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NOTES ON THE HARDENING AND ANNEALING OF STEEL.

By CAPT. G. H. WILLIS, M.V.O., R.E.

(Read at a recent meeting of the Institution of Mechanical Engineers, Calcutta and District Section).

HEAT treatment of steel is attracting every year more and more attention from the physicist, the chemist, the steel maker and the user. The Faraday Society last November had a general discussion on the hardening of metals to which I am indebted for part of the notes which follow. I extract two items which struck me from the report of this discussion which appeared in *Engineering* of November 27th.

Sir Robert Hadfield mentioned in his contribution that "he had quite recently received from Mr. Bhandarkar, the Superintendent of Archæology in Western India, a specimen of a metal containing 0·7 per cent. of carbon, which was really a steel in the modern sense, whilst the many other steels which had been sent to him were iron. The specimen, from the base of the stone pillar of Heliodorus (the name of the Greek who erected it) at Besnagar, dated from 125 B.C.; it was a plate ½ in. thick, weighing ½ lb., which could still be hardened by heating and quenching, showing that it had undergone no change of structure in two thousand years beyond surface oxidation." As dwellers in the land which produced this the most ancient piece of steel known, this discovery is of special interest to us.

The other extract is from the report of the written communication of Doctor J. E. Stead, and runs: "The fact is we have not sufficient data to found any definite conclusion as to why steel is hardened by heating to above Ac_{1-2-3} followed by quenching." Hence I think I may, without personal blame, claim that the subject I have the temerity to bring before you to-night is one of which very little is really known. My excuse for this temerity must be first, that this session was likely to suffer from a paucity of papers, and secondly, that I have been giving some time to an investigation of the matter, which would have been much more thorough and consequently much more useful had I more time at my disposal. The conclusions, such as they are, that I have arrived at after my investigations I now lay before you in the hope that even if I am unable to give you any new facts or ideas yet I may call your attention to some small points which may be of use to you in your work.

There are among the older school of engineers those who claim a complete knowledge of steel hardening and annealing, the result of long experience, but a very cursory examination of their claims soon proves an ignorance as vast as their self-satisfaction. For instance, you will be told that experienced steel hardeners can judge with great accuracy the temperature of hot steel by the colour, and this irrespective of the brightness or dullness of the day, and the state of the man's health. Either of these factors is sufficient to upset completely a man's judgment, and actually it will be found by testing the claimant of such powers against accurate instruments that he cannot gauge temperature to 50° C. There are many empirical beliefs which have grown up round the practice of the heat treatment of steel which have no real *raison d'être*, such, for instance, as the statement which has been gravely made to me that the reason for the good work done at Sheffield is to be found in the nature of the water there. Those who advance such a theory are ascribing to a fictitious cause their own inability to outdo or even to equal the work of those who have been born and brought up in an atmosphere of steel and consequently are able to obtain results that the rest of us would willingly purchase at a great price, though (tell it not in Sheffield) even the Sheffielder has been known to fail, and that badly, in the treatment of his own steel.

Turning now from the practical to the theoretical side we have those who, by chemical analysis, microscopic investigation, and other subtle tests, prove to us that all we have to do in order to get our steel hard or soft is to produce within it by our treatment certain forms of iron carbides, pearlite, martensite, troostite and others, *ad lib.*, or to alter the quantity of carbon in solid solution in the iron and there we are. But these doctors disagree among themselves with a wonderful unanimity and, at the best, their investigations are so far confined to ascertaining the results of any process, and though in the end, doubtless, the data obtained will be most valuable, for the present they do not much help the man who desires to harden or to anneal properly a given piece of steel.

During my investigation I visited not only several representative steel makers' works at Sheffield but also the shops of certain firms who specialize in the heat treatment of steel, and by comparison of what I saw and what I heard at these various works I arrived at certain conclusions, which, while they will not be new to all here, will, I hope, be useful to some.

Special steels containing vanadium, tungsten, etc., were really outside the scope of my enquiry, and they differ so in composition and properties that a large book would be necessary to deal with them. On the other hand we, as mechanical engineers, are all brought daily into contact with carbon steels, and any guide to the right treatment of these should be of use. The theory advanced by certain of our scientific guides and the one which I accept for the present as best accounting for the results obtained in practice, is that steel heated to the recalescence point loses at that temperature its normal crystalline structure and becomes amorphous, *i.e.*, the molecules are of all shapes, or if you prefer it, without shape. Roberts-Austen thus expressed it some years ago :—" When iron passes through the temperature of recalescence its molecular constitution is for an instant almost chaotic."

Hardening of Carbon Steels.

When carbon steel is heated the rate at which its temperature increases is regular until a point a little above 700° Centigrade is reached. The rate suddenly diminishes at about 732° or 733° momentarily and thereafter resumes its regular course, save that there are two more minor interruptions at higher points with which we have at present no concern. This critical temperature called Ac_1 by the scientist is the recalescence point, and it is at this point that the steel assumes the amorphous state. Incidentally also carbon steel loses its magnetic properties at this point and is not attracted by a magnet. This latter principle is made use of by one inventor most successfully for the hardening of small steel tools, etc., and he has endeavoured to extend the principle to larger work, by fixing a magnet in the furnace which is released by the steel at the critical temperature ; on release it completes a circuit ringing a bell, thus giving the attendant notice that the recalescence point is reached. This loss of magnetism can however only be utilized in the case of carbon steel, any of the alloy steels are quite unsuitable.

Now it has been found by actual experiment that in steels containing a high proportion of carbon the closer the temperature of the steel to the recalescence point, so long as it is above that point, the harder the result on quenching. Hence, apart from another and very serious disadvantage which I touch on later, it is economically and practically wrong to heat the steel much above that point, as it is a useless waste of time and fuel.

For some reason, which I do not dare to attempt to explain, the crystalline form of steel is soft compared with the amorphous state, and the steel hardener therefore fixes the steel in the amorphous state obtained by heating to recalescence. This he does by quenching in a cool liquid, water for instance, and it is on the rapidity with which the whole body of the heated steel is brought below the recalescence temperature that the efficacy of the treatment and the resulting hardness of the steel depends. The hardening of a given carbon steel depends then on two things, heating of the whole body of the steel to the recalescence point and very rapid quenching, also of the whole body of the steel to a temperature well below the recalescence point so as to prevent the steel from assuming again its crystalline form, a process which takes some appreciable time.

Now when the structure of the steel has been successfully fixed in this amorphous state, there appears to be little room for doubt that the steel itself is in a condition of great internal stress, and it is perhaps due to this stress that the steel is hard. A fact that has come under my personal observation tends to confirm this view very strongly. In the Calcutta Mint a number of die blocks were got ready for an anticipated rush of work which did not come. They were stored away in their hardened state for a long time, many months in fact, and when taken into use a considerable number were found to have developed cracks and could not be used, while of the remainder the majority cracked very early in use and their average useful life was incomparably less than usual, and also than that of freshly made dies struck up from the same steel and treated in the same way with the exception of the long storage. To my mind this is strong evidence not only of the internal stress in hardened steel but also of the yielding of the steel itself under a lengthy application of this stress. I feel sure that had these dies been left soft and hardened when required, or perhaps had they been tempered before storing instead of at the time they were put to work, they would have had the normal life when used.

Quenching Temperature.—Until we have tables giving accurately determined recalescence points for steels of all varying proportions of carbon, we must rely for our quenching points on the maker of the steel, or, far better, ascertain it ourselves by trial of test pieces cut from the steel we are dealing with by using pyrometers.

A firm with a very high reputation for the excellence of their hardening work informed me that they adopted the following procedure. On receipt of each new batch of steel thin discs are cut from the bars and nicked across the centre, so as to facilitate fracture when hardened. These discs are then heated to temperatures rising by 5° Centigrade from say 720° up to 820° Centigrade as ascertained by an accurate pyrometer and quenched. Owing to the discs being thin there is certainty that they are thoroughly heated through and also completely quenched. The hardened discs are then fractured along the fracture nick and tested for hardness, also being carefully examined with a magnifying glass. In this way the temperature for that batch of steel is fixed, and all the steel of the batch is worked at that temperature within as small a limit as 2° Centigrade. Samples taken from the finished stock of the firm show a remarkable uniformity of hardness under test, thus demonstrating that the method adopted is efficient.

Quenching Water.—Those whom I venture to call the empiricists contend strongly that the quenching water must be as cold as possible and advise various methods of application such as opposed jets. It would seem however that a difference of a few degrees in the water is of small account when compared with the great difference between the recalescence temperature, something well over 700° Centigrade, and that of even boiling water. Remembering that the rate of transfer of heat from one body to another varies directly as the difference in temperature between the two bodies, it still appears in practice that ordinary cold water gives perfectly good results, such refinements as adding ice not improving the result, nor so far as I am able to ascertain does the addition of salt.

Burning of Steel.—If in heating the steel the temperature be taken considerably above the recalescence point, or if the steel be kept at a temperature above that point for any considerable time, the nature of the steel changes, probably due to rearrangement of its carbon contents. As it is found that in steel so treated the fracture becomes coarser and coarser the worse the treatment, it appears reasonable to assume that the carbon originally in solid solution in the iron becomes separated and interposes carbon molecules or molecules of various iron carbides between the molecules of true steel. This may or may not be the true effect, but we who are concerned with results have to bear in mind that whatever does take place, it is detrimental to the quality of our steel. Great care should therefore be taken to heat no more than is necessary to ensure that the whole body of the steel under treatment has reached a temperature but slightly in excess of the recalescence point. Should the steel by carelessness or accident become coarse in grain through this cause it may be restored, at least partially, by several annealings in which it is brought very slowly up to the recalescence point *and no further* and then cooled as slowly as possible.

Annealing before Hardening.—There is a point that may be noticed which was impressed very strongly upon me by several of those whom I consulted. When steel is worked on by hammering it is put into a state of strain, and though it appears most probable that the strains are removed when it is heated to the recalescence point for hardening, it would appear safer to make sure that the steel is in its normal soft state before hardening. It is therefore suggested that any steel upon which work has been done should be first annealed and then hardened. There is then no possibility of stresses of varying nature and perhaps direction being caused in hardening.

ANNEALING OF CARBON STEEL.

Perhaps it is rather putting the cart before the horse to deal with hardening before annealing, as more frequently annealing is the first process carried out in order to work the steel and produce the finished article which it is required to harden. But the short excursion into the theory of heat treatment with which I started my remarks on hardening seems to fall more naturally under that head.

As in hardening we wish to fix the chaotic or amorphous condition of the steel, induced by raising its temperature to the recalescence point, so in annealing or softening we have to avoid this amorphous condition and bring the steel back from the strained state induced by working it or by heat treatment to the natural crystalline form of soft steel. This, as you all know, is effected by raising the steel to the recalescence point or rather slightly above that point and allowing it to cool so slowly that it takes that internal structure which is natural to it. Now just as in hardening, the steel can be spoilt or so altered in structure as to be inferior, so in annealing also. By going much above the recalescence temperature or by keeping the steel soaking for a long time above that temperature during annealing we materially alter its internal structure for the worse. This is a very important point as it seems that, to some minds, it must be that prolonged heat will do what as a matter of fact is done only by prolonged cooling. Old workmen will frequently assert most strongly that to get steel soft it is necessary to get the temperature up and keep it up, and that the longer you do so the softer the steel, while they are careless regarding the true cause of softness and on withdrawing the steel to be annealed from the furnace will place the containing vessel on iron plates, which conduct away the heat rapidly, or in a draught of air. Any practice which results in too rapid cooling after heating will tend to give hard spots in the steel on the outside while the interior will be satisfactorily softened, just as in hardening inefficient quenching will fail to harden the interior of the steel, while the outside may be glass hard and flake off in use.

The best way to cool the steel after reaching the recalescence point is to draw the fire or put out the gas and allow the whole furnace to cool down with the dampers shut. Where the unavoidable delay of this method renders it impracticable the steel should be removed quickly from the furnace and buried in hot sand. If however it is, as it should be whenever possible, enclosed in a vessel of some sort, the vessel should be removed from the furnace, the steel being left in it, and placed on some non-conducting material such as firebrick or sand and out of any draught.

Furnaces.—Though perfectly good work both in hardening and annealing can be done in the old type of coal-fired flue furnace it is more economical and far more satisfactory to use the gas-fired muffle, and still better, the gas or oil-fired salt bath furnace. This latter furnace ensures an even application of heat to the whole of the outside of the article under treatment since the salt used being in a molten condition must perforce be of the same temperature throughout if occasionally stirred and must also be in intimate contact throughout with anything submerged in it. Previously the salts used had a tendency to decarbonize to some small extent the surface of the steel, but this has been got over, and the salt in addition to ensuring even heating acts as an efficient protector against oxidation of the surface. To prevent oxidation of the steel in a gas-fired muffle, a small luminous gas flame should be kept burning just inside the door. This will consume all the oxygen which may leak in around the door when it is shut, and does away with the necessity for packing the steel to be hardened in pots with charcoal, as must be done in the old type of coal-fired furnace. For those who have not seen the salt bath furnace, I may explain that it consists of an uncovered receptacle filled with a salt mixture of which barium chloride forms the major part, the receptacle being heated from below and round the sides with a bunsen flame of gas or oil. A pyrometer is fixed so as to dip into the salt, and the articles to be hardened are placed on a tray which can be lowered into or raised out of the molten salt as required. The raising and lowering of this tray, which is perforated, at frequent intervals during heating ensures evenness of temperature in the salt bath.

Temperature Measuring.—Pyrometers or heat gauges of some sort are absolutely necessary for efficient work, but it must be remembered that they must be frequently checked, if of the electric thermo-couple or the radiation type, preferably by means of some substance with a known melting point close to the region in which the readings of the pyrometer are of importance. Two useful melting points are 800° Centigrade, the temperature at which pure common salt melts, and 730° Centigrade, the melting point of an alloy consisting of 68·2 per cent. of copper and 31·8 per cent. of tin by weight. This latter is particularly suitable as the recalescence point of ordinary carbon tool steel is 732° or 733° Centigrade. Melting point gauges such as the Sentinel which are usually small capsules of alloys having known melting points are useful, both as a working guide to the uninstructed workman, especially the Indian, and as a rapid and fairly accurate check on a pyrometer.

These few notes may perhaps be usefully terminated by a summary of "Don'ts."

Don't imagine you can gauge the temperature of hot steel by looking at it. You cannot.

Don't throw the article to be hardened into the quenching water and leave it there, but hold it with the tongs or otherwise and move it through the water rapidly in several directions so as to sweep off the bubbles of steam which form and which will cling to the surface if this precaution is neglected, producing soft spots.

Don't get the steel any hotter than is necessary whether annealing or hardening, and don't keep it hot longer than is necessary to ensure the heat getting right through, otherwise in annealing you will get a coarse grain and in hardening you are likely to crack your work.

Don't forget to check your pyrometers fairly often as they are unfortunately not infallible, and it is probable that many complaints about the quality of the steel are due to the worker's own failure to work at the correct temperature.

Don't waste time and money on empirical recipes or on treatments suggested by the "practical" man unless careful experiment plainly demonstrates their real worth.

EXPERIMENTS IN THE PHOTOMETRY OF SEARCHLIGHTS.

By H. M. EDMUNDS, Lieut., London Electrical Engineers, R.E.(T.).

SOME experiments have recently been made by the writer in the photometry of searchlights, and as the results may add something to the existing knowledge of the subject they have been collected with explanatory notes in the present form.

DEFINITIONS OF TERMS.

