantry must therefore be prepared at any point on the front to fight their way forward with their platoon weapons. But infantry cannot progress unless the fire of the defenders is continuously neutralised. And to ensure such continuous neutralisation we require in the " échelon de feu," one *groupe* for the 50 metres of front, which is all that each can cover with its fire; more than this leads only to heavier losses, less than this will not provide the necessary fire. This density must, therefore, be maintained throughout the attack; gaps due to loss of direction or to *groupes* being placed " hors de cause " must be filled if the progress of the attack is to be maintained. Hence one of the duties of the support and reserve units is to " reinforce " the " échelon de feu," not, be it observed, to build up the firing line to a greater density but to maintain the minimum density necessary for progress.

The argument is logical—where has the error crept in? At what point does it depart from the teaching of our *Infantry Training, Vol. II*, Amendment 2? Is the error due to a misreading of experience, or to a difference in national characteristics or in organisation? Or is it due to a difference in the type of warfare which our respective regulations contemplate? What are the factors which determine infantry frontages? On what arguments and experiences are our own normal frontages based?

These are questions on which the reader can profitably exercise his mind. We could wish that Colonel Alléhaut had proved the correctness of his premises by further historical examples. But we still more greatly wish that more officers of experience would utilise our military periodicals to demonstrate the correctness of our own doctrine in this and other matters by battle pictures related with an equal skill.

L.V.B.

THE TESTING OF HIGH SPEED INTERNAL COMBUSTION ENGINES.

By ARTHUR W. JUDGE. (Chapman & Hall, Ltd.). Price 25s.

This volume deals primarily with the engines of automobiles and aircraft, but the bulk of its contents is applicable to other types of Internal Combustion engines.

Tests are classified under three heads, Routine and Acceptance Tests, Tests of new types to ascertain the effects of changes in design, and Analytical or Research Tests.

Tests under these different heads are described in a clear concise manner, the results of tests being shown in easily read graphs. Test sheets are given showing the best way of recording test data, but the majority of the tests require apparatus which is not as a rule available in the service.

Many types of absorption Dynamometers are described, from the simple rope brake to the electric swinging field Absorption apparatus.

Though practically none of these dynamometers are to be found in the service, no one, after reading the chapter on the measurement of Brake Horse Power could fail to pick up information that might be of great assistance to him if called upon to take the B.H.P. of a high speed engine with only improvised gear.

The taking of pressure measurements and indicated horse power diagrams of high speed I.C. engines is fully described, but it is obvious that accurate instruments are required before any useful results can be obtained.

The chapters on pressure measurements are full of interest, but the actual taking of such measurements is a laboratory business, and is the work of the specialist.

Many Indicator and Light Spring diagrams of high speed engines are reproduced; most of these are, however, to illustrate faults in the indicator apparatus rather than faults in the engines under test.

Various forms of Pyrometers used in taking temperatures of valve heads, combustion chamber walls, etc., are also described.

A chapter is devoted to notes concerning the road tests of the chassis of road vehicles as carried out for commercial and research purposes. No attempt is made in these at really accurate measurement of quantities, and apart from the accelerometer and drawbar tests, the road trials described are mostly of a type that could be carried out on service vehicles and are therefore of interest to the service reader.

The volume under review is intended primarily for internal combustion, in fact for specialists who have at hand the necessary apparatus for making accurate tests. The accurate testing of high speed I.C. engines is outside the scope of the ordinary R.E. Officer, but as a potential user of internal combustion engines he should become acquainted with the methods of testing employed, and as such will read this book with great interest, and will probably learn a lot in so doing.

G.C.G.

DU HAUT DE LA TOUR DE BABEL: COMMENTAIRE SUR LA PREPARATION A LA GUERRE ET LA SITUATION STRATEGIQUE DE LA BELGIQUE EN 1914.

By Lieut-General de Selliers de Moranville. (Paris: Berger-Levrault.) 8 francs.

The general, who was Chief of the Staff of the Belgian Army at the outbreak of war in 1914, has written this book to correct the errors and confusion which writers of history will meet with in many published documents dealing with the military side of Belgium's share in the outbreak of the Great War, and which he likens to the confusion of tongues during the building of the Tower of Babel. The greater part of the book is taken up by an exposition and criticism of the French and German plans of campaign, but the interest centres in the third part, describing those of the Belgian Army. The difficulties of preparation of a scheme of defence were very great. The uncertainty as to which of their neighbours would violate their territory, the complication of the Dutch Limbourg, with its *tête-du-pont* on the left bank of the Meuse at Maestricht, and the incompleteness of the reorganisation of the Belgian Army, all had to be considered. On the 30th July the General presented to the King his plan of concentration of the Field Army, of one Cavalry and six Infantry Divisions, in the quadrilateral Saint-Trond—Eghezée—Hougarde—Tirlemont, but the King, anxious to give no possible cause of offence to Germany, moved it further west to Tirlemont—Perwaz—Louvain—Wavre. Later on, the 3rd and 4th Divisions were left in Liège and Namur, from which garrisons both were fortunate to escape, though with serious loss of men and material. There seems to be no doubt that the defence of Liège, so glorious to the Belgian Army and valuable to their *moral*, did not actually cause any delay in the programme of the German *aufmarsch*, but the General claims that, on the 18th August, the Field Army on the Géthe did actually delay the right of Kluck's army for more than a day, and procured a very profitable gain in time to the armies of their Allies. Against a powerful nation like Germany, Belgium could not hope to hold her territory, but the preservation of her Field Army was a political necessity of the first order.

F.E.G.S.

IMPERIAL MILITARY GEOGRAPHY.

Captain D. H. Cole, M.B.E., Army Educational Corps. 2nd Edition. (Sifton Praed,) 10s.

A new edition under a shortened title has just appeared of Captain Cole's book, originally entitled "Elementary Imperial Military Geography." The book needs little introduction to military readers, especially those who have recently found it necessary to face the examiners who dog the footsteps of Junior Officers. In the short eleven months of its existence the book has become a standard work on the subject, and is worthy of the closest study by all those, military or civilian, who desire to understand the military problems of the Empire in their widest sense. The information though full of detail is presented in an attractive and readable form.

In the new edition Captain Cole has included a great deal of valuable matter, especially in the direction of political and strategical deductions based on the mass of detailed information which the book contains. Among the subjects which have received extra attention may be mentioned Imperial Resources, Oil, the Middle East, and the Gateways of India. Certain minor details of the forces of the self-governing Dominions have wisely been omitted. Some of the Maps with which the book is very well supplied, have been enlarged and redrawn; bibliographies have been appended to each chapter; a valuable index, without which no book of the kind should ever be published, has been added; the appendices dealing with the methods of government of the Dominions and Colonies have been enlarged and rearranged; and last but not least the price, in spite of the considerable enlargement, has remained at 10s., which in view of the excellent paper and printing and the liberal supply of well drawn maps, cannot be considered excessive.

The study of this book is almost a necessity for Officers preparing for the Staff College entrance or Promotion examinations.

R.P.P-W.

NOTICE SUMMAIRE SUR L'EMPLOI DES EXPLOSIFS.

Par R. DEGUENT, Major du Génie, et F. VAN DEN BERGHE, Capitaine-Commandant du Génie. Brussels: Imprinterie du Ministere de la Défense Nationale. 12 francs.

THE thorough and systematic demolition of communications in an area has become to be recognised as so important a strategical weapon, that the publication of this little book has come at an opportune time. Written by Major Deguent and Captain Van den Berghe of the Belgian Artillery and Engineer School and published by the Belgian National Defence Ministry, it is full of useful information, tables, formulæ, for demolitions in the field. The formulæ look at times alarming but the diagrams and examples are clear. Unfortunately the demolition of ferro-concrete is only lightly touched on and the authors recommend the detonation of a preliminary charge to lay bare the reinforcement.

A useful table gives the equivalent explosion value, in T.N.T., of various shells, which may have to be used when explosives are scarce, and the question of organisation, placing and damping of charges is fully dealt with.

The authors rightly lay great stress on the cardinal point of all demolitions in the face of the enemy. *They must not fail.* Every care, forethought and preparation must be taken to ensure success. We are not given a second chance.

E.H.K.

CHARTS FOR BATTLE LANDSCAPE TARGETS.

Designed by CAPTAIN D. P. J. KELLY, M.C., A.E.C. (Gale & Polden; Aldershot), 6d. post free.

The object of these charts is to assist in making scale models for miniature ranges up to 25 yards. One set of graphs shows the necessary dimensions for a model to represent correctly an object of known size at various ranges. Another gives the rate at which any model, from an infantry column to an aeroplane, should be made to move in order to give a correct representation at any range up to 2000 yards. Useful hints as to operating models are also given.

I.S.O.P.

MANUEL PRATIQUE DE TIR ET D'APPRECIATION DES DISTANCES.

By CAPITAINE A. VILLEDIEU. (Berger-Levrault), 2 fr. 50.

This is an elementary pamphlet on musketry instruction and judging distance, with illustrations. It has some value as a means of learning the French technical terms relating to aiming and firing, ballistics, the parts of the rifle, etc. Among its hints to pupils are the following:—" Evitez absolument l'usage de l'alcool et du tabac; faites de l'hydrothérapie le plus possible, et fuyez toute occasion de débauche."

I.S.O.P.

MAGAZINES.

REVUE MILITAIRE GENERALE.

(*August*, 1924.)—*The 4th Army Corps on the Ourcq.* The article by General Boëlle is concluded, describing in considerable detail the events of the 8th and 9th September, and is illustrated by two clear maps. On the 10th the general retreat of the Germans commenced.

Les " Engins d'Acompagnement." The article by Commandant Biswang is continued, reviewing the weapons adopted or on trial in (*c*) Russia, (*d*) the United States), (*e*) Italy, and (*f*) Germany. The two latter are dealt with at some length. (*To be continued.*)

The 6th Cavalry Division and its Tanks at the Grand Manœuvres on the Rhone. By X. (probably an officer of high rank). The writer was privileged to follow the movements of the tanks at close quarters, and offers criticisms in regard to their employment, and suggestions for better organisation and action in future. To begin with, the realism of the manœuvres was marred owing to all but one of the regiments in the Cavalry Division having strengths of only one-third of their establishments, and to none of them having worked in conjunction with tanks beforehand. The result was that the Division was like a sick man encumbered with weapons he was too weak to wield, and the umpires had to intervene at least once to rectify incongruities in the dispositions adopted. The views advanced are instructive and worthy of consideration. (*Accompanied by a map* 1/80,000 *of the manœuvre area, and a diagram* 1/200,000.)

Military Chronicles of Economic Questions. M. Pierre Bruneau this month deals with the activities of the Chief Commissioners in Syria—General Gouraud till 1923, and subsequently General Weygand. Both have shown themselves talented economists and financiers as well as able politicians and military leaders. Chambers of Commerce and sea-ports have been ameliorated and improved, roads and railways repaired, separate states brought into one federation, customs reorganised, a colonial office and model farms instituted, with an experimental cotton station in the plains of Tripoli, and commerce stimulated by a fair at Beyrout. Irrigation is receiving attention and the valley of the Orontes is being developed for the cultivation of cotton. Motor transport is increasing, and it must be remembered that the service between Beyrout and Bagdad is not entirely English, and must traverse Syria to link Palestine with Iraq.

