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FOREIGN SECTION.

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VISUAL SIGNALLING.

By Dr. Ph. FREDERIC WÄCHTER.

(Compiled from Official Sources.)

Communicated by Major A. H. BAGNOLD, R.E.

THE following somewhat literal translation of a report published in the *Mittheilungen über Gegenstände des Artillerie- und Geniewesens*, G—68, 1894, will, it is thought, be of interest to all branches of the Services, in which the art of visual signalling is so much practised.

That there are very considerable defects in the lamp signalling equipment of the British Army, is well known. The results, therefore, of the prolonged experiments in Austria are the more particularly interesting.

It will be seen from the report that the general conclusion is in favour of the use of a large spherical or quasi-parabolic mirror.

The theoretical reasons which support this conclusion are not far to seek.

It has been shown by Professor André Blondel, in his "Theory of Projectors," that the illumination produced at any given distance by any properly-constructed optical projector is, subject to the application of certain co-efficients, and neglecting the absorption of the atmosphere, equal to the product of the *intrinsic brilliancy* of the source of light and of the *area of aperture* of the projector, divided by the *square of the distance*. By the *intrinsic brilliancy*, is meant the candle-power per unit area of surface of the source of light.

It follows, therefore, that the actual size of the source of light does not enter into the question of the illumination produced, but only governs the dimensions of the illuminated field.

The simplest case to deal with analytically is that of a parabolic mirror, and this has been treated very clearly by M. Jean Rey, in the *Electrical Engineer*, of 13th December, 1895.

It will be easily seen by studying that article that a central cone of maximum uniform illumination is produced, and that this cone is surrounded by a luminous fringe which is of little value for signalling purposes. The same is true for all projectors, whether fitted with mirrors or lenses.

Now, the application of illuminants of high intrinsic brilliancy, such as the electric arc, the lime light or the magnesium light, to field signalling equipment has been found to be attended with considerable difficulty.

We must, therefore, be content to employ oil lamps which may

produce intrinsic brilliancies of from 10 to 30 candle-power per square inch of flame.

The electric arc light has an intrinsic brilliancy of about 116,100 candle-power per square inch, and the lime light with spirit jet as used in our Service has an intrinsic brilliancy of about 200 per square inch.

If, therefore, we are forced to use a source of light having only an intrinsic brilliancy of about 20 candle-power per square inch, it is quite obvious that a large lens or reflector must be employed.

Lenses of large size are expensive, and, moreover, they are very heavy. It follows, then, that the use of a light reflector must be resorted to.

There is every reason to believe that light and efficient reflectors of 12 or 15 inches diameter can be produced at a moderate cost, and it remains to consider what focal length is the best to employ.

In Professor Blondel's work, before quoted, it is clearly shown that, with a parabolic mirror, the largest cone of maximum illumination is produced when the focal length is 1·2 times the radius of the aperture of the mirror.

This evidently gives the best proportions for a so-called "reflector lantern."

The obscuring arrangements need special consideration, and it is regretted that Dr. Wächter has not given us some details under this head.

In any case, attempts to produce a reliable signalling lamp with an aperture of 3, 4, or 5 inches only, should be abandoned. A. H. B.

Although visual signalling, in comparison with the electric telegraph and telephone, appears to be only an imperfect and clumsy makeshift, it nevertheless possesses some peculiar advantages which, for special military purposes, make it sufficiently important and valuable to justify the subject being given a somewhat searching consideration.

The advantages consist of the following :—

1. In visual signalling one is not dependent on previously prepared connections, either above or below the ground, but one is enabled, within certain limits, to open communication between any selected points.

2. Given a practical choice of suitable stations and apparatus, only a comparatively short time is required to establish lines of communication by the process of visual signalling. A few minutes are sufficient in most cases to effect the exchange of messages at relatively very long distances (perhaps 20, 30, and even 40 kilometres).

Considering the time required to construct an electric line of 40 kilometres, it is obvious that under certain circumstances the visual telegraph can considerably excel the electric line in celerity of despatching messages.

3. The most important advantage is, however, that correspondence can be sent over the enemy's head without his being able, even should he be cognisant of the progress of the work, to prevent or disturb the operation. This point is of special importance in the connection of fortified positions. It may be urged that fortresses, as a rule, are connected by subterranean electric wires, but their detection and destruction, by

chance or treachery, is always possible, and then communication by visual signalling, as constituting a means not subject to interference by the enemy, affords the only practicable method. Again, visual signalling makes it possible to communicate from an effectually invested place with the mobile friendly army, over the heads of the investing forces, which by electric telegraph would only be possible in exceptional cases.

4. Finally, an advantage, which should not be underrated, consists in the cheapness and portability of the signalling stores.

Opposed to these advantages is the great drawback that fog renders visual signalling impossible, and that the range of the apparatus depends to a great extent on the condition of the atmosphere, on the light, and on the more or less favourable situation of the signal stations. Naturally such influences are greater in proportion to the distance, but it may be assumed that comparatively few days would occur in Central Europe on which it would not be possible to signal over a distance of at least 8 to 10 kilometres. The conditions are only unfavourable for distances of 40 to 100 kilometres, when such a clear atmosphere as seldom prevails in our surroundings is indispensable.