Candle power is a measure of the quantity of light, under specified conditions, available from any given source. Various standard sources of light exist, constructed in accordance with definite specifications.

The unit candle is used as one of the standards of reference. Other sources of light can be compared with it by means of a photometer.

The photometer is in reality a device for measuring illumination. A screen is moved between the standard and the light to be measured until the illumination on each side is equal. A white paper screen with a grease spot is the commonest form. The spot disappears from view when the illumination is balanced.

The unit of *illumination* is the illumination produced by one candle power at a distance of 1 ft. It is called *1-ft. candle*.

Lumen—the Unit of Flux.—The total area of a sphere of 1-ft. radius is 4π sq. feet.

The standard candle, or any form of standard lamp gives out its specified unit illumination in one direction only. If it could be made to radiate unit illumination in every direction then the total flux of light from such a source would be 4π lumens.

One lumen is therefore the quantity of light passing across unit solid angle from unit source.

Law of Inverse Squares.—It is one of the laws of optics (borne out by experiment) that the quantity of light or flux contained in any solid angle subtending from a source of light remains unchanged whatever the distance from the source.

From this the law of inverse squares follows by simple geometry. That is:—Illumination varies inversely as the square of the distance from the source.

Brilliancy.—Surface brightness or brilliancy is a measure of the degree of concentration of a source of light. It is usually measured in candle power per sq. millimetre.

The electric arc is by far the most brilliant source of light as yet obtained. Various figures are given for its value and about 180 candle power per sq. millimetre is most generally adopted.

Searchlights.—A searchlight is a device for collecting the light from a given source and concentrating it within a narrow beam. It therefore produces an apparent candle power much greater than the actual candle power of the source.

The effective candle power of the source will be the apparent candle power multiplied by the ratio of the solid angle of the beam to the total solid angle of a sphere (or 4π).

In the case of a $3°$ beam this ratio is 5830.

Professor Blondel has stated that at great distances from a searchlight the apparent brilliance of the whole surface of the mirror is equal to that of the arc crater reduced only by the co-efficient of reflection. This is, of course, in the case of paraboloid mirrors only; in which every part of the mirror reflects the light in beams whose centre lines are parallel.

The apparent anomaly of this fact is explained by noting that although the area of the source of light is increased from the small dimensions of the crater to larger ones of the mirror, yet the angle of action is decreased in the same ratio leaving the total flux of light undiminished except for losses of reflection.

Radius of Action and Visibility.—By radius of action is meant the extreme useful range of a searchlight. The distance of any object from the observer is said to be the range of that object.

It is a generally accepted principle that the visibility of a given target varies inversely as the square of the distance between observer and target and varies directly as the illumination of the target.

These two principles are adopted in calculations of radius of action. They are incomplete and (under many circumstances) inaccurate but they serve a useful purpose in calculating the relative effectiveness of various searchlights.

Calling visibility, V.
Illumination of target, I.
Distance from observer to target, *d*.
Then $V = K_1 \frac{I}{d^2}$, K being used to denote some constant.

Assuming a perfect parabolic mirror, the illumination in the centre of the beam at any given distance will be independent of the *diameter* of the crater and directly proportional to the intrinsic brightness of the source of light. The only effect of increasing the diameter of the crater will be to broaden the beam thus illuminating a larger area at a given distance. The advantage of a broader beam is that any given point is under observation for a longer period in traversing at a given rate.

Assuming that the observer is at a flank of the light and at a distance short compared with the range, so that " d " may be used for distance of target from both searchlight and observer. Then :—

$$I = \frac{K_2}{d^2} \text{ for a given arc and mirror,}$$

and $$V = K_1 \frac{K_2}{d^2} \times \frac{1}{d^2} = K_3 \frac{1}{d^4}.$$

That is :—With a given searchlight in perfectly clear weather the visibility varies inversely as the fourth power of the range.

The illumination of the target at a given range is proportional to the square of the mirror diameter and directly as the intrinsic brightness of the crater.

The latter fact is obvious, the former assumes a constant ratio of diameter to focal length in different size mirrors. In the case of two mirrors, one twice the diameter of the other and assuming an identical crater in each, the solid angle subtended by the crater on the mirror with the larger projector will be one quarter the size of that with the smaller mirror of half the focal length.

The solid angle of the reflected beam is equal to that of the incident, therefore the area illuminated at a given range with the double-sized mirror will be one quarter that of the other. Since the total flux of light given out by the crater and condensed by each mirror is the same, it follows that the illumination will be four times as great at a given distance with the mirror of double diameter.

Calling D the diameter of the mirror.

And i the surface brightness of the crater.

Then $$V = K_4 D^2 i \frac{1}{d^4},$$

or $$d^4 = K_4 \frac{D^2 i}{V},$$

or $$d = \sqrt[4]{K_4} \sqrt{D} \sqrt[4]{i} \sqrt[4]{\frac{1}{V}},$$

or in words :—

The radius of action of a searchlight varies directly as :—

(1). The square root of the diameter of the mirror.

(2). The fourth root of the intrinsic brilliancy of the crater.

The above conditions while useful in determining the relation between various dimensions of a searchlight and its effective range are misleading in implying a numerical dimension for the property of visibility. In the writer's opinion it is absurd to speak of one object being, say, twice as visible as another; but, having determined the limit of visibility in the case of one beam, one is able to forecast at what range a searchlight of different dimensions will give the same degree of visibility. For example, if the effective radius of action of a 90-c.m. beam is 1,000 yards we can safely assume that a beam from a mirror of 180-c.m. diameter would give the same visibility at $1{,}000 \times \sqrt{2}$, or 1,415 yards. This effective radius would also be given by superimposing four 90-c.m. beams.

Atmospheric absorption will affect the above conditions somewhat and will tend to reduce the differences of range between different beams.

EXPERIMENTAL RESULTS.

The experimental work was carried out at a point where it was possible to have concentrated and dispersed beams at various distances centred or adjusted as required for the purposes of the tests.

The photometer employed for the tests was a small portable instrument called a "luxometer," and made by Everett-Edgecumbe & Co., Ltd. It consists of a device for striking a balance between the illumination produced by the light to be measured and a standard source of light. The range of the instrument employed is from 0·005 to 2,400-ft. candles.

In the experiments the following points were investigated :—

(1). To determine the relative illumination from different beams in order to show the efficiency of the mirrors.

(2). Observations made of the illumination due to the same beams under different weather conditions to determine the effect of atmospheric absorption.

(3). To investigate the effect on the illumination of varying the focus of the beam.

1. *Relative Illumination of Different Beams.*—The following measurements were made with beams carefully focussed by the respective E.L.D.'s. The weather conditions were exceptionally clear :—

Description of Beam.	Condition of Mirror.	Distance in Yards.	Average Reading of Luxometer in Foot-Candles.	Apparent Candle Power.	Effective Candle Power.
1. 90-c.m. × 42-c.m. paraboloid	good	1,690	0·99	25,000,000	4,360
2. ,, ,, ,,	v. good	1,690	0·50	12,900,000	2,200
3. ,, ,, ,,	good	2,560	0·34	20,000,000	3,430
4. ,, ,, ,,	good	2,560	0·60	35,400,000	6,070
5. 120-c.m. × 60-c.m. paraboloid	v. good	3,440	0·83	88,300,000	6,750
6. 90-c.m. × 45-c.m. Maugin ..	good	3,440	0·19	20,200,000	3,470
7. 90-c.m. × 42-c.m paraboloid	fair	2,120	1·17	47,300,000	8,120
8. ,, ,, ,,	good	2,120	1·18	47,700,000	8,200
9. 16° dispersed	good	1,690	0·23	5,900,000	5,400

NOTE.—3° beams are assumed for 90-c.m. mirrors.
2° ,, ,, ,, ,, 120-c.m. ,,
3° × 16° for 16° dispersed.

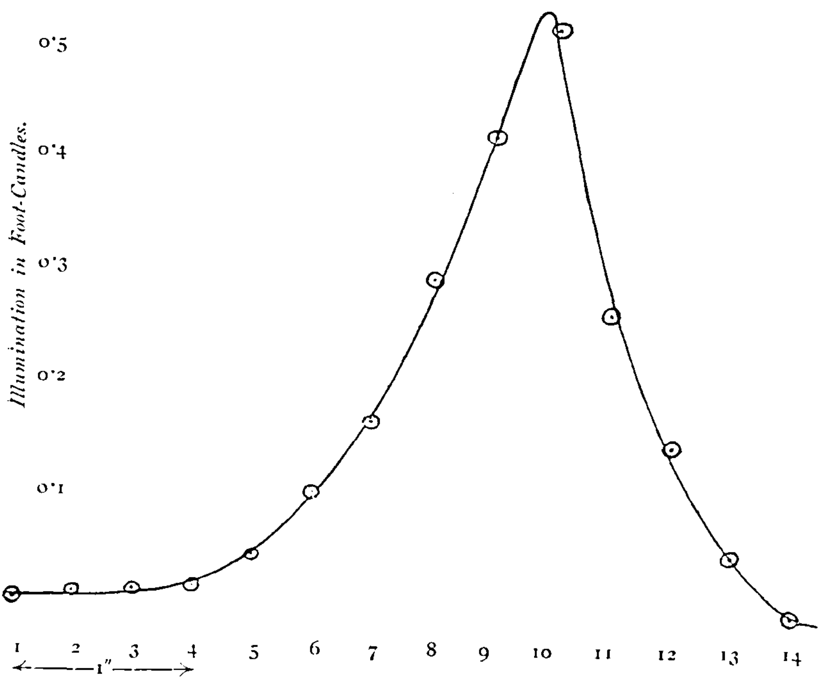
(2). *Weather Conditions.*—Beam at 2,560 yards 90-c.m. × 42-c.m. paraboloid.

Weather Conditions.	Foot-Candles.	Apparent Candle Power.
Very clear	0·96	9,700
Clear	0·58	5,880
Moderate rain, atmosphere clear ..	0·36	3,640
Thick weather, beams appear yellow	0	0

The results show that the difference between average clear conditions and very clear has a big effect on the atmospheric absorption. The first measurements were made after rain when an extraordinary clearness, very rare in England, was noted. The second reading was on what would be described as a clear night.

(3). *Effect of Focus on Illumination.*—A series of readings were made with a beam at 1,690 yards distance. The focussing screw of the lamp was moved two revolutions between each reading. The light in question had a paraboloid mirror 90-c.m. diameter by 42-c.m. focal length. The results are plotted in the curve and illustrate in a remarkable way the importance of accurate focus.

Curve Showing Effect of Focus on Illumination.



→ *Travel of Arc away from Mirror.*
90-*c.m. diam. by* 42-*c.m. Focus* (3° *Beam*).

It is interesting to note that the E.L.D. at the searchlight considered the focus best at the positions 8 and 9 on the curve. In reality point 10 was 20 per cent. better than 9. This curve shows that an inaccuracy of half an inch in the position of the arc diminishes the illumination by approximately *one half,* thus emphasizing the importance of maintaining accurate focus for the best results.

Superimposed Beams.—As a useful check to the accuracy of the instrument for different illuminations several tests were made of two beams independently and then superimposed. The results showed a remarkable confirmation of the well-known optical law that the illumination of the combined beam is the sum of the illuminations of the separate components. This is of interest as observers in directing stations have often expressed a contrary opinion.

SIEGES AND THE DEFENCE OF FORTIFIED PLACES BY THE BRITISH AND INDIAN ARMIES IN THE XIXth CENTURY.

(*Continued*).

By COLONEL SIR EDWARD T. THACKERAY, V.C., K.C.B. (LATE R.E.).

THE SIEGE OF DELHI.

June—September, 1857.

In the early months of 1857, signs of unrest began to be prevalent among the native regiments of the Bengal Army, but it was not until May that the outbreak of the Indian Mutiny actually burst forth in all its violence.

At the large military cantonment of Meerut, the headquarters of the Meerut Division, 89 men of the Third Bengal Cavalry had been tried by court-martial for refusing to use the cartridges issued from the arsenals, which they declared to be made with lard or pig's fat, thus destroying their caste and religion. They were sentenced to long periods of imprisonment, and heavily manacled, were removed to the military jail. On Sunday, May 11th, the native troops at Meerut broke into open mutiny, setting fire to the bungalows, releasing the prisoners, and murdering their officers, and any unfortunate Europeans whom they happened to meet. After committing these outrages they made off to Delhi and were not pursued.

On arrival at Delhi, being joined by the inhabitants of the city, they proclaimed the old pensioned King of Delhi as Emperor of India and committed similar massacres to those at Meerut, shooting down the English officers of the native regiments and murdering the Europeans. A force under the command of Brig.-General Wilson—afterwards Sir Archdale Wilson, G.C.B., marched out of Meerut on the 27th May and completely defeated the rebels with great losses on the Hindun River, capturing all their guns. After the junction of this force with that under the Commander-in-Chief, General Sir W. Anson, which had marched from Umballa, the combined forces under Major-General Sir H. Barnard (General Anson having died of cholera at Kurnul) marched towards Delhi and defeated the rebels who had taken up a strong position at Badle-ka-Serai on the Grand Trunk Road about 4 miles from the city.

The result of the successful action on the 8th June, 1857, at Badle-ka-Serai was to give to the field force under the command of Major-General Sir Henry Barnard complete possession of the low ridge of hills to the westward of the city. The highest parts of the ridge rise to a height of about 50 to 60 ft. above the general level of the interior of the city, while the average command may be taken for practical purposes at about 40 ft. The greatest length of the ridge occupied at any time during the preliminary operations was a little more than 2 miles, and of this position the extreme left was so far retired from the place as to be in no serious danger at any time, while the right invited attack from the moment of occupation to the close of the operations.

Along the crest of the ridge, posts of considerable strength existed. They were formed either of ancient or modern buildings of good materials and substantial construction. Of these the group on the extreme right, distinguished during the progress of the siege as Hindoo Rao's house, was at once the most important and most exposed. The Mahratta Prince by whom it was built had occupied it for many years, regarding it as his home, and had surrounded the principal house with many inferior offices, all of which were capable of supplying shelter to men and cattle, though not by any means shotproof.

Hindoo Rao having died some time before the mutiny broke out, the place was unoccupied. About 180 yards to the left of Hindoo Rao's house stands the Observatory, an ancient structure suited to the purposes of Hindoo astronomy, built by the Rajpoot astronomer, Rajah Jai Singh. It is of irregular form, dark and ill-ventilated, but as a support to Hindoo Rao's house was found very useful, and was permanently occupied during the siege. About 650 yards further to the left there was an abandoned mosque of the oldest Pathan type in a somewhat ruinous condition, but still affording accommodation for an outpost of respectable strength. This also was suited for a permanent position.

At the distance of nearly a mile from Hindoo Rao's house stands the Flagstaff Tower, a double-storied circular building of Gothic design, which commands an excellent view of the ground lying between the city and the ridge. This building offered sufficient means of shelter to make it useful as a post. Other posts were decided upon from time to time during the siege. On driving the enemy from every point of the ridge on the 8th June, Sir Henry Barnard occupied at once, in strength, the four points just alluded to. He established the headquarters of the Sirmoor Battalion, 2nd Goorkhas, under Major Charles Reid, in Hindoo Rao's house, and there this distinguished corps remained unrelieved from the first day of the siege to the last. Each of the picquets mentioned was supported by two field guns.