Books. La Belgique et les Belges pendant la Guerre. By Commandant A. de Gerlache (Berger-Levrault). Sketches the history of Belgium since its separation from Holland in 1821, and analyses the conditions of its neutrality and the circumstances which led to its participation in the war. The remainder of the book relates the atrocities of the invasion of 1914, the heroic days of the Yser, and the physical and moral sufferings of the inhabitants.

Les Conquérants du Tchad. By Colonel O. Meynier (Flammarion). An account of the progress of the French in this district of equatorial Africa from pioneer days to the present time.

L'Effondrement. By M. Philipp Scheidemann (Payot). Written in the form of memoirs, this book describes as a succession of episodes the critical periods in Germany from 1914 to the Armistice and the months following it. It relates in full detail the part played by the social democrats from their resolution to vote the war credits on 3rd August, 1914, their impassivity when Belgium was invaded, their agreement with the Austrian socialist annexationists, their vain struggles for a "*paix d'entente,*" and against the submarine war. Precise details are given of the internal situation of Germany, social and economic, especially of the strikes of 1917 and 1918. Based on documents of indisputable veracity, this narrative of events shatters the fable of the "dagger thrust in the back," and clearly explains the attitude of the various political parties in Germany at the present time.

(*September,* 1924.)—*Ludendorff's Battles on the Russian Front.* By General Camon.—This article begins with a disquisition on the systems of Hannibal at Cannae, of Epaminondas at Leuctra, of Frederick II., Napoleon, Moltke and Schlieffen, and shows how the German generals in the late war were influenced by the views of the last named, which were in reality a return to those of Hannibal. An interesting article. (*To be continued.*)

Infantry in Open Warfare. By Commandant Padovani.—Posing as axioms (1) that infantry cannot perform evolutions when exposed to the fire of hostile infantry, and (2) that in order to be able to advance superiority of fire power must be developed, the writer studies in Chapter I. the offensive action of infantry, dividing it into five phases: (1) the approach, (2) making contact with the enemy, (3) the attack, including the assault, (4) holding the ground won, and (5) exploiting the success. He then considers the appropriate action of the various commanders, regimental, battalion, company and section, the orders they should issue for each phase, and their normal positions on the battlefield. *(To be continued.)*

Les " Engins d'Acompagnement." The article by Commandant Biswang is concluded. The French and German regulations are compared, the main differences lying in the greater number of heavy weapons attributed to the infantry by the latter, and in the allotment of " infantry guns," as they are called, from the earliest stage of an engagement. Chapter VI. discusses the weapons of the future, probably a heavy anti-aircraft machine gun, and a special " gun-howitzer," the essential characteristics of which are set out with much thought and detail, a battery of which, manned by gunners, should be the sole property of each regiment, with, perhaps, an extra battery per division as reserve. In Chapter VII. it is argued that an additional weapon, which would be useful, would be " powerful light artillery," a new name for the trench mortar, and that the caterpillar machine gun, which has been proposed, is superfluous and utopian.

Study of the Transport of a Division in Motor Vehicles. By Capt. Salmon.—The move selected for study is that of the French 38th Division in support of the light corps after the battles of the Marne. It shows what precautions it is necessary to take, road repairs, flank guards, night marches, and also that troops so moved can afford powerful support to the light troops pursuing a retreating enemy, but that they can only be put in motion behind a substantial cavalry screen. It demonstrates that mechanical progress does not diminish the importance of the old arms, infantry, artillery and cavalry, but can increase their efficiency.

(October, 1924.)—*Ludendorff's Battles on the Russian Front.* The article by General Camon is continued, and sketches in clear outline the strategy and tactics resulting in the German victories at Tannenberg and the Masurian Lakes. The former, a " Battle of Cannae," aimed at encircling, but with sensibly equal numbers, both wings of Sansanov's Army of the Narew, and, although the shattered wings escaped, the centre was cut to pieces or taken prisoner. The latter, fought against Rennenkampf's vastly superior Army of the Niemen, aimed at out-flanking his right and threatening his communications. A timely retreat foiled the stroke, but deteriorating into a rout, left Rennenkampf's Army incapable of action for some months.

The 10th Army Corps and the 42nd Division at the Battle of the Marne. By Lieut.-Colonel Lucas.—A clear and concise account of the events of the 6th and 7th September, 1914, as far as concerned the 5th Army (General Franchet d'Esperey) and the 42nd Division on the left of the 9th Army (General Foch). Much of the information is drawn from " La Batailles de la Marne," a recently published book by M. Hanotaux, and supplements the account of the action of the 42nd Division published in the *Revue* for 15th February, 1920.

Infantry in Open Warfare. The conclusion of the article by Commandant Padovani. Chapter II. continues the offensive action, dealing with special cases—open ground, close country—especially woods—night attacks and action with tanks. The remarks on the French theory of the employment of tanks are of interest. Chapter III. studies the defence, and ends with some remarks on the conduct of a retreat.

The Japanese Army. By Lucien Bec.—Commencing with a brief history of the modern army since the abolition of feudalism in 1868, the Japanese doctrines of war and the moral forces animating officers and men are studied in Part II. Part III. deals with organisation and Part IV. with the effect of the Washington Agreement on the Army. Briefly the infantry, cavalry, field artillery and engineers are being reduced, while mountain and heavy artillery, railway, telegraph and aviation units are being augmented.

Military Chronicle of Economic Questions. M. Pierre Bruneau this month provides an eulogistic dissertation on French military and civil aerial communication with and between the Motherland and Colonies in the Near and Far East and North Africa, and the use of aircraft for surveying and political missions.

(*November,* 1924.)—*What the Germans think of the French Artillery.* By F. de Castlenau, Artillery Squadron Commander.—The writer quotes extracts from recent publications by German Generals, which betray the extent to which French artillery development before and during the war occupied the attention of the German High Command. He advances arguments in explanation of French superiority in this arm, and closes with a hope that impending Army legislation will not alter an organisation which has achieved such notable and proved results.

Essay on the 4th Bureau of the Army General Staff. By Major S. Raoult, General Staff.—This article recounts the failure of the pre-war organization called the D.E.S. (*Direction des Etapes et des Services*), which worked under the General Staff, and its replacement by an actual branch of the Staff. This 4th Bureau consisted of three sections, to which were entrusted all arrangements for ordering and distributing munitions, engineer stores, provisions, medical and veterinary stores, transport of reserves, evacuation of casualties, salvage operations, pay and post offices, including the provision of new and the extension of old railway stations and maintenance of light railways and roads therefrom, in fact, all Army services, except aviation and signals. Of interest to students of French Army organization. (*To be continued.*)

A.R.R.

REVUE MILITAIRE SUISSE.

(1924. *Nos.* 10 *to* 12 *inclusive.*)

THE article by M. Jean Fleurier entitled *Une légende. La faillite de la fortification permanente pendant la grande guerre* is continued (No. 10); matters affecting the armament and garrison of Antwerp, and the operations of the Germans against the Belgian citadel are dealt with. M. Fleurier points out that the real weakness of Antwerp lay in the inadequacy of its artillery, and considers it astonishing that, having provided fortifications with a lavish hand, and even sacrificed solidity by reason of the profusion with which defence works were constructed, the Belgians should, in the circumstances, have neglected to pay adequate attention to the matter of maintaining the armament of the citadel up to the standard required by the continual advance in gunnery. He justly considers that fortifications, although designed primarily for the purpose of playing a defensive role, should at the same time be capable of a measure of offensive action: without suitable and sufficient artillery, the most costly defence works, he says, become nothing more than inert and useless buildings. The prevailing idea in Belgium being that the fortress of Antwerp was a *place of refuge*, it would seem that the successors of Brialmont lost sight of one of the most important of the essential needs of a fortified centre. When first planned in 1859, the proposed armament for the Citadel defences were, for the purposes of that time, both adequate in character and ample in number—*inter alia*—pieces of 12 and 15 centimetres being provided. In 1914, a large number of the guns mounted in the works, as well as those in the Artillery Park of the fortress, were of an obsolete type—details of the armament of Antwerp at the outbreak of the war are given in the original article. The ammunition available for the artillery was also insufficient; at most, there were only 1,000 rounds per piece for the 15 cm. guns and 120 rounds per piece for the 12 cm. howitzers. The ammunition for the field pieces was also inadequate. Further, insufficient attention had been paid to matters affecting the fire tactics of the artillery; no range tables had been prepared for some of the howitzers and there was only one observation balloon, and that was without the means for rapid communication with the guns. Again, no steps had been taken to organise a system of artillery observation posts in anticipation of a coming war. Among other defects and deficiencies to which M. Fleurier draws attention are the small number of machine-guns and the inadequacy of the supply of small arms ammunition in Antwerp; in one Sector of the defence there were only nine sections of machine-guns for a trench line system 17 km. in extent. On October 2nd, during the Battle on the Néthe it was discovered that only 1,800,000 Mauser cartridges were available in the place, and four days later, when the retreat from the river began, in certain cases, the infantry ammunition supply was so reduced that only 30 rounds per man remained on hand. Commenting upon the character of the garrison of Antwerp, M. Fleurier points out that the Divisions of the Field Army which had been engaged with the enemy before retiring to the shelter of the fortress had suffered heavy casualties, particularly in officers. Arrangements did not exist in Belgium at the outbreak of war for replacing the casualties in the ranks of the officers; this accounts for the deterioration of the offensive spirit of the infantry of the Field Army and the caution displayed in connection with the sorties made from Antwerp. Further, the fortress troops were distinctly poor in quality; they were insufficiently trained and their *morale* was at a low ebb. That the Germans assumed a defensive attitude before Antwerp from August 20th to September 27th arose, M. Fleurier points out, from the fact that the German High Command very properly desired to utilise the bulk of the forces at its command for the purpose of crushing, if possible, the Franco-British Army; in order thus to reach Paris in as short a time as possible. Once the Meuse was crossed the Belgian Army was, in German eyes, a negligeable quantity which could be dealt with at leisure. Moreover, an attack on Antwerp was rightly held to be a task of far greater magnitude than that of forcing the defences of Liège and Namur. The experiment of the *attaque brusquée* at Liège taught the Germans a serious lesson and brought home to them in practical fashion that such an operation was a very costly affair and that success was only to be purchased at a high premium; the Germans naturally did not wish to purchase a victory on the Scheldt at a price comparable to that paid by them on the Meuse, but preferred to obtain the discount which their super-cannons were capable of winning for them. However, at the outbreak of war, the Central Powers were not plentifully endowed with weapons of this kind, and as Maubeuge, among other French fortresses, had yet to be reduced, the demands on the German heavy artillery were then sufficiently exacting to necessitate a cautious advance against the defences of Belgium's Citadel. Finally, when the Germans did push their attack against Antwerp, no attempt was made properly to invest the fortress; the troops employed by them in that region consisted almost entirely of reserve units, and they allowed the Belgian Army to escape from them and to gain the Yser, thus depriving the Central Powers, to a great extent, of the fruits resulting from the capture of the Belgian stronghold.

W.A.J.O'M.

BULLETIN BELGE DES SCIENCES MILITAIRES.