The various systems of visual signalling and their merits, the results of experiments of the Military Committee gained by exhaustive trials extending over several years, are considered below:—

I. *Flag Signals.*—The simplest, best, and cheapest method of visual signalling consists in the use of the white-red flags, about 1 metre square.

Two such flags, with a good telescope and a light telescope stand, form a capital signalling outfit, which renders good service in daytime for distances of from 4 to 14 kilometres, and which constitutes a portable equipment, as the total weight does not exceed 5 to 6 kilogrammes, and could, therefore, be carried comfortably by one man even up the steepest mountain top.

The method of signalling consists in the raising of flags, one flag signifying a dot, and the simultaneous raising of two flags a dash, in the Morse alphabet. With some practice the process becomes sufficiently rapid. The time required for the delivery of a message may be shortened by adopting certain preconcerted signals by waving the flags once, twice, three, or more times, which may be understood to mean "end of word," "end of message," "end of sentence," "not understood," etc., etc.

For the reception of signals, and as an invariable component of all signalling outfits, only the best and most efficient telescopes should be selected. For this purpose the telescopes of Merz, which possess a magnifying power of 28 to 30 and a field of vision of $1\frac{1}{4}^{\circ}$, are to be specially recommended; with an object glass of 40 millimetres diameter sufficient clearness is assured, and the weight, with leather case, is about 1.7 kilogrammes only. The price in round figures is 40 florins.

A light, and at the same time steady, stand is a most necessary accompaniment of the telescope, because the vibration of it in the wind disturbs observation. Such a stand can be produced at an approximate cost of 20 florins. Thus the cost of a complete outfit, inclusive of two

flags, amounts to about 65 florins. If a cheaper telescope be selected, the cost may be reduced to one-half, or even one-third, but it would act prejudicially on the range, which must be determined by the quality of the telescope. It must be observed that practice in observation plays a most important rôle, and that the correct handling and use of a telescope have to be practised just as much as the use of a microscope or of a levelling instrument, and require to be mastered in a similar manner to any other scientific and technical apparatus, which can only be effectively used after a thorough course of practice.

Special stress is laid upon this point, because a general opinion prevails that no manner of previous practice is required in the use of a telescope, and that anybody can at once observe effectually with one, particularly if he be already accustomed to the use of binocular or field glasses. However, this view is decidedly wrong, and is most clearly refuted when, for instance, the observation of astronomical objects, say planets, is in question.

Irrespective of the fact that the quick focussing of strong magnifiers is in itself not the easiest of operations, experience teaches that a layman looking at a planet observes only a luminous circular disc, and in spite of sound eyesight and his best endeavour fails to detect such small details on the disc which the eye of the astronomer, trained by many years' practice, perceives even when Nature has favoured it less than the untrained eye of the layman. Similar phenomena appear also in optical telegraphy, when the expert recognises the signals, even under unfavourable conditions, whilst the novice is perhaps unable to find the distant station, and, having found it, fails to see that which he should see.

The varying opinions given by several individuals on the same pattern of signalling apparatus are often explained by the varying degrees of efficiency in the use of the telescope.

II. *The Optical Shutter Telegraph.*—Shutter telegraphy is effected, as a rule, by an arrangement whereby the window opening of a fort can be quickly covered or exposed by means of a shutter painted white. For this purpose the shutter must be so constructed that it is easily movable, and can be made to appear or disappear by simply pulling at the cord.

If the fort and its environs have the appearance, more or less, of a white surface as seen from the opposite station, the open window represents a dark spot on the light ground, and the window in this case disappears from view when its space is filled by the white shutter. If, on the contrary, the surroundings are very sombre, as in the case of mountain slopes with thick grass, shrubs, and trees, it is advisable that the exposed parts of the fort should be dark-coloured, and in such conditions a window opening will not stand out very clearly from the surroundings, but appears as a white spot when covered by a light-coloured shutter.

The appearance of the dark window opening or of the white shutter for a longer or shorter period (about 4 and 1 beats of marching time) signifies dashes and dots of the Morse alphabet, which by means of the telescope are read from the opposite station. In this case a telescope stand is not required, as a loop-hole with a specially prepared bed for the

instrument would be more suitable. The size of the shutters is naturally dependent on the required range. But given flags and shutters of equal dimensions, one can obtain a considerably longer range with the former, which is explained by the effect of contrast in such case. With flags, which allow of positions at selected points, it may be arranged to have as a background either the clear horizon or, in mountainous districts, the slope of a distant mountain.

In both cases the flag stands out as a dark or light object more clearly than a shutter at the same distance, and for that reason the former is visible at greater distance.

Practical experiments taught that signalling with shutters 0·8 metre wide and 1·9 metres high could only under very favourable conditions be carried out to a distance of 13 kilometres, whilst under normal conditions a range of from 4 to 6 kilometres only could be relied on.

It is needless to mention that shutters are only applicable to stationary positions, and are unfit for movable equipments.