The headquarter camp was established on the plains to the westward of the ridge, and occupied the old parade ground of the

Delhi Cantonment. Immediately in rear of the camp there runs a broad, rapid stream, being a drainage channel from the Nujufghur Jheel to the river Jumna, and along the right flank, at a distance of about a mile, flows the Western Jumna Canal, which, crossing the ridge by a bold cutting through the solid rock executed in the time of the Emperor Shah Jehan, passed through the suburbs of Kissengunge, and enters the city through a culvert in the wall near the Lahore Gate, and traversing the entire breadth of the city, falls into the river Jumna close to the Begumabad Gateway.

Three main lines of road only were immediately connected with the operations before Delhi. The first and most important was the Grand Trunk Road, by which communication was maintained with the Punjab, and along which all reinforcements and supplies were necessarily brought from the country lying to the rear of the force, on the resources of which it was mainly dependent. The second was merely a branch of the first, connecting the camp with the Grand Trunk line at about 1½ miles to the rear.

It formed the old cantonment road to the city, crossing the Nujufghur Drain by a substantial bridge, damaged, but not destroyed, by the enemy during his retreat from the field at Badle-ka-Serai on the 8th June. The third was the line of road connecting Delhi with Rohtuk, Hissar, and other places to the south-westward, along which the enemy drew a considerable portion of his supplies. All the other roads centring at Delhi were completely commanded by the enemy, and it was only by long and precarious détours that any communication was maintained with the districts to the eastward or southward.

The ground around Delhi which was traversed by these canals and roads was, at the time of the siege, a tangled mass of old ruins, dense woodland, rice fields, and swamps of notorious insalubrity. It offered innumerable facilities for occupation by armed men of any degree of discipline, and, indeed, so incompatible were its features with the action of a mass of disciplined troops, that the many combats of which it was the scene were rather trials of skill between small bodies than operation by masses.

At the beginning of the siege the ordnance available for operation consisted of :—

24-pounders	2
18-pounders	9
8-in. howitzers	4
6-in. mortars	6
Total	21
5½-in. Coëhorns	12
Grand total	33

Many fluctuations in the strength of the force occurred and it is of little practical use attempting to give the precise numbers, but from 500 to 600 sabres, from 2,500 to 3,000 bayonets, and 22 field guns, may be taken as fairly representing the strength during the earlier operations. It is, of course, also extremely difficult to form any accurate estimate of the strength of the enemy, but as some of the most important accessions which he received did not occur until the siege had been for some time in progress, it may be inferred that on the 8th June the garrison of the place did not exceed 8,000 or 9,000 disciplined soldiers, supported by probably about the same number of half-disciplined and wholly undisciplined though armed men. For operations in the open field the sole strength of the garrison was in the trained soldiers, but for the operations in the rugged ground around Delhi, resolute men, familiar with their weapons and profiting by the universal cover everywhere supplied in some house or other, were antagonists whom it was necessary to respect.

In all the important materials and munitions of war the command of the arsenal in Delhi made the resources of the enemy, practically speaking, unlimited. Food was drawn with unrestricted freedom from the whole of the open districts to the east, south, and south-west, and there is no reason to suppose that money was deficient. With all the primary elements of a successful and vigorous defence the enemy was, therefore, abundantly provided.

The permanent posts for the ridge had scarcely been occupied on the 8th June when the enemy, rallied with such reinforcements as the garrison could supply, attacked the position on its whole length, but were immediately driven back on the picquets being reinforced. The most notable point in connection with this attack was the vigorous support it received from the fire of the heavy guns on the Moree and Cashmere Bastions, and the first engineer operations resolved on were directed against the former of these works.

It was determined by the Chief Engineer, in communication with the brigadier commanding the Artillery, to commence on the night of the 8th—9th June two batteries in the neighbourhood of Hindoo Rao's house for two guns each. These were designated Salkeld's and Wilson's Batteries. The armament of each was an 18-pounder and an 8-in. howitzer, and it was supposed that the fire of these four pieces would suffice to subdue, if not to silence, the guns on the Moree and Cashmere Bastions. The range to the Moree Bastion was about 1,500 yards; to the Cashmere Bastion 2,100 yards, and to the Martello Tower, between these two main works, from which occasional support was given to them, about 1,830 yards. Several casualties occurred from round shot. The enemy again attacked on the right flank in great force, but were beaten back with heavy loss.

By the morning of the 9th June Salkeld's Battery was completed, armed, and opened fire on the Moree Bastion, and by noon of the same day Wilson's Battery was also completed, its howitzer being directed on the Cashmere Bastion, and its 18-pounder on the Martello Tower, where the enemy had placed a gun *en barbette*.

Heavy fire continued uninterruptedly on both sides, and it very soon became apparent that the enemy held a decided superiority. The fire of the four guns in Salkeld's and Wilson's Batteries produced no apparent effect on any of the enemy's works ; casualties became serious, and it was clear that if any result was to be produced it was essential that the strength of the batteries on the ridge must be increased. Accordingly, Maunsell's mortar battery* (two mortars) was commenced, and an additional gun portion was added to Salkeld's, Wilson's, and Maunsell's Batteries respectively. While these works were in progress the enemy attacked the right of the position with great vigour, but was repulsed, and on the 11th the whole of the guns, aided by the mortars, opened fire.

The effect of the increased fire from the ridge batteries was so far satisfactory that the enemy's fire was somewhat subdued, but the general result was not encouraging. The enemy still maintained a most effective fire action, and having a vast reserve store of heavy guns, he was more reckless in his method of firing, and took much more out of his guns than the British could venture to do with their scanty supply of pieces of large calibre, the disabling of even one of which was a great misfortune. Hence no real progress had been made.

On the morning of the 12th another resolute attack on the whole position was made by the enemy. It was carried out with unusual determination, and had partial success, a picquet at the Flagstaff post having been cut off, and the two guns there being nearly captured. Ultimately, however, the enemy was driven back at all points with loss. The weakness of the left centre of the position was, however, made so apparent by the partial success of the enemy's first attack that means of strengthening it were essential. Between the ridge and the river in front of the part of the position now under notice lies a low, flat piece of ground traversed by the main road from the cantonment to the city, and on the eastward of this road is Metcalfe's house, a large building which had been sacked and partially destroyed during the outbreak on the 11th and 12th May ; about 200 yards to the right of the house there was a substantial masonry building formerly used as a cow-house, while about 400 yards further in advance, or nearer to the place, there was at that time, a large roomy row of stables. The stables and cow-house were occupied on the evening of the 12th June by strong infantry

* Named after Capt. Maunsell, afterwards General Sir Frederick Maunsell, K.C.B., R.E.

picquets, supported by a troop of cavalry at first, and afterwards by some field guns stationed on a high artificial mound, probably an old brick kiln, near the dwelling house. Considerable variations in details for the tenure of this advanced position subsequently occurred, but throughout the whole of the preliminary operations the stable and cow-house picquets were regularly maintained and proved of great value in protecting the left and left centre of the main line of picquets on the ridge. The distance of the stable picquet from the Water Bastion was about 1,300 yards, and from the centre of the British camp about 2,830 yards, or rather more than $1\frac{1}{2}$ miles.

On the night of the 11th—12th June a new mortar battery, called Perkins' Battery, named after Lieut. Perkins (afterwards General Sir Æneas Perkins, K.C.B., R.E.), was commenced, and during the action of the 12th a working party of 60 Sappers, under Lieut. Geneste,* employed at the time on the batteries, made a very gallant attack on a large body of the enemy, beat them back from the position, and killed a considerable number of them. The casualties among the sappers were three men wounded.

On the 13th the new mortar battery, having been armed during the previous night with two guns, opened fire. The enemy was found to have erected substantial earthen works on the Cashmere and Moree Bastions for the protection of the guns placed there *en barbette*, and the firing during the day was not vigorous. An attack was, however, again made on the right of our position, but was repulsed without difficulty, although supported by a very heavy fire from the whole of the batteries of the place. In the course of this attack the enemy made one very dangerous movement of advancing from Kissengunge with field guns up to the crest of the ridge on the extreme right, and from thence enfilading the entire line of the British batteries. The movement, however, was not persisted in, but it was plain that the enemy had observed a very weak point in the position, and was likely to renew his attempt upon it.

On the night of the 15th—16th June a trench of communication was made between Salkeld's and Wilson's Batteries, revetted inside with stones; the soil being very rocky, the work was one of great difficulty, and proceeded slowly. The enemy was very quiet all night and day, and no attack was made on the position.

It was observed, on the 17th, that the enemy had commenced work on a battery in the suburbs of Pahareepore, and although the mortar practice from the batteries on the ridge was excellent, progress was not stopped. It being of the greatest importance that no permanent lodgment should be permitted on a site where guns

* Lieut. Geneste died very soon after the siege from the result of the exposure he had undergone.

would take all the ridge batteries in reverse with disastrous effect, Sir Henry Barnard determined on an attack in order to clear the suburb. This duty was effected with characteristic brilliancy by Major Charles Reid* and Major Henry Tombs† with the small columns under their respective commands, supported by four guns. The enemy's battery was captured and entirely destroyed, some loss was inflicted, and the only gun he had brought out from the place was taken.

The great danger of leaving the extreme right of the position unprovided with permanent means of defence now became apparent, and accordingly, on the night of the 17th, a new 3-gun battery, called Johnson's Battery, was traced out on the rocky plateau, about 300 yards to the right of Hindoo Rao's house. Not a spadeful of earth was locally available for the construction of the battery, the soil being bare rock. Material had, therefore, to be brought from the low ground in rear of the ridge, and the progress of the work was accordingly slow. In the morning the enemy kept up such a constant hot fire, that during the remainder of the day progress was virtually suspended. On the night of the 18th—19th it was resumed as vigorously as circumstances permitted, and by the morning of the 19th the parapet of the battery and epaulments was raised to a height of 5 ft. on the left and 6 ft. on the right. The rocky terreplein was raised by aid of the jumper; and platform space for two guns secured. But more could not be done by daylight as the enemy's fire was incessant and heavy, causing some casualties among the working parties. By incessant labour on the part of the sappers and pioneers employed, the battery was at last completed, and mounted with three guns by the 22nd June. But while this work was in progress on the extreme right front of the position, movements of most critical importance were taking place on the right flank and rear. The garrison having been powerfully reinforced about this time by the junction of the Nusseerabad Brigade, a general attack on the British position seems to have been resolved on.

The various outlook posts reported on the afternoon of the 19th that masses of infantry, supported by artillery and cavalry, were steadily defiling through the Lahore and Ajmeer Gates, and gradually extending through all the strong ground in front and on the right flank of the position. About an hour before sunset the high ground immediately in rear of the camp was seen to be occupied by a powerful detachment of the enemy, strongly posted in the gardens and among the ruined walls thickly strewed over the neighbourhood. The crisis was very grave, for the enemy immediately attacked the camp from this position, directing a vigorous fire of artillery upon

* Afterwards General Sir Charles Reid, G.C.B.

† Afterwards Lieut.-General Sir Henry Tombs, K.C.B.

it, while so general was the threatening aspect of affairs on the front and flanks that only a very feeble fire could be spared to meet this most dangerous movement.

The cavalry and field artillery, however, under Brigadier Hope Grant, after a severe engagement, checked the advance of the enemy for that night, and on the morning of the 20th he was found to have retired from the ground. His retirement was, however, merely momentary, and the position being reoccupied almost before the troops reached camp, it was necessary to repeat the attack. A vigorous fight ensued, ending in the complete rout of the enemy, but with heavy loss in officers and men to the column engaged, which had about one-third of its number killed or wounded out of 600 strong of all arms. The result was, however, so far decisive that no attempt was again made by the enemy to operate on the camp itself from the rear, and the construction of a strong breast-work and battery for two 24-pounders added still further to the security of this part of the position. During the fighting, on the 19th Major Yule, of the 9th Lancers, was killed; Daly (afterwards General Sir Henry Daly, G.C.B.), of the Guides, and Becher (afterwards General Sir Arthur Becher, G.C.B.), Quartermaster-General, were wounded.

On the night of the 23rd a working party, under Capt. Maunsell, accompanied by Lieut. Jones,* of the Engineers, destroyed the only other bridges across the drain in the immediate vicinity of Delhi. Both bridges were completely demolished, and, as it instantly appeared, with excellent results, as the engineer detachment had scarcely left the ground when a strong party of the enemy, with artillery, occupied it in preparation for a general attack on the British position. On the 24th it was found impossible for him, however, to transport his guns across the broad, deep, and rapid stream which had unexpectedly interposed, and it followed that during the vigorous assault of the 24th that the rear of the camp was not threatened as before. The whole of the right of the position was, however, enveloped by the enemy's attack on that day. The suburb of Subsee-Mundee was occupied by him in force, and held with much tenacity. Johnson's Battery was attacked, and from Pahareepore the works near Hindoo Rao's house were taken in flank by a battery of field guns, and some loss inflicted on the troops occupying them.

But the result of the fight was, as it had ever been, the defeat of the enemy at all points, heavy loss being inflicted on him while he retired sullenly into the city. Subsee-Mundee was subsequently held in strength by a regiment of Europeans; a large serai, or travellers' resting place, and a Hindoo temple being prepared for occupation by the troops, and fortified as efficiently as means would

* Killed during the siege.

permit. Considerable clearances of old ruins and jungle were effected in the vicinity of this post, and its maintenance in support of the advanced battery on the ridge was found to be of much use.

In the many attacks of the enemy on the position, the detachments of artillery with the light guns at Hindoo Rao's house suffered seriously, and cover was accordingly provided for them in a new battery marked " Champain's." * This work was rather of the nature of a breastwork than a regular field battery, the object being to cover the men as much as possible without excessively restricting the sweep of the guns. A similar covering breastwork was provided for the guns at the Mosque, with great labour and difficulty, however, owing to the scarcity of materials. Reports having been received of the intentions of the commander of the garrison to convert the dry ditch of the fort into a wet one by turning into it the waters of the West Jumna Canal, it was determined to cut off the supply at the ancient aqueduct before mentioned. This was done in the first instance by a party of sappers, under Lieut. Champain, who cut through the bank of the canal above the aqueduct, and this turned the whole stream into the Nujufgurh Jheel Drain. Subsequently the partial demolition of the aqueduct was effected by powder, and the passage of the canal permanently interrupted. From the 28th June, accordingly, no water entered the city through the canal channel, but no practical inconvenience was thereby caused to the garrison, as they had complete command of the river Jumna. The fact is noteworthy, as very erroneous conceptions on this, as on many other points, prevailed in England at the time and since.

On the 28th June the Engineer Brigade was strengthened by the arrival of Capt. Alexander Taylor (afterwards General Sir Alexander Taylor, G.C.B., and W. W. Greathed (afterwards Major-General and C.B.), who had up to that time been acting as extra Aide-de-Camp to the Major-General commanding. Capt. Taylor relieved Major Laughton on the 29th.