(1924. *Nos. 7 to 9 inclusive.*)

THE account of the operations of the Belgian Army during the War of 1914-1918 is continued in Nos. 7 to 9 inclusive; therein the narrative of the events of October 5th in connection with the defence of the line of the Scheldt is concluded; the happenings in the area under General Clooten, *i.e.*, the area not yet penetrated by the Germans, are dealt with; the measures taken to establish a secondary base are described; the movements of the Anglo-French force sent to succour the Belgian Army, and the steps taken to secure the safety of the Channel route during its transport are detailed; and particulars are given of the progress of the German advance on October 6th (against the sub-sector held by the 1st Division). It is pointed out that the Germans were not at this time pushing their attack against the western defences of Antwerp with any vigour, because they were hampered by the existence of the waterways in that region and by the general situation. It is suggested also that, perhaps, the real reason why the Germans proceeded in a somewhat leisurely fashion with their siege operations was because they felt certain that the Belgian Field Army would never leave the shelter of the defences of their famous stronghold, and the convictions of the German High Command in this matter were strengthened by the knowledge that British reinforcements had been pushed into Antwerp. The Germans may well have argued that it was not at all likely that the British military authorities would have made special efforts to reinforce the garrison of the fortress had not a decision been arrived at to put up a defence *à toute outrance.* In the circumstances, the much criticised move of the ill-equipped units of the R.N.D. into the beleaguered city seems to have served a useful purpose; the Germans were completely deceived by the measures taken, and possibly it was this fact that made it possible for King Albert to withdraw the bulk of the Belgian Field Army from the doomed city without any serious molestation on the part of the enemy. A secondary base had, since October 4th, been established at Ostend and Zeebrugge; in view of the possibility of damage being done to the railways by raiding parties, working parties and a couple of trains loaded with the materials necessary for effecting rapid repairs thereto were constantly held in readiness at Ghent to proceed at a moment's notice to any spot designated by the General Staff. The Belgians were able to maintain a railway service, in spite of many serious difficulties, between the coast and Antwerp; fortunately, the Germans took no steps to damage the line, the only one available for the purpose, which was being used. The Belgian High Command, it is made evident, was bitterly disappointed with the measures taken for reinforcing the Belgian Army; of the reinforcements promised, only the three British Naval Brigades joined the Belgians in time to take part in the defence of their citadel. By October 6th the troops of the Belgian 5th Division had reached the limit of their resisting power and began to retire. The Naval Brigade under General Paris, however, was still holding out in its position north of Lierre, and, owing largely to this circumstance, the Belgian 1st Division also continued to occupy its defensive line for a short time longer. During the afternoon the Germans made a serious breach in a part of the main line in No. 3 Sector of Defence, and, in consequence, orders reached the Belgian 1st Division at 5.30 p.m., directing it to retire towards Hemixem. Just when orders for this move had been issued, fresh instructions reached the Divisional Commander directing him to retire to Aertselaer, and to take steps to cross to the left bank of the Scheldt by the bridge at Hemixem. In the meantime, in view of the fact that the chances of the Belgians regaining the line of the Nethe near Lierre seemed hopeless, King Albert summoned a final meeting of the *Conseil de Défense Nationale.* A decision was now arrived at to move the bulk of the Belgian Field Army to the left bank of the Scheldt, and the further defence of the fortress was entrusted to the Belgian 2nd Division, the 2nd Brigade Mixte, the brigades of the R.N.D. and the permanent garrison consisting of fortress troops.

The article by Baron W. de Heusch entitled *L'Enveloppement à la Guerre* is concluded in No. 7. The German enveloping movement in the Great War, 1914-1918, is dealt with, and the excuses given by the Germans for its failure recorded. Baron de Heusch points out that an enveloping movement cannot in the altered circumstances of warfare, where very large masses of troops are employed and the latest developments of science, such as improved optical apparatus, aviation and wireless telegraphy, called in aid, be carried out with that measure of secrecy which is essential for effecting the surprise of an adversary; consequently, the chances of success of such a manœuvre are to-day at a serious discount. As soon as an opponent discovers an enveloping movement, and this is likely to occur the moment it is put into operation, he will assuredly at once adopt tactical dispositions to meet the situation, and thus bring about a failure of his enemy's enterprise.

The article by Major B. E. M. de Grox, entitled *Le Terrain et la Guerre* is continued in Nos. 7, 8 and 9. In some quarters the view is held that nowadays the character of the *terrain* on which the collision of *national armies* takes place matters little. Major de Grox shows in his article that such a view is mischievous, and that, on the contrary, a comprehensive study of the features of the *terrain* of a future theatre of operations and the adaptations of the strategical plans thereto are, if anything, of greater importance than of yore; extracts from many important publications are given to show the importance in which the *terrain* has been held in olden times.

Among other articles of interest in the numbers under notice are:—*Quelques considerations sur les couverts* (Nos. 7 and 8); *La defensive de retraite* (No. 9); and *Reflexions à propos de la 5e arme* (No. 9).

MILITÄR WOCHENBLATT.

(*10th January*, 1924).—In this issue is an interesting review of a brochure on march dispositions as affected by the air arm, written by Hauptmann Waldemar Pfeiffer, and based on his, apparently, extensive war experiences. The book deals with the question of the extent to which marches in closed up columns on roads are possible, particularly by day, when opposed to a superior hostile air force, and according to the critic incites not only the higher and " middle " leaders, but even the subordinate leaders, to serious thought, which leads to new, unusual and, perhaps, disturbing views. As the offensive capabilities of the hostile airmen must be taken into consideration much more seriously than formerly, especially in view of an insufficient anti-aircraft defence, the consequence, according to the author, will be that through the increase of their vehicles (first line transport and train) troops have become extraordinarily vulnerable to air attack and will only dare to carry out operation marches by night; further, that it will be found desirable to continue these marches by night up to the point of gaining touch, whilst the reconnaissance and establishment of routes will follow in the day time. But where it is necessary to go from night to day marches and tactical touch must be got not only by reconnoitring detachments, but by the infantry division itself by day, it will then be necessary for the division to deploy at dawn and only to advance deployed. This means that not only will the troops have, out of all proportion, far more taken out of them than formerly, but also certain units will always be more held up by physical obstacles than others. The author deduces from this the necessity of reviving the old " lines of demarcation," that is to say, to lay down fixed lines on the ground up to which for the time being the advance is to go and beyond which further advance is only to be made on receipt of specific orders, after connection laterally and in depth has been established. Advances of this nature, deployed and piece-meal fashion, will, of course, restrict appreciably the rate of marching, so that two kilometres an hour may well prove an absolute maximum.

The author has also something to say about the distribution of transport vehicles *in the deployment, so that they shall offer the least target to* hostile aircraft.

E.G.W.

HEERESTECHNIK.

(October, November and December 1924, *Numbers).*

THE "official" articles in *Heerestechnik* are getting fewer in number as time goes on. In the three numbers under review there is one official article apiece.

In *October,* caterpillar traction is described with special reference to tanks. A few interesting general statements are made, such as the fact that the pressure per square foot on the ground in the case of a German brand of caterpillar (weight 3,000 Kg.) is only $\frac{1}{6}$th of that under the hoof of a walking horse. The American "Christie" system, which allows of the use of eight indiarubber tyred wheels (28 Km. an hour on a road), or alternatively of an added caterpillar arrangement (14 Km. across country), comes in for notice, as does the French "Kegresse." In America it is the field gun, with its constant cross-country journeys, which is thought most suitable for such traction, and experiments have been made with caterpillar gun carriages. The inevitable drawbacks are classified as three in number :—

1. The exposure of the motor to possible damage.
2. The necessity for using the motor in making big switches.
3. The weight.

Very large guns and howitzers are to be caterpillar drawn (in order to get them off the railway). The writer then describes tanks and begins with a tactical discourse. He quotes the destroyer tank, tank of the line, and torpedo tank, which we have heard talked of in England. The classification preferred by the author is small, medium and heavy. The nine principal desiderata of a tank are tabulated and end off with desirability of floating. (A screw is mentioned as a proved method of tank propulsion in water.) There is a chance of some small low tank in which one man (lying) shall control the motor, steer, work the machine gun and keep touch with his neighbours! The French types, Renault, Schneider, St. Chamond, are briefly described and also illustrated. English, American and Italian types follow. In describing anti-tank measures the relatively poor practice of tank gunners is insisted on. Great emphasis is laid on the identification of type (and hence choice of counter-measures). The use of obstacles is to shepherd tanks into definite avenues of approach. Mine fields are useless because the tank exerts less pressure than a man's foot and the remedy is more dangerous than the disease. The heavy anti-tank rifle will deal with light fast moving craft, the infantry gun or light trench mortar with mediums—but the field gun is the best answer for all. (Armoured aeroplanes are mentioned as likely to be valuable in this connection).

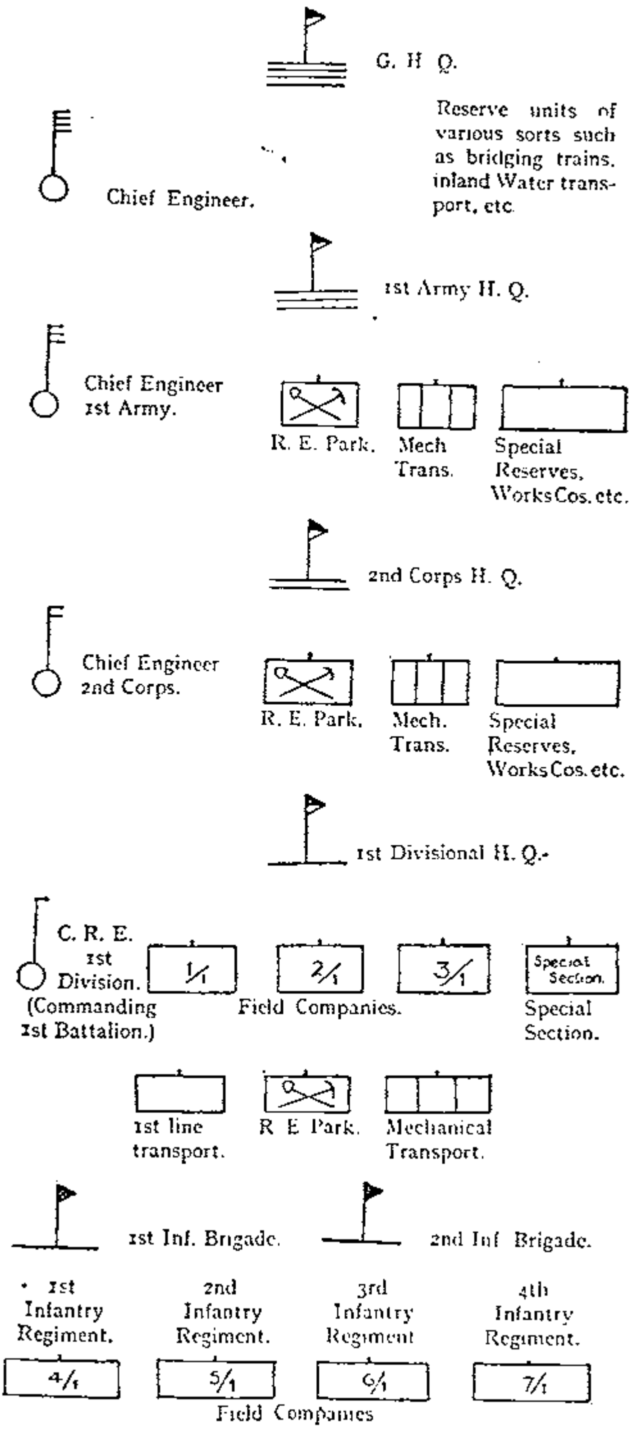
Captain Justrow writes in the November number on ballistics. He quotes an Inspector General of French Artillery on the ranges desirable for certain calibres. Here they are :—

		Metres.
7.5 c.m.	Field gun	14,000
10.5	How.	12,000
10.5	Gun	16,000
15.5	Gun	25,000
15.5	How.	14,000
24	Gun	40,000
24	How.	16,000

But German guns anyhow don't do it. Why? The muzzle energy is used up partly in the weight of the projectile, partly in the initial velocity. Not enough attention is paid to the former. The Frenchman's ideal is attainable if the weights of gun and carriage necessary for it are tactically allowable. Tables and graphs are given. I feel sure the article is sound and informing and leave it to our friends of the Regiment.