During the first three weeks of the siege the Delhi Field Force was engaged in repelling the enemy's sorties. There were usually three or four sorties in each week, and some of these were on a very large scale. Large bodies of the rebels (cavalry, artillery, and infantry) could be seen issuing from the Lahore Gate. The general plan of the sorties was to turn our right flank by a large force, and to penetrate into our camp, while smaller numbers advanced under cover of the rocks and bushes for a direct attack on the ridge. In crossing the road leading from the Lahore Gate to the Subsee-Mundee the cavalry and artillery came under the view of our right battery, which poured a heavy fire into the enemy's troops. Those that

* Named after Lieut. Champain, Bengal Engineers (afterwards Colonel Sir John Champain, K.C.M.G., who died in 1887).

escaped this ordeal apparently swerved to their left, and returned in a disorganized state by the Kabul Gate or by some of the other gates. The repelling of these sorties sometimes occupied several hours. The enemy also made night attacks on our position, and a continual roll of musketry would be kept up for hours. There was a small post among the rocks on the right hand of this position called the Sammy House, and the corpses of the mutineers after one of these attacks were piled in heaps, there being no men available to bury them. How great was the disparity of numbers may be conjectured from the fact that on our arrival on the Delhi Ridge on the 8th June, the Delhi Field Force did not muster more than 3,800 men, and on the day of assault, on the 14th September, were only about 14,000. The number of revolted Sepoys and men in the city varied during the siege from 12,000 to 35,000, in addition to the armed inhabitants. Scarcely a house in the old cantonment was left untouched by the rebels. At this time about 20 native regiments of the Bengal Native Army had mutinied, and accounts were received daily of the mutiny of some regiment.

On the 18th June the rebels were reinforced by the brigade from Nusseerabad, which had joined the mutiny, bringing six guns with them. To celebrate the event, they came out in force, and made an attack on our rear. The contest was most desperate, and the loss on both sides was great. Major Yule, of the 9th Lancers, was killed; Daly of the Guides, and Becher the Quartermaster-General, were wounded.

The Commissioner of Delhi, Sir Theophilus Metcalfe, was in camp at this time. His house, as before mentioned, which had been completely gutted by the rebels, was occupied by our picquets. The mutineers used our bugle calls, and frequently came out to fight wearing their red coats. The buttons on the uniforms of the corpses bore the numbers of the regiments that had mutinied. The work of the artillery in the batteries at this time was most arduous. The most dangerous part was getting into the batteries, as the enemy had constructed a battery on the right of our position, at a place called the Eed Gurh, from which their shot enfiladed the ridge, the shot and shell crashing along the ridge, and striking down anyone who happened to be exposed. One shot fired from this battery entered the doorway of Hindoo Rao's house and killed an officer, Lieut. Wheatley, and eight men of the 2nd Goorkha Regiment, and wounded seven men. After this a large earthen traverse was thrown up in front of the doorway, which prevented the shot from entering the building. The Goorkha Regiment (Sirmoor Battalion) made use of the upper storey of Hindoo Rao's house as a hospital.

At this time news was received of the revolt of the whole of the Province of Oudh and of the Gwalior contingent. The enemy received reinforcements almost daily. The strains of the bands of the mutineer regiments could be heard as they marched into the city across the bridge of boats. They played "Cheer, boys, cheer," and other English tunes. However, we also received some welcome reinforcements. A battalion of the 8th King's, a detachment of the 61st Regiment, and two regiments of Sikhs marched into camp at this period.

Lieut.-Colonel Baird Smith took command of the Engineer Brigade on the 3rd July, having travelled about 75 miles the previous day by such aid as he was able to procure, in the hope of being present at an assault of the place planned for the morning of the 3rd. On reaching camp, however, at about 2 a.m., the Chief Engineer learnt that the project, like others of the same kind previously entertained, had been abandoned. He also learnt that the enemy was threatening in force the road from Badle-ka-Serai. On the same day, a strong column, under Major Coke (afterwards Major-General Sir John Coke, K.C.B.), was directed to proceed to Alipore, a point on the line of communication with the Punjab, where the enemy had established himself, having turned the position of the English force by a movement past its right flank on the 3rd of July. Happily, however, he withdrew, abandoning the advantages of his position, after inflicting some loss on the Commissariat post at Alipore.

After carefully inspecting the ground, and becoming acquainted with the details of the position occupied by the force, its capabilities, resources, and future prospects, the Chief Engineer arrived at the following conclusions :—As regarded the plan of defence adopted by the enemy, it was quite clear that two leading ideas pervaded it ; first, to drive Sir Henry Barnard from his advanced position on the heights by incessant attacks on the position itself ; and secondly, to force him to abandon that position by operations on his line of communications with the Punjab.

Of these two ideas, the enemy held the first with perfect clearness, and acted on it with an unswerving tenacity of purpose, which repeated defeats could scarcely shake. The second was neither apprehended distinctly, appreciated properly, or acted on vigorously by him. It is scarcely necessary to add that this want of discrimination influenced most gravely the fortune of the siege.

The garrison by the beginning of July must have consisted of not less than from 15,000 to 18,000 trained soldiers, and irregulars in even larger numbers. The besieging force numbered of all arms under 5,500 fighting men, Europeans and natives. An enterprising enemy might, therefore, with perfect ease, have maintained one or more strong movable columns, operating constantly on the communication, stopping convoys, harassing small detachments, disturbing the whole tract of country whence supplies were obtained, and finally, in all human probability, compelling the General to raise the siege from the impossibility of procuring subsistence for his army in a position so utterly insecure. Instead, however, of obstinate and continuous operations of this class, the enemy was satisfied to make feeble efforts, never sustained for any considerable time, and easily warded off by corresponding movements of columns detached from the force. It was necessary, however, at the time now under notice, to take precautions against both forms of attack. The vast numerical superiority of the enemy converted the position of Sir Henry Barnard's force from the very first into that of a besieged, instead of a besieging, army.

Commencing on the 8th June, the attacks by the garrison on all points of the ground held outside the walls were incessant. The casualties of the force day by day were most serious. Many of its bravest and best officers had been killed or severely wounded; the daily average of casualties among the soldiers averaged from 30 to 40, and on occasions of vigorous combats the loss rose from 100 to 150. It was scarcely possible to resist the conviction that the army was steadily and surely being used up by the ordinary process of the siege, and it seemed as though a simple calculation would show that at such a rate of waste of life the status of a force numerically so feeble could not be sustained for long. To shorten the siege, or limit the waste of life, were the urgent necessities of the position. The former could be effected only in one of two ways, the first by regular operations against the place, or second by an assault *de vive force*. The insufficiency of artillery and engineer *matériel* for even the most limited formal operation made the first plan wholly impracticable. An official return supplied to the Chief Engineer on the 4th July showed that in the Artillery Park the entire ordnance supplies of the force were:—

Round shot, 24-pounders	150
,, ,, 18-pounders	628
Shells, common, 8-in.	2,016
,, spherical, 8-in.	192
,, common, 24-pounders	240
,, spherical, 24-pounders	43
,, $5\frac{1}{2}$-in., 24-pounders	3,200

These details tell their own tale, and require no emphasis.

The whole supply of ordnance powder for 17 siege pieces in position was no more than 11,600 lbs., barely sufficient for one day's active firing, and even the musketry powder had sunk to 12,900 lbs. The Engineer Park was quite as insufficiently supplied for even the briefest formal operations. It is questionable whether batteries could have been maintained, even if their first construction had been practicable, as revetting materials were in extremely small numbers. Hence there was no hesitation whatever in abandoning all idea of operations of this class.

The second course, viz., an assault *de vive force*, was plainly a most desperate expedient in the actual condition of the force at the moment. It could only have been justified by assurances of the highest authority that the critical emergency of political circumstances had been such that all risks must be run to achieve a success.

The possibilities of success were sufficient to have warranted the General in making an attack even so desperate as that on Delhi would have been. The Chief Engineer came to this conclusion at the time, and adhered to it until circumstances to be explained hereafter had completely changed.

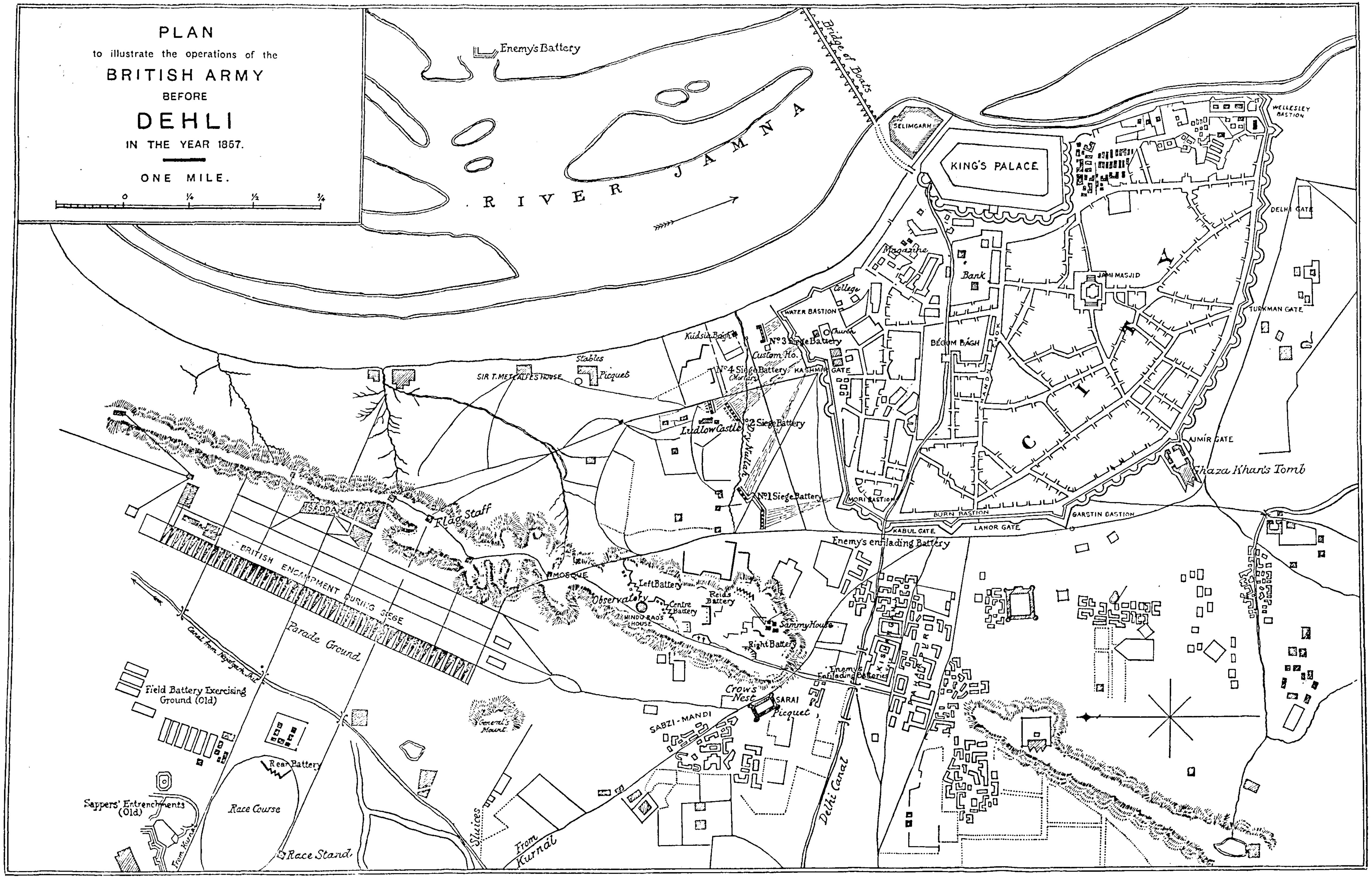
Assuming, however, that an assault involving such undeniable risks might be deferred, systematic provision for reducing the waste of life on the ridge was of the most urgent necessity, and though the means were small, both in men and material, it was absolutely necessary that they should be used and multiplied if the position were to be maintained for even a day.

On the morning of the 5th July, Sir Henry Barnard received the Chief Engineer at a confidential interview, which lasted about three hours.

The General in command explained to the Chief Engineer in most unreserved terms his views of the position of the force, and at first, especially, was evidently and most justly impressed with the deepest anxiety for its safety, and felt acutely the heavy weight of personal responsibility that must attach to his decisions. The general conclusions to which the Chief Engineer had come, as briefly detailed above, were duly submitted to the General, and were fully discussed. Reserving his final decision, however, at the moment, he appointed a second meeting at noon of the same day, when he expected to be prepared to give definite orders.

There were no external signs of fatal sickness at that time apparent about Sir H. Barnard. A worn and anxious expression of face, with a certain heaviness and dimness of eye, not at all natural to him, were the only signs of suffering that attracted the Chief Engineer's notice. And even these passed away as the discussion advanced, till the general cheerfulness of bearing under all difficulties, which did so much to win for him the warm affection of the whole force he commanded, resumed its usual glow, and the Chief Engineer left Sir Henry Barnard at the close of the interview as resolute for the present, and as hopeful for the future as ever. Scarcely an hour or two passed before the General was stricken with an attack of cholera, and on the Chief Engineer's return to headquarters at about 11 a.m. he was met by the medical attendants with the assurance that Sir Henry could now see no one, and that the worst was to be feared as to the issue of the disease. The anticipation was realized the same afternoon, and it was with the truest sorrow that the army learnt of the loss it had sustained in the premature death of a chief admired by all for his undaunted courage, his unwearying activity, his single-hearted devotion to duty, and beloved by all for his thoughtful care, courteous bearing, generous appreciation of the efforts of his officers and men, and the general spirit he diffused around him. No one can make the conduct of Sir Henry Barnard during that terrible month of June, 1857, a careful study without feeling that few soldiers have ever faced sterner perils with a stouter heart, and none have surpassed him in devotion to the Crown, or in the resolute discharge of duty under physical and moral conditions, so exhausting that life sunk beneath their pressure. On the death of Sir Henry Barnard, Major-General Reed, C.B., assumed the command of the Delhi Field Force.

(*To be continued*).


PLAN
to illustrate the operations of the
BRITISH ARMY
BEFORE
DEHLI
IN THE YEAR 1857.
ONE MILE.
0
¼
½
¾
Enemy's Battery
Bridge of Boats
RIVER JAMNA
SELIMGARH
KING'S PALACE
WELLESLEY BASTION
DELHI GATE
Magazine
College
Bank
JAMI MASJID
WATER BASTION
Church
BEGUM BAGH
TURKMAN GATE
CITY
Kudsia Bagh
No. 3 Siege Battery
Custom Ho.
No. 4 Siege Battery
KASHMIR GATE
SIR T. METCALFE'S HOUSE
Stables
Picquets
Ludlow Castle
No. 2 Siege Battery
No. 1 Siege Battery
MORI BASTION
BURN BASTION
AJMIR GATE
Ghaza Khan's Tomb
KABUL GATE
LAHOR GATE
GARSTIN BASTION
Enemy's enfilading Battery
Flag Staff
MOSQUE
BRITISH ENCAMPMENT DURING SIEGE
Left Battery
Observatory
Centre Battery
Reid's Battery
HINDU RAO'S HOUSE
Sammy House
Right Battery
Parade Ground
Canal from Najafgarh Jhil
Field Battery Exercising Ground (Old)
Crow's Nest
SARAI
Picquet
SABZI-MANDI
Enemy Enfilading Batteries
KISHANPUR
General's Mount
Rear Battery
Race Course
Race Stand
Sappers' Entrenchments (Old)
From Kurnal
Sluices
Delhi Canal

THE ABOR EXPEDITION SURVEY DETACHMENT, 1911–12, *AND OF THE ABOR EXPLORATION SURVEY DETACHMENT,* 1912–13.

By CAPT. O. H. B. TRENCHARD, R.E.

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SURVEY operations extending over two seasons, were carried out in the basin of the Dihāng River by a detachment with the Abor Expeditionary Force in 1911–12 and by a detachment with the Abor Exploration Party in 1912–13. This report deals with the operations of both detachments.