In the December number is an article on the industrial country and national defence, by Major A. D. Drees. England and the highly industrialised France, Italy and Germany are contrasted with America and Russia. We have the engineering, scientific and administrative problems of modern war to the credit of the industrial state. Food, men and horses on the other side. The increasing value of an organised industry on the "home front" is gone into with, one would think, unnecessary thoroughness. It jumps to the eye. The American Civil War is quoted as the first striking illustration of the strength of a mobilised industry in spite of the simplicity of contemporary equipment and armament. In the future it is to be looked for that an industrial state will supply enormous stocks of tabloid foods! As regards horses, the author thinks them too large, too hungry, and too "expendable." The machine must do their work. He is interesting on the man question. The industrial worker, quick to understand modern machinery and weapons, is also physically on the whole better and not worse than his country cousin. He quickly takes the healthy tan of exposure and his capacity for prolonged physical exertion is just as great. Here the value of games is underlined, and Germany congratulated on the way it has taken to Anglo-Saxon pastimes. But the food problem is also most important. The United States are quoted as combining the advantages of industry and agriculture and Russia described as having the resources, but being unable to profit from them because of the political regime. The romance of war is, then, killed by industry and we shall all be "mechanicalized," but in the author's opinion we need not be down-hearted and are promised more "frisch-fröhliches soldatenleben."

There runs through the three numbers under review an article, on the use of engineers (or pioneers) in war, by Captain (on the Staff) Dr. Oskar Regele of the old Austrian Army. He believes first of all that every formation should have its own pioneer units and that regimental pioneers (sog. "Truppenpioniere") are of little use. To-day and to-morrow it is only the real tradesman who can deal with the problems which arise. Here is his proposed organisation anglicized :—


G. H Q.
Reserve units of various sorts such as bridging trains, inland Water transport, etc.
Chief Engineer.
1st Army H. Q.
Chief Engineer 1st Army.
R. E. Park.
Mech Trans.
Special Reserves, Works Cos. etc.
2nd Corps H. Q.
Chief Engineer 2nd Corps.
R. E. Park.
Mech. Trans.
Special Reserves, Works Cos. etc.
1st Divisional H. Q.
C. R. E. 1st Division. (Commanding 1st Battalion.)
1/1
2/1
3/1
Special Section.
Field Companies.
Special Section.
1st line transport.
R E Park.
Mechanical Transport.
1st Inf. Brigade.
2nd Inf Brigade.
1st Infantry Regiment.
2nd Infantry Regiment.
3rd Infantry Regiment
4th Infantry Regiment.
4/1
5/1
6/1
7/1
Field Companies

This organisation gives seven Companies to the Division, 14 to the Corps (with the reserve Corps, 28). In peace, electrical, mechanical, "flammenwerfer," gas and other companies, are represented by cadres. Bridging trains are "scratch" units on mobilisation and engineer troops and bicycle companies accompany cavalry and cycle battalions (to which, judging from current literature, the Austrians have a leaning). It is considered most important to safeguard the command and organisation of all technical work to the C.R.E., the tactical command to the G.O.C. formation, but he leaves the C.R.E. of a Division, in a Corps, between the devil and the deep sea. Divisional engineers may be used to reinforce other divisions on occasion, such as river crossing, etc. It is of importance to arrange alternate spells of front line and rear line duty. (It is not apparent if the author anticipates exchange of divisional units in this connection). Losses should be avoided and pioneers seldom used as infantry. Casualties will be frequent in open warfare, exceptional in a war of position. In battle every formation deficient in pioneers will suffer unnecessary loss in men, fighting energy, and time.

Pioneers in the Attack.—Every attack requires engineer preparation, including :—

(*a*) A technical study of the sector.

(*b*) A combined reconnaissance with staff and other arms.

(*c*) Proper distribution of pioneer units and the concentration of personnel and stores.

Officers must be properly equipped with maps and knowledge of all matters of import in the theatre of operations (R.E. Intelligence). The importance of a combined reconnaissance is heavily underlined. The preparation for attack includes communications (covered), traffic directions, roads, bridges (for tanks especially), splinter proofing dumps etc. Pioneers must rehearse the attack with infantry, and this is particularly important in river crossings. Engineer stores are a most important item of preparation. Every formation should have a certain number of pioneer officers for reconnaissance and "odd jobs" to prevent robbing units. Attacking tanks must have their attendant pioneers (also in Tanks ?) to clear the way. It is only by good organisation and peculiar effort that the artillery can be helped forward in time to exploit success to the full. After a successful attack the roads for supply are the main task. Better one good road than many bad. A river crossing calls for particular pioneer effort and lightly equipped units must be ready to help on the pursuing infantry (infantry bridges, etc.). The pioneer's task in attack is to clear the way for the rest, always to be helpful and on the spot, and to overcome those natural and topographical obstacles which are often the worst.

In the Defence.—If the defence follows on an advance it will be long before all pioneers are up. Communications are always the most important task and it is useless to indulge in other activities till they are put right. Working parties must be asked for. This being done, field fortification, artillery positions and O.Ps., strengthening bridges for heavy guns, camouflage, etc., follow. Mining is a last resort when all other means fail or counter-mining is necessary—for of all occupations it calls for the greatest and most exhausting efforts. For the defence of rivers and bridgeheads water mines are most important. The maintenance of communications during defence makes a continuous pioneer reconnaissance necessary. In retreat drastic demolitions must precede the withdrawal of units. They should then be hurried to the next line of resistance for its preparation. Rearguards have their own pioneers.

Lines of Communication.—Two remarks of interest are:—

(*a*) The necessity for uncommonly efficient and energetic officers for R.E. stores and parks (owing to the vast importance of supply);

(*b*) The necessity for running inland water transport with pioneer staffs.

In giving this article from Austrian sources, the Editor states that he does not thereby endorse the views expressed, but hopes to provoke discussion.

An article of some interest to the student of Ballistics appears in the October number in the form of an answer to Vahlon, the author of a recent book on ballistics, by Dr. Ing. Becker. Becker had reviewed his book. and these two experts are ventilating their respective views.

In the October and November numbers, Major Buhle gives a good summary of the factors affecting heavy draft. The articles are full of statistics dealing with the horse, harness, surface, gradient and pace. Major Buhle is evidently a horse lover and a good horsemaster, and his articles will be useful to many.

An article on anti-aircraft gunnery by Walther describes two methods of estimating the forward angle. One, depending upon the measurement of the angular velocity of the target, finds the forward angle as a function of this angular velocity and the time of flight of the projectile. The other fixes positions on the target's path, the point on this path where the projectile would arrive, and so calculates the forward angle. For the first an electrical measurement is obviously ideal but suffers from the inevitable jerkiness with which the observer follows the movement of the plane. There are many equations and a few diagrams, and the article is not easy reading.

In the December number Karl Lüdeman gives his ideas on a general service theodolite. He wants to combine the instrument for topographical, railway and artillery surveyors but, rightly, excludes from the scope of this combination any instrument wanted for ruling triangulation. We are interested in the same problem, which is a very difficult one in times when so many far-reaching alterations and novelties are being brought out. Lüdeman suggests combining theodolite and alidade as a possibility—a terrible thought, A "bonza" outfit instrument of this sort would please none but the Ordnance Officer.

H.St.J.L.W.

MILITARWISSENSCHAFTLICHE UND TECHNISCHE MITTEILLUNGEN.

(July-August and September-October numbers.)

Major Franz Stuckheil writes of the offensive period in the history of the Defence of Przemysl during its second investment. Like the previous article this is interesting reading and a clear and concise narrative, but no claim is made as to its accuracy in detail, and the information is mainly second-hand. This part of the second investment (November and December, 1914) contains only one effort on the Russian part to take a portion of the defences by storm. The investing troops of value were drawn off in succession to the Carpathian front, and the garrison made a compulsory number of sorties in the attempt to delay these movements and to get identifications. On the 11th, 14th, 16th and 20th November sorties were made; on the 14th, 15 battalions and 8 batteries took part. Successful in fixing the enemy temporarily, and at small cost, the sorties never succeeded in penetrating the main Russian line. On the 28th the Russians made their solitary move and succeeded in establishing themselves in close proximity to a portion of the main line of defence. A counter-attack on the 30th of November accomplished little. In December sorties took a more serious form. On the 8th December the garrison was warned of an impending attack by the Austrian 3rd Army, and asked to co-operate. A force of 19¾ battalions and 15 batteries was told off for the effort and on the 9th and 10th it took place. At a cost of 700-800 casualties the main Russian line was reached, but not broken. On the 13th and 14th came the news of the battle of Limanowa and hopes ran high of almost immediate relief. To meet the advancing Austrian 3rd Army and to cut the Russian line of retreat a sortie was arranged for the 14th. The article breaks off here and will, no doubt, be continued.

Two interesting articles describe the surprise attack by the Roumanians on the Austrian 61st Landsturm Infantry Division at Agasu in the valley of the Trotus. This action, which appears to reflect credit on most of those concerned on both sides, took place on the 17th October, 1916. Charged with the defence of a position with forces insufficient for the purpose, General Boian of the Roumanian Army, decided on a bold turning movement against the advancing Austrian Division and nearly brought it off. The action is described in successive articles from the Austrian and Roumanian points of view, and by participators on either side. A 21-mile march over mountain and forest preceded the attack.

In an article on the German Army of the East in the summer of 1914, Lt.-Colonel Kiszling asks whether the Germans fulfilled their pledges to the Austrians or not. He concludes not. The agreement was that the Austrians were to guard the German rear for six weeks—which was done. The end of that period found the Austrians in serious plight, with threatened flanks, forced to break off the battle of Lemberg and scuttle for safety behind the San.

A definite understanding had been arrived at that the Germans were to fall on from the north at the end of the six weeks, even though v. Moltke, in 1909, had clearly foreseen the difficulties involved. But the Germans had their eye upon the defence of East Prussia. After Tannenberg (end of August) the way to the promised German advance south was open. Instead, however, Hindenberg went for Rennenkampf (Masurian Lakes 7-14th September). The chance of ensuring an Austrian victory over the main Russian forces had now passed, and although German victories had been won, the original agreement had been definitely broken and a great opportunity lost.