Dihāng is the commonly accepted name of that portion of the Tsan-po River on the Indian side of the main range of the Assam Himālayas, *i.e.*, from the eastern end of the gorge through the range to its junction in the plains of Upper Assam with the Dibāng and Luhit Rivers; these three rivers forming the Brahmaputra.

Strictly speaking the river is only known locally as the Dihāng by the Mīris who inhabit small villages on its banks near the confluence of the three rivers; throughout the whole of its course in Abor country it is almost invariably known as the Siang; while in Pemakoi-chen the inhabitants use the Tibetan name of Tsan (Po or Chu = river).

It may be noted that all the local names by which this river is known are merely adjectival; translated into English they all mean " The Big River."

To avoid confusion the name Tsan-po will only be used in this report to denote the river in Tibet proper; the name Dihāng will be used to denote the whole of the remaining portion of the river on the Indian side of the main Himālayan Range.

After the Tsan-po leaves Tibet, by cutting its way through the Himālayas from west to east, about longitude 95°, in a gorge by what must be from all accounts of considerable length and so utterly precipitous as to make it impossible for any man or animal to traverse it, it enters the country of Pemakoi-chen, through which it flows roughly speaking in a south-westerly direction. Pemakoi-chen may be described shortly as the portion of the valley of the Dihāng between latitude 29° (south of which it is bordered by the Abor country) and latitude 30° (north of which the country of Pomed is situated). The valley is a narrow one, of an average width of

30–40 miles, being bounded on the right bank of the river by the well-defined main Himālayan Range and on the left bank by the equally well defined and regular watershed between the Dihāng and Dibāng Rivers.

The northern limits of Pemakoi-chen are at present somewhat vague; our knowledge of them is confined to the information collected by the Political Officer in charge of the Abor Exploration Party from the inhabitants of the Southern Pemakoiba villages which were visited by the party in 1912–13. The surveys now being executed in this area by Capt. Morshead, R.E., should however define the boundary between Pemakoi-chen and Pomed.

The only important tributary received by the Dihāng in its course through Pemakoi-chen appears to be the Chimdru Chu, draining a considerable side valley of the same name, which joins the left bank of the Dihāng just north of the village of Khapu in latitude 29° 30′. Several large mountain torrents drain the eastern slopes of the main range and join the right bank of the Dihāng during its course through Pemakoi-chen, but none of them are large enough to be termed tributary rivers. The largest of them is the Sirapateng (Sigong) River which forms the southern boundary of Pemakoi-chen (as claimed by the Pemakoibas, although there are three Abor villages north of this river) on the right bank. A slightly larger stream called the Yang Sang Chu forms the boundary between Pemakoi-chen and Abor country on the left bank of the Dihāng, which it joins about 10 miles north-east of the Sirapateng Confluence.

South and west of these two boundary rivers the whole basin of the Dihāng is inhabited by the various tribes commonly called Abor.

From the Sirapateng Confluence the Dihāng flows nearly south-east to latitude 28° 30′; thence in a more southerly direction to the Siom Confluence about latitude 28° 15′, whence it again trends east and south-east until it debouches at Pasighat (latitude 28° 4′) from the Abor Hills into the plains on the north bank of the Brahmaputra River.

After leaving Pemakoi-chen the basin of the Dihāng widens out considerably, two large valleys of the Siom and Yamne being situated on either side of the main valley. Both these important tributaries join the Dihāng before it debouches into the plains. The Siom is by far the larger of the two; rising in the main range of the Himālayas in latitude 29° it flows to the west of and roughly parallel to the Dihāng as far south as latitude 28° 12′ whence it turns east for about 20 miles before joining the Dihāng near the village of Yekshing.

The Yamne is a considerable river which rises in the small range (jutting out west about latitude 28° 45′ from the main Dihāng-Dibāng Watershed) that forms the divide between the valley of the Yang Sang Chu and the valley of the Yamne.

It flows to the east of the Dihāng, to which it is for the most part roughly parallel, and joins it below the trade post of Rotung in about latitude 28° 10′.

The Dihāng Basin is thus bounded on the west by the well-defined watershed between the valley of the Siom and that of the Subansirī River to the west; on the east it is bounded by the range which divides Pemakoi-chen and the Yamne Valley from the basin of the Dibāng River to its east.

The range which forms the Dihāng-Subansirī Watershed takes off from the main Himālayan Range in latitude 28° 50′ and longitude 94° 0′, the junction being marked by a clump of three snow peaks all over 16,500 ft. in height, and runs in a south-easterly direction down to about latitude 28° 0′ where it merges into the outer range.

The range which forms the Dihāng-Dibāng Watershed has not been surveyed yet north of latitude 29° 30′; it is not certain therefore whether it actually joins the main Himālayan Range. Between latitudes 29° and 29° 30′ the direction of this range is from south-west to north-east; south of latitude 29° it runs almost due south down to latitude 28° 15′ where it also merges into the outer range.

This outer range is a remarkable feature which runs for many miles parallel to the north bank of the Brahmaputra and at a distance of 20–40 miles from it. It averages between 3,000 to 6,000 ft. in height, and slopes very steeply to the plains of the Brahmaputra. Forming the southern boundary of the Dihāng River basin proper, it completely shuts off all view of this basin from the Brahmaputra Valley. The Dihāng has cut its way through this range at Pasighat before issuing into the plains of the Brahmaputra.

The main range of the Assam Himālayas forms the northern boundary of the Dihāng Basin from longitude 94° on the west to the big gorge in longitude 95°. North and east of the gorge the direction of the range has not yet been defined, and very little is known about the valley of the Po Tsang Chu which drains Potodh, Pomed and Poyul and which constitutes the extreme north-eastern portion of the Dihāng Basin.

Pemakoi-chen is inhabited by a race of people very similar to their neighbours in Tibet proper on the other side of the main range.

They are undoubtedly emigrants from Tibet, but appear to have been settled in the Dihāng Valley for a considerable time, as I understand their language is a very distinct variation of Tibetan spoken in the Kongbu District of Tibet.

Pemakoi-chen appears to be a separate district of the Po country, to the headman of which, called the Po Khanem living at Shawa in Pomed, taxes are remitted by officials who are appointed by him and reside in Pemakoi-chen for the purpose. It is doubtful whether the Po Khanem is a Tibetan official or not; I understand that all the latest evidence points to the fact of the Po country being entirely independent of Tibet.

Pemakoi-chen is certainly not connected officially with the neighbouring Kongbu district of Tibet in any way, although a good deal of trade passes between the two districts over the Himālayas and the Pemakoibas seem to understand and talk the Kongbu dialect well.

The Pemakoibas are sturdy, well-built people and much cleaner than either the Tibetans or the Abors, between whom they act as middlemen in the matter of trade. They have attained (or perhaps not yet lost) a fair degree of civilization, and utterly despise the Abors whom they call Lobas. The Abors call them Menbas (the Abor name for a pure Tibetan being Mimat).

The Pemakoibas dress in Tibetan fashion modified for the heat of the Dihāng Valley, and their religion is the same as that of Tibet. As a rule the Gom-pa (place of worship) is the only masonry building in each village ; the houses being built of boards with well-made shingle roofs and raised off the ground on timber posts or masonry pillars. All the carpentering shows a considerable degree of skill.

The Dihāng Valley does not lend itself to easy cultivation, but the Pemakoibas terrace and irrigate their rice fields wherever possible, and even their jhūmed fields on steep hillsides are properly ploughed and all the paddy transplanted dry. They are open, cheerful and friendly people ; but could probably put up as good a fight as the Tibetans if necessary, being armed with bows and arrows, the long straight sword, and a certain number of matchlocks and ancient pistols.

Tibetan coinage is current in Pemakoi-chen and seems a fairly well-understood medium of exchange. No difficulty was therefore experienced in persuading the Pemakoibas to accept Indian rupees, at the rate of three of their own *tankas* to a rupee. Eight and four-anna pieces did not seem as popular as the rupee, but were accepted. Assamese silk cloths are the most popular articles of gift.

The Abors are very dissimilar from their northern neighbours, although presumably of the same Mongoloid extraction. The irruption of their ancestors from the highlands of Tibet into the Dihāng Valley must have taken place several centuries before that of the Pemakoibas, and in the meantime they have certainly lost all traces of any slight civilization they may have possessed originally.

The chief reason for their present state of savagery appears to be the peculiar political (if such a term can be used) organization which prevails all over the Abor country. The only political unit is the village ; there is no real tribal organization, although the country is divided into several more or less defined sections which, for lack of a better definition, might be termed tribal areas.

In some of these tribal areas there is one dominating village which by its wealth or numbers of fighting men can impose its orders on the other villages of the same tribal area, but in other areas there are two or more big villages of equal importance which seem far more disposed to quarrel with each other than to combine against the villages of another tribal area. In fact the only features which appear to distinguish the various tribal areas as such, are the separate dialects of each and the intermarriage in the different sects of all the villages in each area.

The more important tribal areas may be roughly defined as follows :—

(1). The Simongs, so called by the name of the most important village of the group, occupy the left bank of the Dihāng from the Yang Sang Chu (Pemakoi-chen boundary) in the north down to about latitude 28° 30′ and stretch over into the north-west corner of the Yamne Valley. This is perhaps the most important group, though not the largest numerically, in the whole Abor country.

(2). South of the Simongs, on the left bank of the Dihāng and stretching across the Dihāng-Yamne Divide into the Yamne Valley, are the Pangis, a small tribe which seems closely allied to the Simongs and undoubtedly has to take orders from the head village of Simong.

(3). On the right bank of the Dihāng, immediately south of Pemakoi-chen, is a group of seven villages, the two most important of which are Janbo and Bomo, the most southerly. This group does not appear to have a tribal name.

(4). South of Bomo on the right bank of the Dihāng are the Karkos, a small group of four villages, of which Karko is the most important.

(5). South of the Karkos are the Minyongs, who inhabit a small portion of the Siom Valley, a few villages on the left bank of the Dihāng south and west of the Pangis, all the right bank of the Dihāng (including the Shimang Valley) south of latitude 28° 30′ right over the outer range into the foothills just above the north bank of the Brahmaputra.

This Minyong tribe is the largest numerically, but there are a number of large and powerful villages in it which do not pull together. Of these *Riga* is the largest village and *Dosing* (at the mouth of the Shimang Valley) the most powerful.

(6). The Yamne Valley is mainly inhabited by Padams, who also thrust a wedge into the Dihāng Valley between the Simongs and Pangis and stretch across the outer range into the foothills between the Dihāng and Sesseri Rivers. This is a large tribe and the head village of Damro is the largest in the whole Abor country.

(7). The Boris occupy the head-waters of the Siom Valley down to about latitude 28° 36′. As all the Bori villages have not yet been visited it is impossible to say which is the most important.

(8). The remainder of the Siom Valley and the valley of the Simen River, the only river of any size on the south of the outer range between the Dihāng and Subansirī Rivers, are occupied by a number of cognate subdivisions which in the bulk are known as Galongs. The largest village in this area is Kombong, in the south-east corner of the Siom Valley.

In all these areas each village is entirely self-contained and independent except in so far as it has to take orders from some neighbouring and more powerful village. As the only method of cultivation known to the Abors is by jhūming, it follows that each village requires a large area of land to enable it to exist ; hence the villages are all at a considerable distance from one another, and there seems to be little communication between the villages. A *jhūm* (not an Abor word, but one commonly used all over Assam) is a clearing in the forest used for cultivation. As the only iron instrument the Abor possesses is a dao, this forest clearing is a matter of infinite labour.

The crops raised are rice, maize, and millet ; the last principally for brewing apong, a mild and unpleasant intoxicant of which the Abors drink inordinate quantities.

Not more than two or three crops can be raised in successive years from the same soil, as the principle of manuring is unknown ; so patches of forest have to be cleared in rotation, trees and jungle being allowed to grow on each clearing again after it passes out of cultivation until its turn comes round again.

Industry in all matters agricultural seems to be the Abor's one redeeming feature. In other respects he possesses all the usual traits and vices of the savage. His fighting qualities are not very conspicuous, but his intense hatred and suspiciousness of strangers combined with a full measure of treachery will make it unsafe to neglect military precautions when travelling through the Abor country until it has been brought under proper political control.

The village has already been mentioned as the sole political unit of the Abor country. A village may have one or more Gams (headmen), but these dignitaries do not seem to have any real power other than that they may acquire by wealth, force of character, or a large following of fighting men in the village. An Abor village is one of the most democratic institutions in the world, and exhibits all the effects of unrestrained democracy. Every matter, however trifling, is referred to the Kebang (village council) which all men and most boys seem at liberty to attend and at which they all talk at length. If the Gam or Gams be strong enough they can sway the Kebang; otherwise they are merely the mouthpieces of the temporary majority in the Kebang.

This system of self-government does not tend to simplify the dealings of outsiders with the Abors.

These are further complicated by an extraordinary system of octroi which prevails, under which every village takes its toll of all the merchandise which passes through its territory. Trade does not prosper under these conditions, and is limited to the bare necessities such as iron, cloth, and salt.

The natural hatred of a foreigner imbued in every Abor is not lessened by the feeling that he can only be coming into the country to deprive the Abor of his middleman's profits.

The Abor does not possess nor does he understand a coinage; all trade is by barter. Now that a British trade post has been opened in the lower part of the country the value of money may gradually come to be understood; for many years however its acceptance can only be guaranteed by a sufficient backing of military force.

Salt, red blankets, cloths (ordinary and silk), buttons, needles, cheap ornaments, knives, pipes, etc., are all useful and appreciated by the Abor as gifts or in payment for labour and the few commodities he is able or willing to dispose of. It may be noted however that the Abor dislikes nothing so intensely as cooly work even for liberal payment. It is very difficult to persuade an Abor village to provide transport; even if one can get it at all only the women and children will turn out as a rule.

Opium is at present practically unknown, but the habit will soon be introduced no doubt when intercommunication between the hills and plains is an established fact. Rum is useful for entering into relations with an Abor village.

Abors wear little clothing, the male dress sometimes consists of a loin cloth and a loose cloth or woollen coat is worn in the cold weather. The women all wear a curious girdle of metal discs, called a *boyop*, from babyhood until the first child is born; their clothing consists of a short petticoat and a shoulder wrap. The women do most of the field work and are excellent carriers.

In assuming his war dress the Abor adds a rain coat (made of sago palm) to his scanty attire; and his equipment consists of bow and arrows, long Tibetan sword, dao, cane helmet and a large ruksack woven out of bamboo shavings.

The Dihāng Basin is for the most part extremely mountainous; Dihāng itself and all its tributaries running in deep, narrow, and most tortuous gorges which the rivers have cut in the course of ages. Wherever by some change in the geological formation the valleys widen out bold precipitous spurs run down steeply from the crest of the ranges bordering each valley to river level. The only comparatively flat and level spot in the whole basin is contained in about 20 square miles of plateau in the south-east corner of the Siom Valley on which Kombong Village is situated.

An excessive rainfall causes the whole of this precipitous mountain region to be covered with dense forest and semi-tropical vegetation right up to permanent snow level, which is estimated to be about 14,000 ft. Large trees of many varieties, but all excessively difficult to cut, flourish on steep slopes (which only the Serow can traverse) right up to 10,000 ft., interlaced with all kinds of impenetrable undergrowth, among which the rhododendron, small bamboo and ringalls growing in thick clumps, and prickly cane seem to preponderate.

A kind of cypress covers the hillsides and tops in the Abor country above 10,000 ft. ; in the higher latitudes of Pemakoi-chen this tree is to be found as low as 6,000 ft. The pine is only met with in the Tsan-po Valley where it flourishes exceedingly.