In the July-August number, Fritz Heigl gives his third article on Camouflage. He finishes off the camouflage of individual objects with some remarks on O.P.'s and then describes Painting Camouflage under the three headings :—

A. Painting to represent three dimensional objects.
B. Painting in smallish stipple.
C. Painting in large stipple or stripe (" Jazz " painting.)

After pointing out how, in case *A*, one must copy local nature or art, he describes a bad case—(German Aerodrome). As regards *B*, whose object is to sink the object into the background, he quotes the Spithead Forts. Colour is not so important to the neutral effect as the patchwork design. Under heading *C* the aim is to deceive, not the eye, but the understanding. Jazz painted ships and tanks are described. Photographs illustrate the article.

The failure to exploit the Austro-German victory of 1917 in Venetia by pushing on beyond the Piave is discussed by Dr. Oskar Regele. The pontoon and bridging trains were not available when and where they were wanted. Teams had been handed over for artillery and supply work. Such scratch teams as were got together foundered almost at once. The magnitude of the operation had, indeed, been allowed for in the demands from the Pioneers on the spot, but these demands were not complied with.

Successive articles deal with the armament of the Artilleries of Europe and the United States. The state of each before the war is contrasted with its present position. The main item of interest is in the description of the measures which have been taken in America to design the types of ordnance advocated by General Winterveldt's commission after its studies in England, France and Italy.

Major Rendalic continues his digest of the infantry tactics of the attack. This number talks of the assault and break-through. Austrian, German, French and English ideas are compared. The tactics of the forward movement through the zone of resistance are most important to think out and to practice, but in fact this is seldom done. Manœuvre and training generally stop at the assault. The difficulty of stage-managing further " in-fighting " prevents practice, which is none the less essential, for here, if anywhere, the group and section must fight forward on an intelligent model. Our tactics are considered too complicated, and the brigading of machine guns too likely to rob the battalion of its proper fire support.

Italian light and heavy tanks are described in the September-October number with good illustrations.

Colonel Franz Andarle contrasts Radio-telegraphy with Radio-telephony. The former, illustrated by a 5 watt (antennæ) emitting set, with an 8 metre mast, and a working radius of 50 k.m., allows of the installation of one set every 500 metres. If calculated for an area of 4 k.m. side, 98 stations can be in use simultaneously. This calculation is based on tuning to wave lengths separated by $1\frac{1}{2}$ per cent. But a radius of action of 50 k.m. may be considered much too high, and by reducing it suitably one might put 196 stations in the same sized area.

With Radio-telephony, however, a much greater percentage must be allowed between wave lengths and much greater power. The 4 k.m. side square will now hold only five stations.

As an illustration of " concentration camouflage " in connection with the series of articles on Camouflage now appearing, Colonel Schwarzleitner instances the measures taken to disguise the actual point at which the German troops were to operate in the 1917 offensive against Italy.

Major Erhard Raus describes the activities of a cyclist battalion at the Col de Lana.

Several books of obvious interest are reviewed, amongst them

Geheime Machte. Nicolai. Leipzig, 1924. (Espionage and contre Espionage.)

Die deutsche Wehrmacht in Wort u: Bild. Schwarte Offene Worte, Berlin, Charlottenburg, 1924.

Generaloberst Arz." Rikola Verlag Wien, 1924. (A record of the War Work of the last Austrian Chief of the Staff).

(*November-December Number*).—Field Marshal Conrad is in the process of writing " My Service years from 1906-1918." (Aus meiner dienst zeit, 1906-1918.) Four volumes have appeared, and the last includes the Battle of the Marne, that of Lemberg, and the Austrian retreat behind the San. A review of these four volumes opens the November-December number.

An interesting article on company training starts by saying that in war one company does not fight little battles all to itself either on reconnaissance or protective duties. Training must aim then at a real picture of the preparation for either attack or defence, and the gradual development of the situation. In fact, the same scheme should last many days, an actual (not hypothetical) enemy (also training) must be provided, and the gaps (if any) between situations must be lectured about.

The general idea is illustrated by an exercise in daily parts—which are—1. A defensive position and a sector of that position—its occupation and preparation. 2. A forward company—its position, defence, manning, etc. 3. The enemy's approach—till touch is established, lecture only. 4. Practical again—the deployment and advance of a company of the enemy towards the position of 2. 5 and 6. The attack up to 400 yards from 2. 7 and 8. Close fighting into the battle zone. 9. A partially successful counter attack leaving some elements still in the position. 10. Reserves thrown in, and a final successful attack.

Twenty-seven pages and accompanying diagrams work out the various situations—which repay study.

Tanks absorb a lot of room in German and Austrian military journals. In this journal British, German and Italian tanks have been described already. Now it is France's turn, and D. Ing Fritz Heigl gives a long description of all French types, except the Char 2 C, which will follow in a later number. There is little tactical detail, but armament, armouring and engines are carefully described.

Colonel a. D. Ing. Wilhelm Junck describes the substitutes and makeshifts used in Austrian munitions during the war. It would seem that a great deal of Austrian ammunition of this kind is still in existence—principally, no doubt, in the countries of the Little Entente—and the question is one, therefore, of interest to us all. Fuzes, propellants, shell and cartridge cases, driving bands, etc., were all experimented on. A curious point, and one dealt with pretty thoroughly in this article, is the effect of using iron shrapnel bullets in place of lead. Iron bullets to come up to the required weight per bullet are larger than lead, and in addition do not pack so well. They had to be used, however, and consequently the weight of the projectile had to be altered, and there followed an alteration in the range. This is only one example of how each makeshift altered every dependent factor, but it is of value to have a description of these makeshifts on record.

L. (he might give his full name, for he has lots to say) writes on the place of the Air Arm in the state. Difficulties will occur in the use of flying units where the personnel does not actually belong to, and interchange with, that of the service it serves. For all that, the balance of opinion is in favour of a definite Air Arm. But there are grave difficulties. Given half a chance, each service will arrogate to itself the principal role. Moreover, every operation undertaken separately by one service requires the aid of the others. Quite temporarily, and in peace particularly, the solution may be found in raising marines for the Navy, or in attaching Army units to the Air Force (Iraq is quoted). But such a procedure is bound to be ephemeral, and the exchange of such units—their relief when wanted, etc.—is impossible in the limited time which emergencies offer. The only way, indeed, is to have some central and directing staff which may use all its resources without being answered back. Especially must this be so in national defence (again we are quoted) in view of the quicker development of danger due to flying. In peace, cabinet decisions and political direction may answer. In war they never could, and the common high command and staff becomes inevitable—otherwise we fall into the troubles common to divided councils and coalitions without a head. It is pleasant to see ourselves described as "conservative in form, open-minded in fact," and it will be very interesting to see if anyone else wishes to break a lance with L.

H.St.G.L.W.

VOINA I MIR.

No. 15.—An article entitled "Verdun—place of destiny for Germany and France in the World War," by General von François, who held a high command during the attack, is of considerable interest. Verdun was the centre of the strategic and tactical plans of the two nations, and the battles fought there afford an abundant source from which instruction can be drawn, not only in matters of the higher direction, but in the finest details of the tactical conduct of position warfare.

The five German armies began their advance into France on August 18th, preceded by two cavalry corps. The left flank of the advancing group of German armies approached the northern edge of the fortified periphery of Verdun, which became the axis of their great strategical turning movement. The further the turning movement progressed, the greater became its danger to the German communications. A strong French counter-attack from Verdun would immediately react on the life-giving arteries of five German armies and might stop the whole advance.

The possession of Verdun, which was not in a condition of complete preparedness, was, therefore, of great importance, but the German Crown Prince, commanding the 5th Army, had not sufficient means at his disposal for an attack, and was, therefore, obliged to modify his efforts to carry out the order of August 28th from G.H.Q., which said: "The 5th Army will advance to the line Châlons-Vitry en François. This army must by refusing its left cover the flank of the wheeling armies until the 6th Army can take this responsibility on itself west of the Meuse. Verdun must be bottled up."

This Army remained for long held up before Verdun. The encirclement of the fortress was accompanied by the fiercest fighting. The night attack of September 10th led to a grip being obtained on the fortress from the north. The fate of Verdun hung on a hair, it only remained to occupy St. Mihiel on the South.

At this point Colonel Hentsch was sent by Moltke to visit the armies to take stock of the position. He visited the Crown Prince's headquarters on September 8th, but the latter tried to get rid of him as soon as possible. On September 11th Moltke himself visited the Crown Prince; he was already a broken man, and his outlook was pessimistic. An explanation took place between them. The Crown Prince expostulated against a hasty retreat and was allowed to withdraw his troops in good order on September 12th and 13th. Verdun again breathed freely.

When the enfeebled von Moltke was replaced by General von Falkenhayn, the latter succeeded in establishing equilibrium on the western front. The Crown Prince's army was again moved against the northern front of the fortress and severe fighting began. On the eastern bank of the Meuse, south of Verdun, the fort of the Camp des Romains at St. Mihiel was taken by the Bavarians.

In the middle of October, 1914, the Crown Prince received the order to capture Verdun by means of an accelerated attack, but his demands in troops, artillery and stores to effect this end were so great that the attack was postponed. At Christmas, 1915, the High Command was again bent on the idea of attacking Verdun.

The Crown Prince, correctly appreciating the situation, asked for permission to attack on both banks of the Meuse, but it was decided by the High Command to limit the attack to the east bank. This was a half-hearted plan, which indicated an under-estimate of the enemy resistance.

On February 21st, 1916, the attack began in bright winter weather. By the 24th the advanced defensive system of the French on the eastern bank of the Meuse had been broken through, and German guns were able to shell the outer belt of forts and the fortress itself. Verdun would have been taken if fresh troops had been poured into the fighting lines to continue the attack. The High Command promised them to the Crown Prince, but they never arrived. The French gained time to bring up reinforcements and the attack hung fire. The Crown Prince renewed his proposal to carry out an attack on the west bank of the Meuse. He insistently begged permission to take the height, "Le Mort Homme" and the crest adjoining it, so that he might from it stop the very effective flanking fire of the French on the east bank. This time the High Command consented. On March 6th the attack on the west bank began in a heavy snow storm. By March 14th the 6th Reserve Corps had reached the foot of the northern slope of "Le Mort Homme." The French resistance stiffened, and the Germans advanced but slowly.

At first the attack on both banks was carried out under one direction, but there was a distinct improvement in the conduct of affairs when at the end of March the Crown Prince divided the fighting area into two sectors, handing over the eastern sector to General Müder and the western to General von Gallwitz.

On April 9th the 22nd Reserve Corps, under the command of General von Falkenhayn, brother of the Chief of Staff, captured a part of "Le Mort Homme;" on May 8th the 4th Infantry Division occupied height 304. Strong French counter-attacks met with some success. The possession of these two heights became more and more a question of national honour, and the daily papers in France and Germany expressed a keen interest in them. By the end of May, 1916, the objective on the western bank had been attained. The troops were in need of rest. The 6th Corps was replaced by the 24th Reserve Corps and the 22nd Reserve Corps by troops of the 7th Army Corps commanded by General von François. On June 8th, 1916, he reported to the Commander of the western attack, General von Gallwitz, the arrival of his troops. He inquired about artillery resources and was told that the staff of the Army would direct artillery operations. This was by no means reassuring, since it rendered close co-operation between infantry and artillery doubtful.