A feature of the country is the width and roundness of most of the actual hilltops. Seeing that they are all as heavily timbered and covered with as dense an undergrowth as the valley bottoms the labour of clearing them for triangulation is immense. It is not always possible to select only the hilltops above permanent snow level as stations of observation ; a triangulator must therefore be accompanied by a strong detachment of men provided with and skilled in the use of cutting instruments, if his work is not to be seriously delayed. The plane-tabler can fortunately make shift as a rule with the innumerable jhüm clearings on the hillsides ; but it is imperative to provide him with good English axes, both of the felling and hand variety, and a number of flexible chain saws which are easy to carry, to enable him to undertake a limited amount of clearing whenever it is unavoidable. Abors very seldom jhüm the actual hilltops of even the lowest hills, as they seem to reserve them for game sanctuaries.

Apart from other considerations it is evident that, in a country like this only good hill climbers used to forest work and skilled in the use of a cutting instrument should be recruited as khalasis. The pure Nepalese is undoubtedly the best man for this sort of work, but any Gurkhali is more useful than men of other races. If possible young ex-sepoys should be recruited through the agency of some Gurkha Regiment or Police Battalion, as they are naturally more reliable in an emergency and understand the necessity and reason of discipline better than a Gurkha who has not been in the ranks.

Communications in the Abor country invariably and in Pemakoi-chen generally are extremely bad.

Even if the Abor habit of exclusiveness, mentioned in the preceding paragraph, did not exist to militate against an expansion of trade and the consequent necessity for better communications, the extraordinary natural difficulties of the country would make it nearly impossible for him to improve the tracks much with the materials at his disposal.

As it is both Abors and Pemakoibas are uncommonly good bridge builders; not only are all the smaller streams provided with good stout log bridges, but very ingenious tubular cane bridges (and in Pemakoi-chen wooden cantilever ones as well) are built over all the larger streams. In the early part of 1913 the Dihāng was found to be bridged in this way at four places in the Abor country and in no less than seven places in that portion of Pemakoi-chen visited.

These tubular cane bridges do not of course permit the passage of animals nor will they stand constant heavy traffic, such as a daily convoy of coolies. For this purpose however they can easily be strengthened by the insertion of two 1 or 1½-in. wire ropes to carry an additional footway of bamboo slats.

No rope bridges of the Mishmi pattern were actually seen, though one is reported to exist over the Tsan-po near Gyala.

In all other respects the tracks are excessively difficult and present many obstacles to a laden cooly. With the exception of 32 miles of mule road built from Pasighat to the Yembung River near Kebang during the Abor Expedition in 1911–12, a road which one monsoon season sufficed to obliterate in most places, the only tracks in the Dihāng Basin are footpaths. From the nature of the country and climate the building and maintenance of the mule roads, which are so urgently required to open the country out, will be a very difficult and expensive undertaking.

The present footpaths invariably go straight up and down hill, the art of grading a road is not understood, or at any rate is despised.

To enable the villages to collect their octroi, all tracks must lead through the different villages; alternative tracks by an easier route are not permitted. The bad places on these switchback paths are often improved as far as possible by galleries and ladders of notched logs; but it may be taken as a general rule that survey parties and their escorts cannot be maintained in the Abor country for any length of time unless they are accompanied by strong detachments of Sappers & Miners to improve the lines of communication by which the convoys of coolies must travel.

Until the country is taken over and properly administered large escorts will be necessary, the rationing of which entails the employment of immense numbers of imported coolies. There are no supplies in the Abor country available for sale or export; under the present system of cultivation the produce barely suffices to support the local population and has to be eked out at certain periods of the year with food stuff prepared from the fruit of the jack tree and even from the fibrous core of a kind of palm tree pounded into pulp. There are no sheep or goats in most parts of the Dihāng Basin; village pigs can sometimes be bought to feed certain classes of Gurkhas and other pig-eating races, but the Englishman and Musalmān have to go without meat as a rule seeing that poultry is scarce and the tame Mithan practically unobtainable.

Fruit does not abound in this country; there are immense quantities of wild plantain trees (the leaves of which are very useful for hunting purposes) but only small patches of the edible variety are to be found in the vicinity of villages. Oranges seem to thrive in the lower parts of the Abor country into which they have probably been introduced from the plains. A few peaches are grown in Pemakoi-chen. Kinds of wild crab apple, wild plum, and lemons grow in certain localities, but only the Abor could eat the two former.

A peculiar feature about the Dihāng River worth noting is the comparatively easy gradient at which it flows throughout its entire course in Pemakoi-chen and the Abor country.

The river has been surveyed accurately up to the Chimdru Chu Confluence in latitude 29° 30′, that is to within a distance from the probable position of the big gorge through the Himālayas of not more than 30 to 40 miles (estimated along the bends of the river).

At this point the height of the river is only 2,750 ft. above mean sea level.

At the Sirapateng Confluence in latitude 28° 53′, about 85 miles further down, the height is 1,270 ft.

In this section therefore the gradient is 1 in 300.

At the Shimang Confluence in latitude 28° 19′, about 80 miles below the Sirapateng Confluence, the height is 700 ft., giving a gradient in this section of 1 in 750.

At Pasighat, where the river debouches into the plains about 45 miles below the Shimang Confluence, the height is 494 ft., the gradient being 1 in 1,200; while 30 miles lower down at the junction of the Dihāng and Dibāng Rivers the height is 400 ft., the gradient being 1 in 1,760.

This gives an average gradient in a total length of some 240 miles of 1 in 530.

Seeing that the height of the Tsan-po at Gyala cannot be less than 9,000 ft. above mean sea level, it is interesting to speculate on the nature of its course in the intervening and still unsurveyed portion of 40–50 miles between Gyala and the Chimdru Chu Confluence, in which it drops 6,250 ft. This drop may be fairly regular, but it seems more probable that it must occur mainly within the limits of the gorge itself.

Unfortunately the Dihāng River is not navigable for any considerable distance above Pasighat owing to innumerable rapids throughout its entire course. The Abors utilize rafts made of bamboos to cross this and other rivers ; we have found Wheatley and Polyansky bag rafts more satisfactory for the same purpose. Berthon boats are very useful in the preliminaries of getting the cable and traveller for the raft across big rivers, but are difficult to carry about over the bad tracks on account of their weight and bulk.

Crossing the Dihāng and its large tributaries on rafts is only practicable between the end of October and the beginning of April. During the other months of the year the river is in high flood from melting snows and sudden storms. In the narrow gorge below the trade post at Rotung for instance the measured difference between low water and high flood level is 78 ft. At the same place the width of the water channel at low water is 160 yards ; during high floods it is nearly 300 yards.

No really satisfactory methods could be devised for measuring the volume of water in the Dihāng River. Lieut. Huddleston, R.E., executed a series of measurements, as accurately as possible under the circumstances, at Pasighat in December, 1912, and has computed the volume at 80,000 cubic feet per second. The volume determined by the late Capt. Harman, R.E., at mean low level of the year in 1878 at a spot a few miles below Pasighat was 55,500 cubic feet per second (*vide* Report on the Explorations of A.K. dated 1884). As however Capt. Harman omitted to measure the volume of water in one of the channels into which the Dihāng divides on entering the plains, Lieut. Huddleston's figure of 80,000 cubic feet per second at mean low level of the year is undoubtedly the more correct.

A marked and unpleasant characteristic of the Dihāng Basin is the extremely heavy rainfall it receives. The main valley appears to act like a funnel up which pours every moisture-laden wind from the Bay of Bengal during most of the year to precipitate all over the valley on striking the Himālayas at its top.

Even when it is not actually raining the higher hills are nearly always enveloped in heavy clouds ; in fact during every single month of the year it is never possible to observe to the higher Himālayan peaks after 9 a.m.

Not having been in the country during the month of September I am not in a position to give a definite opinion as to the wettest portion of the year, but I am inclined to think the months of March, April and May are the worst in this respect.

Curiously enough the three monsoon months of June, July and August in 1913 were infinitely finer and drier than the three preceding months, but I believe the summer of 1913 was an abnormal one all over Upper Assam.

It is now a well-established fact that there are only three months, *i.e.*, from 15th October to 15th January, during which any operations, particularly survey work, can be carried out with any certainty of comparatively fine weather. It has been proved that it is not impossible to carry on survey work in this country throughout the year, but people who have to work or even merely live in the country from the middle of January to the middle of October must be prepared to undergo considerable hardships and suffer a good deal of sickness.

The following table shows the number of days on which plane-tabling either could or could not be carried out during the whole of the season 1912–13.

Month.	Fine Days.	Wet Days.	Total.
November, 1912	7	—	7
December ,, ...	28	3	31
January, 1913	25	6	31
February, ,, ...	18	10	28
March, ,, ...	12	19	31
April, ,, ...	18	12	30
May, ,, ...	8	23	31
June, ,, ...	16	14	30
July, ,, ...	21	10	31
August, ,, ...	12	2	14
TOTAL ..	165	99	264

A similar meteorological record was kept by all survey officers during the season 1911–12 and submitted to the Director-General of Observatories. No copy is however available for this report. Very similar conditions prevailed during the season of 1911–12 as in that of 1912–13. Torrential rain was experienced during the latter end of September and the first week of October, 1911. A period of comparatively fine weather then followed from 9th October, 1911, until about 20th January, 1912. From that date until the detachment left Kobo on 9th April, 1912, very bad weather was experienced, few days being fine or clear enough to permit theodolite observations.

The first consideration therefore in a climate like this is to devise some efficient protection against the rain for all the members and equipment of a detachment, with due regard to the limitations of weight and bulk imposed by coolie transport. Tents (except for the base) are out of the question, efficient huts locally known as *bāshas* can only be made in standing camps ; for temporary bivouacs however it is always possible to run up rough frameworks of timber or bamboo and to roof them with waterproof sheets and tarpaulins.

These should invariably be of stout Willesden canvas or some other rot-proof material, and even the best rot-proof material will not stand the effect of the Dihāng Valley climate for a longer period than six months if used continuously.

It has been found that an officer's or surveyor's squad of khalasis requires one big (12 ft. × 8 ft). paulin for the roof of its *bāsha*. The best patterns are those supplied by the Ordnance Department or Supply and Transport Corps.

If each khalasi is supplied in addition with one rot-proof sheet (7 ft. × $4\frac{3}{4}$ ft.), as issued by the Supply and Transport Corps to all troops and followers, in which to roll up his bedding by day and which serves as a ground sheet by night; and also with one light mackintosh sheet (5 ft. × 5 ft.) which he carries on his person by day for use as a mackintosh, it has been found possible to keep the men comparatively dry and comfortable at night while bivouacking on the march.

The light mackintosh sheets mentioned above which the khalasis carry on the person are also useful in sheltering the plane-tabler when working in light drizzles of rain or in dripping jungles.

For officers and surveyors the light (10-lb.) *tente d'abri* made by the Elgin Mills Company of green rot-proof canvas, size 8 ft. × 7 ft., forms an excellent shelter tied on the underside of a rough framework, on top of which plantain leaves, small branches of trees with the leaves on, etc., can be quickly piled to break the force of the rain.

Theodolite boxes must be provided with stout waterproof covers; the plane-table in its ordinary cover must also be wrapped in an extra sheet (6 ft. × 6 ft.) of Willesden canvas to protect it from the rain.

Intense cold is never experienced on the lower hills and in the valleys of the Dihāng Basin; in fact all members of the Abor Expeditionary Force carried on with remarkably little sickness during the cold weather months of 1911–12 on practically a summer scale of clothing, although several parties had to bivouac above or near the snow line for considerable periods on many occasions.

As a rule however the khalasis should be provided with the winter scale of clothing from the start, seeing that Survey Detachments must work above snow level as far as possible in order to be above tree level.

Arrangements should be made if possible to ensure the escorts and coolies who accompany Survey Detachments above snow level being also provided with winter clothing and good boots. Boots have to be renewed every two months in this region.

If all details of equipment, etc., are carefully worked out on the above lines before the detachment is actually mobilized, it has been found possible to keep officers and men fit for weeks on end in the wettest weather on a very limited scale of transport. The following is the minimum scale of baggage for any period over and above a week :—

	Coolies.
One officer's and his servants' personal baggage and cooking pots (Mess extra according to time)	2
One khalasi	½
Tarpaulin, cooking pots, etc., for one squad of khalasis	1

The coolie's ordinary net load is 60 lbs. This minimum scale only provides the minimum amount of comfort of course ; but it is given to show what has been and can be done to limit the baggage of a detachment without unduly imperilling its health.

Owing to the excessive humidity of the Dihāng Basin it is impossible for men to reach and work at the same heights as in the drier climate of the Western Himālayas. 16,000 ft. is probably the extreme limit of height to which plane-table or theodolite can be carried, but, as men who are quite capable of working at this height on the Western Frontier feel great distress at lower altitudes in this region, it is essential for every member of a Survey Detachment to undergo a careful medical examination before the start of operations.

From the latter end of February survey work in this basin is much impeded during any long spell of dry weather by the haze of jhūm fires.

The obnoxious *dam dim* fly puts in an appearance about the same time. Leeches of course abound at most periods of the year. On account of both these pests a large supply of permanganate of potash should be carried and the men should be made to bathe their feet and legs therein nightly whenever leeches are very prevalent. Unattended bites, sores, and cuts usually put far more men on the sick list than fever and other diseases.

Great heat is usually experienced in all the valleys from July to September and at this period the sandflies are unbearable. They seem to cause a peculiar kind of malarial fever, which medical science has not yet been able, I believe, to define exactly.

Quinine must of course be issued in prophylactic doses to everyone from start to close of operations in this region.

Our geographical knowledge of the Dihāng River Basin and of the eastern reaches of the Tsan-po in Tibet, prior to the surveys now under report, was very scanty.

From time to time between 1858 and 1911 several small military expeditions had been despatched up the Dihāng from Assam to punish the Abors living just behind the outer range for incursions into British territory. None of these expeditions were accompanied by trained surveyors and none of them managed to penetrate very far into the Dihāng Basin, so their contributions to the geography of the country were practically *nil*.

The last and most successful of these expeditions advanced up the Yamne Valley in 1894 to operate against the Padams and managed to reach the vicinity of the most important village, Damro, before retiring back to Assam. There was no trained surveyor with the expedition and the survey work accomplished was practically *nil*.

In 1909 the Assistant Political Officer of Sadiyā (the late Mr. Noel Williamson) made a journey up the right bank of the Dihāng from Pasighat to Kebang Village. He was accompanied by Surveyor Partab Singh, who executed a very accurate survey on the ¼-in. scale of the country traversed, about 300 square miles in extent, although only 11 days in all were spent on both the outward and return journeys.

No surveyor accompanied Mr. Williamson on his last journey up the Dihāng in the spring of 1911, when he was massacred by Abors in Komsing Village.

Much valuable and, as it turns out, extremely reliable information about the Dihāng Basin was however collected by the Explorer Kinthup during the course of his travel between 1880 and 1884.

In order to determine, if possible, the unknown course of the Tsan-po in Eastern Tibet and beyond, the late Capt. Harman, R.E., then in charge of the Assam Survey Party, sent a man known as G.M.N. up to Tibet (*viâ* Darjeeling and Lhāsa) in 1878 to follow down the course of the Tsan-po.

G.M.N. was a Lāma of the Pemiongchi Monastery in Sikkim whom Capt. Harman had engaged as a Munshi to teach him Tibetan. Finding him very intelligent Capt. Harman offered him service as an explorer, which G.M.N. eagerly accepted, and instructed him in the methods of route surveying before despatching him on this journey.

Kinthup, a native of Sikkim, accompanied G.M.N. as an Assistant, and they managed to reach the village of Gyala at the western end of the big gorge through the Himālayas before returning to India by the same route they had gone out.

On G.M.N.'s return to India in 1879 his work was plotted and adjusted by Capt. Harman; the course of the Tsan-po between Chetang and Gyala, as depicted ever since on the maps of the department, depends therefore mainly on this compilation of the surveys and report of G.M.N.

Full details are given in the "General Report on the Operations of the Survey of India" of 1878–79.

G.M.N. had been told at Gyala that the Tsan-po, after passing through the gorge of the Himālayas east of that village, flowed eventually into British territory.

As this report fitted in with the theory (first advanced in 1788 by James Rennell in his "Memoir to the Map of Hindoostan") that the Tsan-po and Dihāng were one and the same river, Capt. Harman engaged a Chinese Lāma in 1880 to continue G.M.N.'s explorations of the Tsan-po. Kinthup was again employed to accompany this Chinese Lāma as an Assistant.

They reached Tibet by way of Darjeeling, visited Lhāsa, and then proceeded down the Tsan-po to Gyala where they crossed to the left bank and continued their journey to Pomed, crossing the mountains by the Dhemu La from Tibet. On reaching a place called Tong-juk Dzong in May, 1881, the Chinese Lāma sold Kinthup as a slave to the Jongpen and decamped with the proceeds. All his instruments, note books, etc., were taken away from Kinthup, who had to work for the Jongpen until March, 1882, when he managed to make his escape into Pemakoi-chen.

He eventually reached the monastery of Marpung on the right bank of the Dihāng, and was kindly received by the head Lāma whom he served (in repayment of the ransom to his pursuers from Tong-juk Dzong) for practically the whole of the time he remained in this region. During this period he managed on several occasions to obtain leave of absence from Marpung on pretence of visiting holy places in different parts of the country, and made several extended journeys of exploration.

The last of these journeys he made was down the Dihāng into Abor country, in the hope of being able to return to India that way.

He managed to reach the vicinity of Damro, but was not allowed to proceed further and had to retrace his footsteps to Pemakoi-chen, from where he returned to Lhāsa and finally to India, which he reached in November, 1884, after four years' absence.

Owing probably to the death of Capt. Harman, which had taken place in the meanwhile, Kinthup's story was not taken down and translated until two years after his return, when Colonel Tanner compiled a sketch map of the Dihāng Basin from Kinthup's narrative.

This map has constituted the sole geographical record of the Dihāng Basin from that day to now.

Kinthup was not a trained explorer, all his instruments, note books, etc., were stolen from him early in his journey, and he had therefore to rely entirely on his memory in giving his account of travels extending over four years and a large area of country. The sketch map prepared by Colonel Tanner was not compiled from information based on any kind of route survey, but from a narrative account only.

These facts are presumably unknown to or else ignored by people who criticize either the map or Kinthup's narrative.

Kinthup's story was corroborated in many particulars by a previous narrative (given to Explorer U.G. of the Survey of India) of a Mongolian Lāma called Serap Gyatsho who had lived and travelled in Pomed and Pemakoi-chen between 1856–68.

Furthermore the important fact, established by Kinthup, of the identity of the Tsan-po and Dihāng was indirectly proved by the explorations made by Surveyor A.K. in Eastern Tibet between 1879 and 1882, who found that the Tsan-po did not continue to flow north or east beyond Gyala and did not join the systems of the Irrawaddy, Salween, Mekong or Yangtse-Kiang Rivers.

In face of all this evidence few geographers have since doubted the fact of the Tsan-po and Dihāng being one river; it has only remained for scientific survey to furnish the final proof.

The complete reports, narrative accounts, etc., of the above-mentioned explorers are given in the following publications :—

(1). Report on the Explorations of Lāma Serap Gyatsho, Explorer K.P., Lāma U.G., Explorers R.N. and P.A. in Sikkim, Bhutān and Tibet (Trigonometrical Branch Office, 1889).

(2). Report on the Explorations in Great Tibet and Mongolia made by A.K. in 1879–82 (Trigonometrical Branch Office, 1884).

Further references to these explorations will also be found in the "General Reports on the Operations of the Survey of India" for 1881–82, 1882–83, 1886–87, 1887–88, 1888–89.

After the murder of Mr. Williamson and his party by Minyong Abors in March, 1911, the Government of India decided, with the sanction of the Secretary of State, to despatch a military expedition up the Dihāng in the cold weather of 1911–12 with the primary object of punishing the Minyongs and of finally establishing our military superiority in the estimation of the Abors. An important but secondary object of the expedition was the survey of as much of the country as possible. The Surveyor-General was accordingly requested to detail a Survey Detachment to accompany the Abor Expeditionary Force. He was also asked to detail two other detachments to accompany friendly missions which it was also decided to send at the same time to co-operate in the general programme of survey operations on the North-East Frontier (of Assam); one to visit the tribes living in the Subansirī Valley; and the other to visit the Mishmis of the Dibāng and Luhit Valleys.

In addition to the main requirements of survey, as stated above, the Government of India also wished an exploring party from the Abor Expeditionary Force to visit the falls (mentioned by Kinthup) of the Tsan-po River in the vicinity of Gyala and incidentally to settle the question of the identity of the Tsan-po and Brahmaputra Rivers.

Orders were issued by the Surveyor-General early in September, 1911, for the formation of the Abor Expedition Survey Detachment (Capt. O. H. B. Trenchard, R.E., in charge; Lieut. G. F. T. Oakes. R.E.; Lieut. J. A. Field, R.E. (from 4th February, 1912); Mr. Sher Jang, K.B.; Surveyor Hamid Gul; Surveyor Abdul Majid (served as computer); Computer Narayan Singh; Surveyor Abdur Rahim (from 4th February, 1912); Surveyor Shankar Singh (from 4th February, 1912); 34 khalasis; 23 khalasis (from 4th February, 1912). Mobilization was completed in Calcutta by 23rd September, 1911; on which date the detachment embarked on the s.s. *Sherani* for the river journey to Kobo, the base of operations, a small clearing on the north bank of the Brahmaputra, a few miles west of the Dihāng Confluence.

The detachment arrived at Kobo, where the troops composing the force were then assembling, on the 8th October, 1911.

Active military operations against the Minyong Abors were in progress from about the 20th October, 1911, until the end of December, 1911. During this period very little survey work was accomplished owing to the exigencies of the military situation. While the main body of the army was advancing up the right bank of the Dihāng River, a small column on the west flank operated against the Minyongs established on the south side of the outer range.

Capt. Trenchard and Mr. Sher Jang followed the main body up the Dihāng; Lieut. Oakes and Surveyor Hamid Gul accompanied the flank column until the end of November, 1911, when the operations of this column came to an end, the troops and Survey Detachment returning to the valley of the Dihāng.

The total out-turn of detailed survey on the ¼-in. scale up to the end of December, 1911, amounted to about 200 square miles. Plane-tabling was rendered possible by the number of great trigonometrical intersected points of the Assam Valley series of triangulation, completed in 1877–78, which cover the whole area traversed up to about latitude 28° 15′.

As the outer range completely shuts out all view from the south of the mountain ranges of the Dihāng Basin behind it, no points in the area, north of latitude 28° 15′, had been fixed by triangulation from the old series, which follows the course of the Brahmaputra River. Lieut. Oakes managed to clear Torne Hill on the outer range and observe therefrom in November, 1911; other than this no triangulation could be carried out up to end of December, 1911.

The exploration parties working in the northern portions of the Dihāng Basin from about the beginning of January, 1912, until the end of March, 1912, when all operations closed, had therefore to enter an area devoid of triangulated points and one in which the dense vegetation, covering all the hills up to permanent snow level, precluded all idea of a hasty reconnaissance triangulation on the march.

On the 27th December, 1911, a small exploration party, commanded by Mr. A. Bentinck, I.C.S., Assistant Political Officer to the General Officer Commanding, left the headquarter camp near the Yembung River and the village of Kebang to penetrate as far up the Dihāng River as possible and to cultivate friendly political relations with all the villages on the line of march.

Capt. Trenchard and Mr. Sher Jang accompanied this party. Singing, a small village of the Simong Group on the left bank of the Dihāng nearly opposite the Sirapateng (Sigong) River Confluence, was reached on the 31st January, 1912. The party was unable to proceed any further up the Dihāng River and retired slowly down the valley, reaching the headquarter camp near Kebang again on 28th March, 1912.

During the advance of this party the detailed survey carried out by Mr. Sher Jang had to depend entirely on a plane-table triangulation made from fixings on or near the path along the bottom of the valley. Although the most northerly point intersected by Mr. Sher Jang is more than 60 miles distant from the two triangulated points (of the old Great Trigonometrical Series) from which this plane-table triangulation was started, there is no plottable error between the positions of any points intersected on the plane-table and afterwards computed from the later triangulation.

Two hilltops, near the villages of Simong and Geku on the right bank of the Dihāng, were cleared by working parties of the 1st Battalion 8th Gurkha Rifles, and transport coolies on the line of communication of the party during its advance.

As no skilled labour or felling tools were available this proved a task of great magnitude.

During the retirement of the party down the valley Capt. Trenchard was able to make theodolite observations from both these cleared hills. At the beginning of March, 1912, Capt. Trenchard crossed the Dihāng and spent 20 days on the top of Arte Hill, the highest point of the Dihāng-Shimang River Divide, clearing the hilltop and waiting for fine weather before the necessary theodolite observations could be made.

At the same time Mr. Sher Jang crossed the Shimang Valley and the hills which divide it from the Siom Valley to the west, and managed to make a reconnaissance survey of a small area in the latter valley before returning to the rest of the party at Riga in the Dihāng Valley. Apart from this and a small area in the vicinity of its confluence with the Dihāng reconnoitred by two other parties, the Siom Valley was neither visited nor mapped during the expedition.

Capt. Trenchard and Mr. Sher Jang finally reached the headquarter camp near Kebang on 28th March, 1912.

Another small party, under the command of Col. D. C. Macintyre and accompanied by Lieut. Oakes and Surveyor Hamid Gul left

Rotung on the 26th December, 1911, to explore the Yamne Valley. Having crossed to the left bank of the Dihāng the party marched down it to Porging Village near the Yamne Confluence, from there advanced up the right bank of the Yamne as far as Sibbum Village, and then crossed the divide into the Dihāng Valley, reaching Geku Village on 1st January, 1912. After halting in this village for two days the party returned by the same route to Rotung where it arrived on the 7th January, 1912.

On the 20th January, 1912, the same party again left the main line of communications on the right bank of the Dihāng, which it crossed a few miles above Pasighat. From here the party followed the route taken by the expedition of 1894 up the left bank of the Yamne and reached Damro Village, where a halt of five days was made to give Lieut. Oakes an opportunity of making theodolite observations from Kallang, a hill in the vicinity. It rained continuously throughout the three days Lieut. Oakes spent in bivouac on top of Kallang, and no triangulation could be carried out. The party then retired down the Yamne and returned to Rotung on the 10th February, 1912.

On the 4th February, 1912, the detachment was reinforced unexpectedly by the arrival at Kobo of Lieut. Field, R.E., and three surveyors. Owing to lack of transport, escorts and other reasons it was found impossible to utilize the services of the three surveyors as fully as could have been wished during the remaining two months; one of them extended by a small amount the surveys (during November, 1911) of Lieut. Oakes and Hamid Gul on the southern slopes of the outer range, another carried out a 1-in. plane-table traverse survey of the mule road from Kobo to the Yembung River, while the third was practically unemployed.

Lieut. Field was usefully employed in carrying out a good minor series of triangulation from two base stations of the Assam Valley (G.T.) series over the outer range and terminating near the latitude of Kebang. He observed at five out of the six stations of this series, Lieut. Oakes completing the observations at the sixth station. Bad weather unfortunately prevented a satisfactory junction of Capt. Trenchard's triangulation with this series.

During February, 1912, a small party accompanied by Surveyor Abdul Majid made a hasty reconnaissance of the lower reaches of the Siom and Shimang Rivers. Practically the whole of this area was recovered by Lieut. Oakes and Surveyor Hamid Gul in March, 1912, who left the headquarter camp near Kebang on 4th March with a small party to explore the Shimang Valley and to extend the triangulation from a station at its head.

The survey of the Shimang Valley was completed, but bad weather and lack of time and transport made it impossible either for Lieut. Oakes to make any theodolite observations or for the party to cross over into the Siom Valley and return down it to the headquarter camp as had been arranged. The party therefore retired down the Shimang Valley and reached the headquarter camp on 23rd March, 1912.

On the 28th March Mr. Bentinck's Dihāng party also reached this camp, and the next day the united detachment accompanied the headquarter staff on the final stage of the retirement to Kobo which was reached at the beginning of April, 1912.

The week which elapsed before demobilization orders were received was spent at Kobo in drawing the originals from which the provisional map of the surveys executed was published later.

The whole detachment left Kobo on the 9th April, 1912, by river steamer. On arrival in Calcutta the khalasis were immediately paid off and sent to their homes, the surveyors returned to their original parties or proceeded on leave, and the detachment was completely demobilized by the end of April, 1912.

The geographical results achieved by the expedition were disappointingly small.

Owing to the inability of the exploring party to penetrate further up the Dihāng Valley than latitude 28° 55′, neither of the geographical objects of the expedition—the survey of a suitable frontier line and the establishment of the identity of the Tsan-po and Dihāng as one and the same river—was accomplished.

As it was found impossible to survey the Siom Valley no connection was made with the work of the Mīri Mission to the west; similarly, the inability of the Mishmi Mission to the east to survey the Sesseri and Dibāng Valleys resulted in no connection being made with their work.

A good minor series of triangulation based on the old Assam Valley (G.T.) series was however carried over the outer range into the Dihāng Basin, as a result of which (and the subsidiary triangulation carried out by Capt. Trenchard) 45 new points were intersected in a previously untriangulated area, 11 of them being situated in a continuous range of high snowy mountains bounding the valley to the north and west which we now know is a portion of the main Himālayan Range. An interesting fact disclosed by this triangulation was the existence of a peak (Namcha Barwa) in this range well over 25,000 ft. in height. Further details of the work completed by the Abor Expedition Survey Detachment are given in other paragraphs of this report.

The detachment suffered very little sickness throughout the expedition. One officer spent the first week at Kobo in hospital with fever, and one of the computers had an attack of jaundice in November, 1911, which necessitated his removal to the base hospital at Dibrugarh for a short period. Only one of the khalasis suffered severely from fever.

(To be continued).

REVIEW.

PAGES D'HISTOIRE, 1914.

(Librairie Militaire Berger-Levrault, Paris: 5, Rue des Beaux-Arts).

New numbers of the *Pages d'Histoire*, 1914 series, in continuation of those already reviewed in the *R.E. Journal*, have recently been published by the Librairie Militaire, Berger-Levrault. The 16th, 17th and 19th numbers are in continuation of the 14th number of the series, and deal with mentions in despatches, promotions, and awards of the Legion of Honour and the Médaille Militaire. The 16th number covers the period 15th—26th October; the 17th number the period 28th October—1st November; and the 19th number the period 6th—10th November, 1914.

The 18th number contains the official communiqués and telegrams issued to the Provincial Authorities by the French Government during the month of November; these communiqués are in continuation of those which appear in the 6th, 7th, 8th and 12th numbers of the series.