His first care was to ascertain by means of aeroplane reconnaissance the exact line to which the advance had reached: the deduction was that possession of Le Mort Homme was by no means complete. The French counter-attack of June 15th recaptured a considerable part of the position from the 56th Infantry Division, which the latter did not succeed in re-taking. General von François gave the command on Le Mort Homme to the far-seeing and energetic commander of the 55th Infantry Regiment, Colonel von Feldman. The French were very active on Le Mort Homme. Attacks followed one another daily, but none of them was successful. According to plan, it was proposed to pass from passive defence to renewed attack. The changes in command which ensued after July 17th put the command of the western attack in the hands of General von François.

On the right flank of his force was the 2nd Wurtemburg Landwehr Division, east of it was the 24th Reserve Corps, composed of the 54th and 38th and 192nd Infantry Divisions. The 7th Army Corps formed the left flank, resting on the Meuse. On Le Mort Homme the 13th Infantry Division had replaced the 56th Infantry Division. Before point 304 was the 38th Division, which had already three times vainly tried to capture the height.

Owing to lack of munitions, attacks could not be undertaken on a large scale. The method adopted was one of sudden blows and modest objectives; for example, a short bombardment by artillery and mine throwers, which drove the enemy garrison into their dugouts, followed by infantry storming parties.

Behind the front was established a practice school for the attack of trenches, equipped exactly like those destined for attack; every man had to know his task. This method proved very useful. In the twenty-four major and minor contests which ensued the troops of the Western Meuse force gradually occupied the enemy positions with comparatively trifling losses.

At the beginning of July, 1917, Le Mort Homme and point 304 were completely captured. More than one interruption in the continuity of the operations took place owing to the despatch of divisions to other parts. In their place exhausted divisions were sent, which had to be hardened in a moral and physical sense before they could be used.

The differences of opinion between the Crown Prince and his Chief of Staff, von Knobelsdorff, respecting the further conduct of the attack, had a paralysing effect on the forward movements. Since August, 1916, the Crown Prince had been convinced of the uselessness of the attack and wanted to stop the advance. But General von Knobelsdorff considered the continuation of the attack on the eastern bank essential for tactical reasons.

Finally, General von Knobelsdorff was replaced by General von Luttwitz. At the end of August, 1916, further changes followed which had a decisive effect on the position before Verdun. General von Hindenburg replaced General von Falkenhayn, and the Crown Prince took over the group of armies, retaining command of the 5th Army. The attack on Verdun was stopped, but General von François had to continue his operations with limited objectives. There was no doubt that the cessation of operations on the eastern bank would adversely affect the situation of the western bank. The activity of the French increased, the power of their counter-attacks grew, and the supremacy on the eastern bank passed more and more into their hands. Their first important success was gained on October 24th, 1917; they penetrated to a depth of 2-3 kilometres and a considerable number of prisoners and guns was taken.

The enormous work which the Crown Prince's position involved led to the command of the 5th Army being handed over to General von Lochov, but after the defeat following on the French attack of December 15th, that meritorious general was retired to a well-earned rest and the command passed to General von Gallwitz.

"In opposition to our serious setbacks on the east bank," says the Crown Prince in his memoirs, "our activity on the west bank always rewarded us. Frequent, carefully extended, aggressive enterprises of small scope brought comforting results."

The complete possession of " Le Mort Homme " and point 304 was a signal success, but movement across the extensive plateau of Le Mort Homme could only be carried out with difficulty and immense losses. It was, therefore, decided to construct ways of communication below ground. Work was at once started by Reserve Lt. Lange, Leader of a section of electricians, a devoted and energetic man, and in a comparatively short time two tunnels were driven, which were a model of skill. One, which was 903 metres long, passed through the hill of Ravens Wood. Inside the tunnels were road material, habitations, tools, sanitary points, kitchens, stores, wagon sheds and even a soda water factory.

By the end of July, 1917, a considerable area on the eastern bank had been won back by the French. At the beginning of August the French threatened the General's left flank, and the whole area south of Forges Stream had to be evacuated. There arose a question about Le Mort Homme and point 304, monuments of German heroism. The general situation demanded that a position should be taken up on the north bank of the Forges Stream. Twice reports to that effect were made and were supported by the Crown Prince, but for reasons of *morale* on neither occasion did the High Command approve.

It was well known that the French were preparing a strong attack on the position on the west bank and measures had been taken for offering an energetic resistance. In the first line were disposed, from right to left :

2nd Wurtemburg Landwehr division—opposite Avocourt.
206th Division—east of Avocourt.
213th Division—on point 304.
6th Reserve Division—on Le Mort Homme.

Behind the line there were the 29th Division and the 48th Reserve Division.

The defence of point 304 was not easy ; there was a single trench along the narrow crest from which a communication trench led down the slope exposed to enemy fire. In spite of this, General von François believed in success, for there stood the hardened troops of the 213th Division. The General also thought hopefully of the defence of Le Mort Homme. The flat surface of this hill-top, where there was a strongly developed system of trenches with tunnelled communications, gave the defence great advantages. The troops there were brave and of an excellent type. They had lately arrived from the Russian front, where they had fought with conspicuous success, but they had not yet become accustomed to the conditions of warfare on the French front.

On August 12th, 1917, French artillery fire began against the front. A bombardment of observed enemy batteries was ordered with shells filled with yellow, green and blue cross gases. For 24 hours the action of the gases made itself felt, and then fire was started at other points. Under cover of patrols and small striking detachments the French front line troops were reinforced by fresh units. The French shattering fire increased from day to day ; our barrage fire no longer frightened them. From his observation post the General could observe the whole battlefield. Le Mort Homme and point 304 were like fire-breathing volcanoes. They were wrapped in thick clouds of smoke and vapour, which were uninterruptedly pierced by the flashes of bursting charges. Heavy bombs were falling in rear, bridges over the Forges were turned into splinters, and in its valley the poisonous fumes from the French gas bombs settled down. Nineteen balloons were hanging over the enemy position and directed the fire of his artillery. Squadrons of twenty or more aeroplanes cut through the air as far as Staray and cast their bombs there.

The shattering fire lasted for eight days, and in the early hours of August 20th an infantry attack began on the whole French front. Le Mort Homme was lost and a counter-attack delivered by the 48th Reserve Division failed. After the loss of this point the retention of point 304 was useless, and with the consent of the Crown Prince it was evacuated. During the night of August 22nd the brave 213th Division evacuated the position unnoticed by the enemy. Only on August 24th did the French renew the attack and move with all precautions on to the hill which had been evacuated three days before.

On the new position north of the Forges Stream the 206th, 213th and 6th Reserve Divisions were replaced by the newly arrived 54th Reserve, 15th Bavarian and 30th Divisions.

The French lapsed into inactivity. On Le Mort Homme and in Ravens Wood they behaved with such timidity that the 30th Division succeeded, in a series of nocturnal raids, in saving the guns which had been abandoned south of Forges Stream, eleven of which were quite fit for use.

Le Mort Homme and point 304 remained in the hands of the French. Verdun, the corner-stone of the French fortified system held out against the German storm. Verdun proved to be the saviour of France.

A.H.B.

THE MILITARY ENGINEER.

(*September-October*, 1924.)

Our Sister Service in England.—Major Gillette recently vacated the post of Assistant Military Attaché in London. In this article he gives a brief account of the history, achievements, and present-day activities of our Corps.

Doctrine of Permanent Fortification.—Lt.-General Schwarz, ex-Director General, Russian Corps of Engineers, discusses the development of permanent fortification in recent years. His views may be summarised as follows :—

1. All the artillery of the defence, which constitutes the essential element of such defence, and which includes everything from field guns up to the heaviest modern guns, should be organised as movable artillery and should have splinter-proof shields. During the siege, this artillery would fight in the same way as did the artilleries of the field armies during the last war, when they were on the defensive. All the peace time preparations for this artillery, as far as it is connected with the defence of fortified regions, should consist of the organisation of a network of roads for manœuvring, of firing positions covered against observation, of a network of observation posts for the observation of the results of the fire, and of a network of communications.

1. Neither bulkheads nor groynes can be recommended for use singly, except in special cases.

2. The use of concrete for bulkheads is not recommended, except for those heavier and more permanent types that may be classed as sea-walls.

3. Timber bulkheads should always be provided with riprap protection. To be most effective, there should be added to the timber jetty or groyne a bank of riprap on each side. The riprap should be of substantial size and the whole bank of riprap with the timber groyne should have a width at the top of from 12 to 20 feet, dependent on the locality; the purpose of the riprap being to add substance to the groyne and to decrease the scour of the receding waves, the purpose of the timber work to constitute a tight core.

4. The construction of bulkheads seaward of the high-water line should not be permitted, except for urgent reasons to the contrary.

5. The groynes must be spaced dependent on the slope of the beach, and the location of the inlets; the steeper beach necessitating groynes closer together than the flat beach. Also, it is not believed that any benefit, except in isolated cases and under particular conditions, will result in the groynes being otherwise than straight and generally normal to the beach.

6. Groynes should always be securely connected back to a bulkhead or, lacking that, to the line of sand dunes or other points well above the high-water line.

Sheet piles should be never less than ten feet. Riprap should not be less than one-man stone pieces weighing about 100 pounds. The larger the stone the less the effect of wave action upon it.

7. Groynes for purposes other than that of holding the beach should be permitted only for special reasons and after careful study.

8. A sand-tight core should always be provided for groynes. Either sheet piling or a compact one of gravel, quarry refuse, etc., may be used.

9. The core should always be solidly protected by piles, riprap, or by both.

10. Groynes more than three feet above the normal profile of the beach should be permitted only for special reasons. The top of the groyne should conform to the general slope of the beach and should be, on the average, three feet above the level of the beach, and, where erosions have occurred in the past, and it is desirable to recapture the beach and restore it, the groynes should be designed with the piles projecting up, so that additional boards may be added between the vertical piles if the beach rises.

11. Care should be exercised in permitting the construction of curved groynes.

12. Groynes should be spaced, roughly, a distance apart equal to their length.

13. The growth of sand dunes along the coast should be encouraged and promoted. They are best promoted by aiding the

Fixed turrets and emplacements may be used in very exceptional circumstances.

2. The fortified zone proper should have a considerable depth. All the effort of peace time preparation should tend, besides the above mentioned organisation of the artillery, towards the organisation of this fortified zone.

3. This fortified zone, and still more the battery positions, which should also have considerable depth and be extended well backwards, should be completely concealed and should include a certain number of points of support, distributed backwards as well as laterally, which serve to prevent the deployment of the enemy in this zone.

4. A point of support should consist of a central shell-proof subterranean barracks, with a certain number of mine galleries radiating from it; each of these galleries should have its outlet at a point from which the surrounding ground could be observed; each of these outlets, which ought to be well-concealed, should consist of a small dug-out for the men and material—machine guns, rifles or anti-tank guns, searchlights or, better still, rifles for signalling—protected by a network of obstacles. These supporting points should be big enough to allow for the concentration there, at a given moment, of several battalions of artillery.

5. The intervals between these works should be protected not only by the mutual flanking fire of their moats, invisible barbed wire entanglements, etc., guns and other engines of war, but also by obstacles. As these obstructions are in a great measure independent of the outlines of the works, they do not show up the position of the latter.