The 20th number is a reproduction of the Belgian Grey Book, and contains a copy of the Belgian diplomatic correspondence arising out of the ultimatum sent by Austria to Servia in July last. This number contains 79 separate despatches, with their appendices, the first of them being dated 24th July and the last 29th August. They are arranged in groups under the dates borne by them, each group being preceded by a short summary of its contents. The correspondence forms an important addition to the volume of evidence already published in the British White Paper and the French Yellow Book in relation to the part played by Germany during the crisis of July last. The despatches show that at a very early date after the development of the crisis the Belgian Government notified the several Powers which had, under the Treaty of April, 1839, undertaken to protect Belgium's neutrality, the firm resolve of the Belgian people strictly to carry out all the obligations imposed upon a Neutral State. So that there should be no mistake as to the intentions of the Belgian Government its diplomatic representatives abroad were instructed on the 29th July that the Belgian Army was immediately being placed on the footing known as "paix renforcée," and the distinction between this state of military preparedness and a mobilization was briefly explained, in order that the real military situation in Belgium might be made clear should enquiries on the subject be addressed to the Belgian embassies. The original German text of the first ultimatum handed to the Belgian Foreign Minister by the German Ambassador at Brussels on the 2nd August, as well as that of the second German ultimatum presented through the Dutch Foreign Office on the 10th August after Liège had fallen, are reproduced in this number, together with the French translations of the same with notes thereon. Among the other documents appearing in this number are copies of the declaration of Dutch neutrality, and the decree issued at The Hague on the 6th August last for regulating the navigation of the Scheldt during the existence of hostilities.

Under the regulations contained in this decree, the use of the Dutch portion of the river is prohibited to vessels of war of all kinds belonging to the belligerent Powers, as well as to their subjects liable for military service. The last of the series of despatches in this number are dated from Antwerp, and deal with the text of a telegram, dated Berlin, 31st July, from Sir E. Goschen to Sir E. Grey, published in the British White Paper. In this telegram it was stated that, according to the German Government, certain hostile acts had been committed by Belgium; it being alleged that a consignment of corn for Germany had been placed under an embargo. In the correspondence on this point, it is made abundantly clear that the Belgium Customs authorities at Antwerp had merely misinterpreted the terms of a decree forbidding the export of cereals from Belgium, and had detained for a short time only a consignment of corn for Germany which was being transhipped in the Scheldt; the consignment being in reality in transit was not affected under the terms of the decree. As soon as the matter was brought to the notice of the Belgian Foreign Office, the German consignment of corn was at once released. But the Berlin authorities decided to make the most out of the incident. Probably it was thought, at the time, that any excuse, however flimsy its basis, was good enough for the purpose of justifying the repudiation by Germany of the pledges given by Prussia in April, 1839.

The 21st number contains a copy of the diplomatic correspondence published in the Russian Orange Book. The despatches, of which there are 79—the first dated 23rd July and the last 6th August, 1914 (new style)—are arranged in groups under the dates borne by them, as in the case of the despatches contained in the preceding number of the series, each group being likewise preceded by a short summary of its contents. The despatches contained in this number tell the same story as that published in the British White Paper, French Yellow Book, and the Belgian Grey Book, and complete the damning evidence in relation to the nefarious design of Germany to make use of Austro-Hungary as a cat's-paw in her great scheme to acquire an overlordship over the nations of the world. A *résumé* of the crisis prepared by the Russian Foreign Office on the 2nd August, and the copy of a despatch of the same date, sent by the Russian Foreign Minister to the Russian diplomatic representatives at the European Courts, placing the responsibility for the rupture of friendly relations on Germany are published in this number, which concludes with the notification, dated 6th August, 1914, handed by the Austro-Hungarian ambassador at St. Petersburg to the Russian Foreign Minister, in which it is declared that in view of the commencement of hostilities by Russia against Germany, Austro-Hungary likewise considers herself at war with the former as from 6 p.m., 6th August, 1914.

W. A. J. O'Meara, *Major, late R.E.*

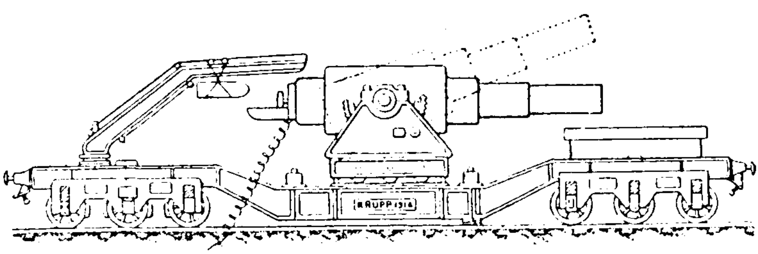
NOTICE OF MAGAZINE.

RIVISTA DI ARTIGLIERIA E GENIO.

December, 1914.

THE SIEGE MORTAR, KRUPP, 42 C.M.

In the pages of the *Génie Civil* (November, 1914) there is published an interesting article on Austrian and German heavy artillery, which contains a description of the 42-c.m. mortar. While, however, the author declares that he is not able to guarantee absolutely the exactness of the information, we may report the following translation of the extract regarding this mysterious mortar :—Much attention has been drawn during the present war to the mortar of 42 c.m. used by the Germans,and in regard to which great secrecy was kept up to the moment of its entry into action at Liège, Namur, Maubeuge, and Antwerp. A mortar of this calibre has the power of throwing a projectile 1·50 m. in length, capable of containing an enormous weight of explosive, and consequently producing destructive effects that can easily be imagined. It is only necessary to consider that the shells from a mortar of 28 c.m. and of smaller calibre are able to put out of service the works of strong fortified places like those above mentioned. It has not yet been proved how much of the destruction of the forts of Belgium and Maubeuge was due to the 42-c.m. mortars. In any case it would seem certain that the 42-c.m. mortar bears an important part in modern warfare, and that the firm of Krupp have constructed a limited number of such mortars, from four to eight, or perhaps more. The accompanying



drawing represents approximately the scheme of this famous siege mortar, drawn from sketches furnished by persons who have been able to see it at the railway station at Cologne. The carriage with the mortar placed upon it has a special platform. Each of the front and hinder portions of the platform are supported upon a truck with three pairs of wheels. The whole can be placed upon the lines of railway, specially prepared. The central part of the platform (on which the carriage is placed) is lower than the front and back parts. The carriage below is joined to a circular base provided with small wheels which allow for the rotation of the carriage on a diameter of about 2·80 metres. The rotation of the carriage for aiming, and the movements of the mortar in elevation and in depression, are obtained by means of special hydraulic transmission. The mortar is fired by electricity. The gunners having arranged the conducting wires, retire to a distance from the piece. The shells are charged with an explosive having picric acid for its base, which when bursting produce an enormous quantity of deleterious gas. It is reported that during the fire practice near Cologne some rabbits were found asphyxiated at a distance of more than 100 m. At an angle of 45 degrees the range of fire reaches 14 k.m. On arrival of the mortar at the battery the platform is lowered to the ground by means of hydraulic cranes and completely unshackled from the two small carriages on wheels. At one extremity of the platform there is fixed a small revolving crane which serves to take the projectiles from the wagons and to place them in the mortar, then charged for firing. The siege train comprises, in addition to the carriage, a locomotive and tender, a wagon carrying ammunition, a wagon for the gunners, and one containing a motor for petrol which serves to put in action the different parts of the accessories, as for example, the hydraulic transmission for the parts of the mechanism connected with aiming, one dynamo, etc. The piece with its carriage and platform weighs from 100 to 110 tons, the entire train about 300 tons. The carriage is about 18 m. in length. Material, such as that described above, evidently cannot be placed on a railway in good condition, and would be quite unable to traverse military bridges constructed in the field to substitute those that may have been destroyed. It would be sufficient to destroy in good time, in a sufficient radius, the railways near the fortified places to impede the mortar of 42 c.m. from being placed in a battery at a convenient distance.

FRANCE.

Aeroplane Armed with Mitrailleuse.—The following is extracted from the *Kriegstechnische Zeitschrift*:—

At the last aeronautical salon held in Paris there were exhibited several aeroplanes of different kinds armed with the Hotchkiss mitrailleuse. Only one presented a satisfactory solution of the system of placing the propeller in the rear part of the machine in such a manner that the mitrailleuse could be used with an extensive vision for fire. But in this type of aeroplane the gun had to be managed by the pilot himself, since the seat of the observer was placed behind that of the pilot.

This naturally is very inconvenient. Signor Loiseau, it would now seem, has solved the problem in a satisfactory manner with a special apparatus placing the propeller in the rear of the machine. The mitrailleuse is fixed on a pivot so as to allow of its being fired in any position, and is placed in front of the pilot. A steel shield, 4 m.m. in thickness, protects the firer from the front and the sides, and behind he also has protection from a metal balustrade. The position of the firer certainly is not perfectly secure, and it also somewhat limits the view of the pilot.

Notwithstanding these drawbacks, this type of aeroplane is better than those armed with the Hotchkiss mitrailleuse. It should be noted that the pilot is able to look below through two small apertures, between the wings of the machine and its protected body, one on the right and the other on the left.

The experiments with the Loiseau apparatus were commenced at Villacoublay, near Paris, on the 10th February, 1914. The trials were not very satisfactory; partly owing to an insufficient number of exercises. However, the trials showed practically the possibility of good results with the mitrailleuse.

January, 1915.

Fortification in Actual War.

In the pages of *Jahrbücher für die Deutsche Armee und Marine* of last November Colonel v. Voelki commences the publication of a series of articles on modern war, with some general considerations of the part taken by fortification in the western sector up to the present time.

The great war—writes the Author—has now lasted three months, and after so many great events it is not yet positively known of the forces employed by the belligerents, nor of their plans of campaign or of the reasons that inspired them. The future only can give the necessary elements for judgment. However, it is now possible to examine the facts so far known as regards the functions exercised by fortifications, and to deduce certain considerations. At the commencement of the campaign there took place the unexpected fall of Liège after an assault *de vive force* of one of the forts, and immediately followed by the capture of the city after a hand-to-hand strife, this again being at once followed by the destruction of the other forts, to which the mortars of 42 c.m. powerfully contributed. According to the report of General Leman, the town was captured on the 7th August; from the 11th to the 14th the principal fort, Loucin, was bombarded by artillery of 10, 15, 21-c.m. calibre; on the 14th there also came into action the 42-c.m. mortar; and on the evening of the 15th August the fort was destroyed.

Namur did not fall so promptly to the German attack, because its defenders had time to throw obstacles in the way of the enemy's advance by all kinds of demolitions, and especially because they succeeded in employing a considerable number of mobile troops in the defence of the place. The success of the attack on the fortress Maubeuge which before might be considered capable of most resistance was also complete.

But all these places, the Author observes, were wanting in a true and complete ceinture; and, they also, had no provision for the defence of the intervals between the forts; there being none at Liège, and only relatively in good condition at Maubeuge. Now these circumstances can essentially explain the rapid conquest of these strong places; with a rapid procedure of attack facilitated by the most powerful means of offence, not forgetting the *élan* and the extraordinary violence with which the assaults were conducted. The attack *de vive force* of a fort, even under favourable conditions, is always an action requiring rare heroism, which, generally, now as in the past, it is impossible to calculate upon. In any case, it may be stated that the competent experts have never approved of the suppression of the ceinture around the nucleus of a strong fort, and there is no one that does not recognize the very great importance of the organization of the intervals between the external forts, without which a long resistance by these forts is not possible. Modern war has demonstrated the inevitable lot of a place violently attacked, when not provided with a ceinture, and perhaps not well organized with regard to the action that should be devolved from the defence of the intervals between the forts. The essential characteristics of the war of to-day, continues the Author, are the unlimited increase in the numbers, and the variety of the means of offence. The active participation of masses has a special importance at the second period of the actual war, which commenced in France on the 22nd August up to the time that the victorious German advance arrested at Nancy, and consequently transformed in the middle of September, after the retirement of the right wing, into a real war of position on a front of Belfort, by Epinal, Verdun, Rheims, to Amiens. What was the cause that brought about this state of affairs ? Evidently it was the force of the circumstances by which, little by little, the forces of the defenders came to nearly equal those of the attack. And this happened when the defenders were deprived of all disposable means, most essentially among these the rapid transport of troops and material, fortifications, and means for the defence of the country, and then the defenders animated by a great energy, indeed a true fanaticism, which in order to create obstacles to the attack did not even stop at a voluntary devastation of its own country.

The part represented, in this period, by the French fortifications was very important, especially by those on the eastern front. It is undeniable that the system of defence of the French territory up to now has efficiently performed its duty, and that the French have known with real talent the value fortification is indisputable. The war has given them the best occasions for obtaining wide advantages from preparation for territorial defence made long ago, and with the greatest care.

The Author contends that for the rest no one has ever doubted the value of fortifications as depôts, rallying points, bases of operation, places of refuge for the defending troops ; and this value is so much the greater as the fortifications are of a more vast area. This is clearly proved in modern war, at Belfort, Epinal, Toul, and Verdun. It is true that the range of action of a fortress is not very extensive, and may be considered as limited to the circle of the zone ranged over by the artillery, but it is indisputable that the works of fortification are most valuable barriers, and it is only after their destruction that the assailants can consider themselves victors.

The fortresses on the eastern front are of the greatest interest for actual war. Paris and Antwerp both considered and organized as central redoubts for extreme defence, Antwerp as being near the sea and Paris being of such an extensive area that it could not be completely surrounded. Antwerp has fallen in front of an unexpected, strong, impetuous attack. But of this siege the final acts are not yet closed and there may yet be much to say. This however is certain, that Antwerp was not equal to its duty, which was to retain possession of an important position until the entry into action of the troops of the defence. But it may be noted that the conditions of this strong place only permitted a limited resistance.

Paris, up to now, has only exercised an indirect action; but, altogether, its influence on the place and conduct of the war has been of the greatest value. And this, not for one only of the belligerents. Paris, as an entrenched camp is a factor of capital importance, either for the assailants or for the defenders. It offers the best conditions for defence in the greatest proportions not only by its position but by its most important disposable means among which are those of rapid transport.

Colonel v. Voelki remarks on the difficulty of placing the action of the fortresses in perfect accord with that of the troops, and on the dangers that are likely to occur from their united action. The power of the troops consists essentially in their freedom of movement, and if this freedom should be lost or worse if it should be renounced they become for the fortress a source of ruin. The activity of the troops, and their rapid dispositions, more than their number, give protection to a fortress. The troops should be most free in their actions and not tied by any fixed laws to the fortifications. The latter represent only points of resistance and security against possible attacks.

The actual war of position, in the western sector, is, according to the Author, a phenomenon of the conditions of the times. We cannot ignore the physiological conditions of the armies which have a tendency to react against the extraordinary tension caused by the exhausting combats which have taken place up to now. Nor is it possible not to take count of the great force of resistance of the defence. In the face of the immense forces employed in the present war, the theories and fine phrases vanish and their place is taken by the war of positions; and calmness and tenacity become the essential factors of success. But is it possible to reconcile the idea of the advance with the decided tendency to remain closed up in the trenches, and to seek a secure protection from the fortifications? Up to the present time neither one nor the other of the belligerents has succeeded in finding a good solution. At first view, there seems no clearness of ideas, and the facts seem unexplainable; positions fall which were thought to be impregnable and others resist that were absolutely valueless. The old truth seems to be verified, that it is not so much the passive resistance as the *élan* and aggressive spirit of the troops that are in every case the more valuable elements of the defence.

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