6. Finally, for the defence of a fortified position, a very well-trained and instructed garrison is essential; militia formations should never be employed.

Topography from Aerial Photographs.—The Corps of Engineers and the Air Service are at present co-operating on mapping work in the Upper Tennessee Valley, in connection with navigation improvements, and hydro-electric schemes. This article contains a description of the methods employed and a discussion on the possibilities of air photography in this field.

(*November-December,* 1924.)—*Problems involved in Coast Erosion.*—An interesting study of the action of waves on a coast. Their effect is dependent principally on the following factors:—

1. The size and character of the waves.
2. The direction of their approach.
3. The profile of the beach and of the bottom of the adjacent shoal water.

The effects of storm waves and high winds are discussed at some length. The article concludes with a list of conclusions and recommendations which have been adopted by the Engineering Advisory Committee of the United States.

As these may well be of value to officers of the Corps, they are given as follows:—

growth of beach-building vegetation, such as sea-oats, sea-wheat and other beach plants.

14. The littoral drifts are of insufficient volume and velocity to warrant the construction of any key works in the way of heavy outshore jetties or current deflectors; that such works are not considered necessary, desirable or justified.

15. That to control the location and navigable depth of inlets, tight jetties are necessary, and that in the case of many inlets two parallel jetties are needed to carry the current into deep water.

16. These jetties may be straight where the tidal prism of the lagoons or bays is large, but may be curved in order to increase velocity where the lagoons or bays are small.

17. In the construction of jetties to control the entrance to inlets, great care must be exercised that such works do not cut off the supply of sand on which beaches adjacent to the inlet depend.

18. The public authorities should discourage, as far as lies within their power, the construction of sand-catchers or arrestors designed and placed for the purpose of extending the high-water line or the low water line toward the sea. Whatever is done in the way of coast protective works should be as such and not as coast extension works.

A Rapidly Constructed Military Road.—The ordinary corduroy road is extravagant in labour and material. A modification of this type has recently been tested with satisfactory results. Timbering is confined to the two wheel tracks. These are first excavated two feet wide by four inches deep, the spoil being used to form the crown. A double course of 2-inch planking is then laid, breaking joint. Two wheel guides of suitable section, secured to the inner edges, prevent the wheels from leaving the track.

As a rapid expedient on reasonably good ground, this method of construction is worthy of note. R.I.M.

COAST ARTILLERY JOURNAL.

(July, 1924).

AFTER practice shoots at Hawaii, it was decided to do away with Machine Gun Batteries for Anti-Aircraft work, and accordingly the M.G. Battalion of the 64th Coast Artillery (Anti-Aircraft) was reorganised as a second gun battalion identical with the first. But each battery of both battalions was supplied with four machine guns as alternative armament and for local protection.

Last year a Board of Officers was appointed to conduct tests to determine the efficiency of aerial bombing and of anti-aircraft fire. The report by the anti-aircraft batteries gives the impression that the bombers would have to maintain a height of some 20,000 feet or be brought down. It would be interesting to see the report of the Hawaiian Air Force.

As regards night firing, the author writes that the finding of a plane at night and its illumination for the guns is the hardest problem which confronts this branch of the service at the present time: he advocates distant control for the lights and increase of destructive radius for the shell.

The target for A.A. fire consisted, by day, of a group of eight or ten red toy ballons released in such a way that they would float past the battery on the wind at about 5,000 feet, or, for night or day practice, of a cylindrically shaped cloth sleeve towed some 2,000 yards behind an aeroplane. The sleeve was 5 feet in diam. and 8 feet long for 4,000-6,000 feet and increased to 10 feet in length for 8,000 feet. It was found that a red sleeve gave best results by day and a white one by night. No danger was apparent to the towing plane, though the original tow line was 3,000 feet long.

The percentage of hits in five days' practice averaged from 11 per cent. within 50 yards to 49.7 per cent. within 100 yards.

Dishpan or open type lights were contrasted with barrel type lights and the results found may be tabulated as under. It is proposed to try aluminium for the body of the lights in order to obtain lightness.

Advantages of barrel type: (*a*) Automatic features can be incorporated in lamp mechanism. (*b*) More rigid frame prevents distortion of mirror. (*c*) Arc protected from wind and consequent increase of illumination. (*d*) Mirror does not get fouled with insects or dust. (*e*) Lower cost of maintenance in mirror breakage. Advantages of open type: (*f*) Lighter for transport and manœuvre. (*g*) Small trunnion height needs lower emplacement for protection. (*h*) Minimum shipping space; this type could be packed in nests. (*j*) Mirror kept cooler with less chance of fracture. (*k*) Lower cost of production. (*l*) No front doors to absorb light.

The Board finally decided in favour of the barrel-type light. They also reported upon the necessity of remote electric control to enable the operator to concentrate all his attention on the target.

An impulse type controller is now being tested, with following results:—(*a*) The operation of control synchronising with the light is not necessary and is, therefore, undesirable. (*b*) A disengaging mechanism is necessary to make the light independent of the control when required. (*c*) The controller motors must be operated from the searchlight power plant without interfering with the power necessary for the efficient maintenance of the arc. (*d*) The speed of the controller must be sufficient to enable the light to keep up with the target. (*e*) There must be no appreciable lag in the response of the light to the control. (*f*) The method of control should be in the form of a "Joystick" or single lever which can be operated in two directions at right angles to one another, one for vertical and the other for horizontal deflection. (*g*) The control must be light enough to enable the observer to change position and take advantage of maximum visibility at all times.

The Board also reported that the high intensity light should receive the greatest attention and development and that medium intensity lights may probably be omitted entirely as a result of future tests. Targets would probably not fly under the conditions of visibility in which the medium intensity light is theoretically superior.

D.M.F.H.

INFANTRY JOURNAL.

THE January, 1925, number of this Journal, published by the United States Infantry Association, of Washington, gives an account, by Lieut. Geo. T. Wyche, 16th Infantry, of the construction of a Concrete Relief Map. Relief maps, for use in the instruction of tactics, etc., had hitherto been made of sand, but it was recognised that something more stable was required for a map of sufficient size to be suitable for practising the manœuvring of a division. The map built by Lieut. Wyche was laid on the floor in a box 15 feet wide, 45 feet long and 12 inches deep. A mixture of one part cement to four parts sand was found to give sufficient strength to permit walking on the map without damage. About half the depth of the box was filled in with cinders, and concrete was used for the top half only. The map was reproduced by the ordinary methods, it represented a base port at one end, leading to hilly country, with roads, railways and the usual features. When the concrete had set the features were painted in, and woods were made by dropping concrete, about a handful at a time, from a height of about six inches, and were later painted with green water paint. Small houses and wooden bridges were placed on the map at the necessary points. Towns were only outlined—streets painted white with a house at each corner of each block. The features were named on small cards held upright in slots in small blocks. The scale of the map was fixed at 3 ft. to one mile, and 250 yds. sub-divisions were painted on the outside of the box and numbered to provide map co-ordinates. The scale was increased when the map was used for the manœuvres of small bodies of troops. The map was built in sections of 2ft. by 15 ft. at a time and took one officer and five other ranks some 60 hours to complete. The troops were represented by painted wooden blocks. The writer describes the various uses to which the map is being put at the Post Intelligence School, Fort Jay, N.Y., in map-reading, patrol and scout tactics and O.P. locating and functioning. Activities in front of the O.P. are simulated by means of small blocks of wood, toy balloons, etc. In the two months during which it has been in use the map has shown that its uses for instruction in tactics are practically unlimited.

F.E.G.S.

SÔDUR.

THE Esthonian weekly military paper, "Sôdur" (The Soldier) of 15th January, 1925, reproduces from the Red Army News "The Krasnoarmiets," No. 61, of July, 1924, a large picture of Zinovieff, backed by five small pictures of gigantic crowds, intended to impress the Red Army with the immense strides which Communism is making in foreign countries. One of these has unfortunately been recognised as a photograph, by Akel of Reval, taken on the occasion of the Esthonian Great National Singing Festival held at Reval in June, 1923. To represent this loyal gathering as a " crowd demanding the abolition of the capitalistic regime and organisation after the example of the Soviet Republics " has come as no small shock to the Esthonians, who stigmatise it as a " trick, probably second to none in the World's history."

F.E.G.S.

CORRESPONDENCE.

WARMING AND COOKING FOR SMALL HOMES.

To the Editor, *R.E. Journal.*

SIR,

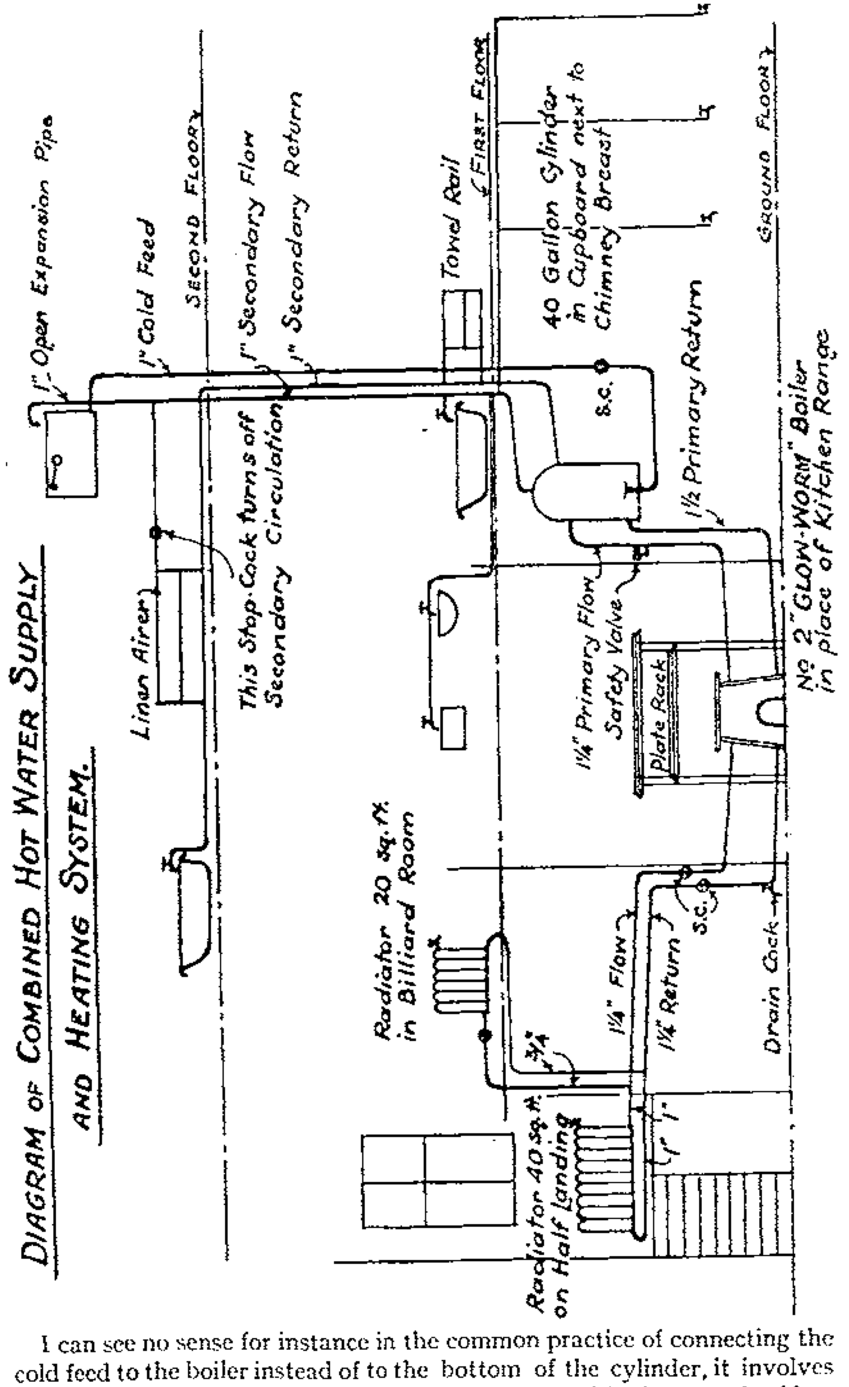
Major General Ferrier in his letter in the September number opens up a subject of interest to many officers both from the personal point of view, and also from the official standpoint now that we are concerned with the building or adaptation of married quarters for officers as well as other ranks in many stations. The subject is one of infinite variety ; depending on the size of the house and the requirements of the family, and I propose only to describe the work I have recently done in my house, which is about the size of a C.O.'s quarter, to show what is in my opinion the best arrangement in a house of that size.

My experience has been that the combination of cooking and hot water supply from one kitchen range is seldom satisfactory; either the ovens are cold or the water is tepid, and the fuel is to a great extent wasted in heating the chimney. I soon found in this house that the boiler at the back of the range could not cope with the demand for hot baths, the connections were so faulty that even when the water was hot in the cylinder it could only be coaxed out of the bath tap by turning it on very gently; if it was turned on full, cold bored through at once and the result was tepid ; the boiler cracked at the top as they usually do if worked at all hard, and something had to be done.

With the convenience of a gas cooker in the scullery I found the kitchen range was little used for cooking, and it served the third purpose of warming the kitchen only moderately well, and at much expense for fuel. I decided therefore, to clear out the old kitchen range, and to put in a modern table type gas cooker in the scullery, on which all the cooking could be done. In place of the kitchen range I installed a No. 2 " Glowworm " boiler to warm the kitchen, and the house, and, from this, connection was made to the existing hot water service with some little modification to get the connections quite satisfactory.

With an independent boiler for hot water supply I see no reason why advantage should not be taken of it to warm the hall and staircase by radiators, provided that the heating system is not overdone and arrangement made to turn it off at night, so that it does not compete with the heating up of the hot water in the morning ; it is best I think, to take the heating pipes quite separately off the other side of the boiler as shown in the diagram. This saves a separate fire in the hall and gives a wonderful degree of comfort by the elimination of cold draughts about the staircase and landings.

Before commencing work I studied carefully the last edition of " Hot Water Supply," by F. Dye, and also lent it to the builder, and plumber, to read, so that we might all be in agreement about the important points on which the success or failure of a hot water system depends, viz. : where to connect the primary flow and return to the cylinder, where to lead in the cold supply pipe, where to take off the secondary flow or expansion pipe and where to return it.



I can see no sense for instance in the common practice of connecting the cold feed to the boiler instead of to the bottom of the cylinder, it involves an extra length of some 10 feet of lead pipe and double that length of loss of head by friction when delivery at the taps is considered. Many a system is spoilt by bringing back the secondary return to near the bottom of the cylinder under the impression that thereby a better circulation will be obtained, the result being that when a tap is opened full a tepid flow comes, as I described was the case in this house.

The position of the cylinder is of great importance, let it be if possible on the direct route between boiler and bath. The nearer it can be to the boiler the better for quick heating up of the water, and the primary flow and return should be of ample size. I brought mine in from the cold lean-to scullery to a snug corner of the kitchen next to the chimney breast where it is just below the bath. It will nearly always, I think, be better to keep it below the kitchen ceiling level so as to shorten the run to ground floor taps, rather than to put it upstairs with the idea of warming the linen cupboard. I tried this once and did not find it a great success.

The connection to towel rails requires careful consideration otherwise they will not work, both connections should be off either the secondary flow or the secondary return, preferably the latter. It is desirable to arrange for a stopcock to cut off the secondary return, whilst leaving a clear open expansion pipe, so as to save loss of heat at night or in the summer when even towel rails may not be wanted. In the course of carrying out this work we struck by accident, what is perhaps the ideal connection; in making up the airing rail for the upper bath room and linen room the plumber used a crooked tee in the top connection to which the flow was led, the result being that the middle and lower rails were shorter by a fraction of an inch, owing to the right hand down pipe being slightly out of vertical. The circulation detects this in an instant and makes for the centre rail, instead of the top rail, returning by the lower rail, leaving the top rail to get what it may in due course. Any towels or linen hung to air get the benefit of the greater heat being below instead of in the top rail as is usually the case.

The work has all been completed some six months and what was a cold and draughty house last winter has been converted into a really comfortable one. Hot baths without stint can be had in rapid succession in either bath room, there is a plentiful hot water service at all taps throughout the day, and when the radiator is turned on at lighting up time in the afternoon a gentle warmth steals up the staircase and landings and takes the chill off the upstairs rooms, without giving any of that oppressive feeling of an overheated hotel. The cook has no flues to clean before lighting the fire in the morning, and in cold weather the Glowworm is banked up with coke and slack so that it keeps in all night. The maid has only two coal fires to attend to, in the drawing and dining rooms, there are gas fires in the study and billiard room for occasional use, and we find a little Kern stove or Beatrice gas heater ample in the bedrooms just to warm them up for dressing on a cold morning. Fuel consumption is appreciably less, the boiler burns no more coke than the old range ate coal, and the cost of the work will soon be repaid, apart from the appreciation in the value of the house.

E. N. STOCKLEY.

MILITARY TERMS.

To the Editor, *R.E. Journal.*

SIR,

A kindly critic of my TS. of a volume of the History of the War, suggested that certain military words used in it had better be explained for the benefit of non-military readers. I said that such persons could look them up in a dictionary. He said "You look them up in the Pocket Oxford Dictionary of Current English." I did, using the 1924 edition published at the Oxford University Press. I append a transcript of what I found. The italics are mine.

Your obedient servant,

J. E. EDMONDS.

BASTION ..	*Pentagonal* projection from a fortification.
BATTERY.. ..	Set of guns with their men and *horses*.
CAMOUFLET ..	Smoke puff.
CAMOUFLAGE ..	Disguise of guns, ships, etc., etc., effected by obscuring outline with splashes of various colours; use of smoke screens, boughs, etc., for same purpose.
CAPONIER ..	(Not given.)
CASEMATE ..	Embrasured room in the thickness of fortress wall.
ESCARP	Steep bank under rampart.
FASCINE	A long faggot used especially in war for lining trenches, etc.
GABION	A cylinder of wicker or woven metal bands *filled with earth*.
LUNETTE.. ..	Arched aperture in concave ceiling to admit light (fortification term not given).
PLATOON ..	Sub-division of a *battalion*.
PONTOON ..	Flat-bottomed boat or closed hollow metal cylinder for use with others as supports of temporary bridge.
REDAN	Fieldwork with two faces forming a salient angle.
REVETMENT ..	Facing of masonry, concrete, faggots, etc., *on rampart or embankment*.
SAP	*Noun.* Digging of siege trenches, covered siege trench (saphead, front end of sap). *Verb,* approach by sapping, dig siege trenches.
SAND-BAG ..	Jute bag filled with sand [one thing it won't hold] for use in fortification.
TAMP	*Verb,* Plug (blasting hole) with clay, etc., to intensify force of explosion.
TAMPING ..	Substance used for this.
TAMBOUR ..	[Not given.]
TROOP	Captain's cavalry unit corresponding to infantry company.

THE HISTORY OF SUBMARINE MINING.

To the Editor, *R.E. Journal*.

DEAR SIR,

I notice in recent issues of the *R.E. Journal* that though you are still advertising the complete set of three volumes of the *History of the Corps*, you have ceased to advertise the *History of Submarine Mining in the British Army*.* I venture to suggest that this omission may give

* Published by the Institution of Royal Engineers, Chatham, Price 5s.

the present and future generations of R.E. a distorted view of Corps History. The Submarine Mining branch of the R.E. employed a large proportion of the Corps for a period of 40 years, and when the mines were handed over to the Navy the S.M. Service numbered nearly one quarter of the whole strength of the Corps and more than this proportion of what were then called the Auxiliary Forces. (R.E.)

When I compiled the record of the Submarine Mining Service at the request of the Committee of the R.E. Institute, I was in very close touch with Sir Charles Watson, who was compiling the third volume of the History of the Corps, and I frequently met him in the R.E. Library in the Horse Guards, where we were both collecting material.

Sir Charles Watson was himself an early Submarine Miner and the first officer in charge of the R.E. inspection branch at Woolwich, and his original intention was to devote some one or more chapters of Vol. III to the submarine mining work. But when he saw the first proofs of my book, he was good enough to say that it covered the whole ground so completely that he had decided to omit all reference to this side of the work in Vol. III of the Corps History.

Although the actual mine defences were handed over to the Navy the service really remained part of the Corps and was continued as the Fortress Electric Light Service, which did such excellent work in the war. It was also the parent of the Field Electric Light service, which was developed so largely for anti-aircraft work. Both these branches still have a definite place in the organisation of the British Army.

The organisation of the R.E. Reserve and Territorial units at the present time is also largely based on the experience of the Submarine Miners.

Without claiming any literary excellence for my own production, I feel justified in submitting that it is a fairly complete record of the work of a very large branch of the Corps of R.E., and as such should be treated as a permanent part of the Corps History.

Yours very truly,

W. BAKER BROWN,

Secretary, R.E. Institution. *Brig.-General.*

NEW ZEALAND.

INFORMATION received from New Zealand states that during the present training year, which ends on 1st June, the whole of the three Field Companies will carry out their annual training at Trentham, which is the Headquarters Camp for the Central Command, and is situated at about 15 miles from Wellington. The Officers and N.C.O.'s of these Companies had a very successful course at Trentham in November.

Steps are being taken to complete the establishment of the Field Park Company, which under the new organisation will accompany the Division in the field, and good progress is being made in arranging with the Institution of Civil Engineers for some of its younger members to take up the first appointments in the commissioned ranks. The importance of securing professional engineers is fully recognised.

THE R.E. WAR AND R.E. KITCHENER SCHOLARSHIPS.

INFORMATION regarding these educational scholarships may be obtained on application to the Secretary, Institution of Royal Engineers, Chatham. The scholarships are of two kinds: "A," of value not exceeding £55 per annum and tenable between the ages of 10 and 18; and "B," of value not exceeding £20 per annum and tenable between the ages of 11 and 16. The *R.E. War Scholarships* are still restricted to the children of dependents of officers and other ranks of the Royal Engineers who were killed or died of wounds or disease contracted on service, or were permanently disabled, in the Great War. The *R.E. Kitchener Scholarships*, which are unfortunately very few in number, are open to the children or dependents of all officers and other ranks of the Royal Engineers who have either died or been permanently disabled while actually serving.