In the past, however, a class of signalling apparatus, which took the form of a Venetian blind mounted on a wooden stand, was employed, but the results were decidedly unsatisfactory. On the other hand, shutters can be used for signalling purposes at night, when combined with the hereafter-mentioned reflector lanterns.

III. *Reflector Lanterns.*—The reflector lanterns consist of a spherical glass or metal mirror with a light at the focus. An ordinary petroleum lamp with a flat or round burner furnishes the simplest means of providing the light, and for protection against wind and weather the mirror and lamp are enclosed in a suitable lantern case. (Plate 6, Fig. 1.)

The range of such a reflector lantern increases in proportion to the area of the reflecting mirror and to the quality of the lamp.

Fig. 2 shows a reflector lantern of very simple form, as used with Ebner's signalling apparatus. The diameter of the metal mirror in this model is 30 centimetres, and the petroleum lamp, with a flat burner, has a candle-power of six and burns for six hours. Comparative trials were made with this lamp, and another to be presently described. They were found to be of approximately equal value.

Very exhaustive and numerous experiments were made with a reflector lantern fitted with a spherical concave mirror of glass (moulded and not ground), of 30 centimetres diameter and 16 centimetres focal length, and using a round burner petroleum lamp of about 15 candle-power. The light of this lantern at night was seen with the naked eye, even in a slightly hazy atmosphere, at a distance of 25 kilometres, and with the telescope a maximum range of 47 kilometres was obtained, this latter result, of course, only in a clear atmosphere, as it is impossible to see objects at that distance through even a slight haze. At times it happens that although the stations are themselves beyond the range of vision owing to fog, yet the light of a lantern, particularly when very powerful, penetrates the veil of fog and makes communication possible. This applies, however, only to a slight density of fog. The light of this lantern is also visible by day at varying distances as a yellow sparkling

point, but the range depends in a great measure on the condition of the light. Even under most unfavourable conditions, in daytime and with clear sunshine, one station being exposed to the direct rays of the sun, the light was seen at 8 kilometres distance; only an open gateway serving as a dark background. However, under better conditions signals can be given in daytime with this pattern of reflector lantern to a distance of 10 to 12 kilometres, and in a few instances experiments under a cloudy sky with a clear atmosphere resulted in a range of 25 kilometres being obtained by day.

IV. *Signalling Projectors*.—Optical signalling lanterns increase considerably in effect when the dimensions of their reflecting mirrors and of the intrinsic brilliancies of their lights are increased. Repeated experiments have been made in this direction, concave mirrors 40 to 60 centimetres in diameter being used. (Figs. 3 and 4.)

With a diameter of 60 centimetres, it may be assumed that the outside practical limit has been reached, not so much on account of the cost which rises considerably with an increase of surface, but more particularly because the dimensions of the mirror govern the proportions of the whole apparatus, and with a 60-centimetre mirror these become fairly bulky and produce difficulties with regard to transport.

Various means were resorted to in order to increase the brilliancy of the light. At first an apparatus was constructed on the principle of the reflector lanterns, with a ground mirror of 40-centimetres diameter and using a petroleum lamp of 40 candle-power. But the results of these experiments were not particularly favourable, as the increased effect was slight in proportion to the simple reflector lantern with 30-centimetre mirror and lamp of 15 candle-power, and was not in proportion to the increased cost and the bulk of the apparatus, the cause of which is explained in the following sentence.

In petroleum lamps a higher candle-power can only be obtained by employing larger wicks, thereby increasing the size of the flame. For visual signalling, however, a large flame is no more useful than is a small one of equal intrinsic brilliancy, because by enlarging the flame the rays of light reflected by the mirror are dispersed to a greater angle than by a smaller one. A large flame is certainly visible over wider limits measured at right angles to its beam, but is not clearer at any fixed point in the beam than with a small flame, and therefore is not visible at greater distances. In addition, there is the difficulty of attending to a larger burner, as compared with that of an ordinary lamp; large burners, moreover, give a reddish-yellow flame, and when not properly attended to they are liable to smoke and burn dimly.

When it was thus ascertained that the light from a petroleum lamp could only be improved to a very slight degree, the necessity was apparent of seeking other sources of more intense intrinsic brilliancy.

V. *Signals with Magnesium Light*.—Magnesium light seems to suggest itself at once as an illuminating agent, being very effective and easily managed.

The metal, as we know, when burnt in the form of thin tapes or threads gives a very intense light, and it is quite possible to produce with a single tape a light of from 130 to 180 candle-power. Certainly, the dense smoke and the rapidity with which a coating of magnesia forms on the lens and on the whole apparatus mar the effect, but good ventilation does much towards remedying this evil. To keep up an even degree of light was found to be much more difficult, and, in fact, almost impossible, as the product of combustion is not a gas as in most other sources of light, but is a solid and refractory substance, viz., oxide of magnesium. The formation of oxide is simultaneous with the burning process, prevents admission of air and has a cooling effect, for which reasons the size and intensity of the light decrease in proportion to the accumulation of oxide, until the layer of oxide drops off, when the flame by the free admission of air again assumes for a time its normal dimensions. It occasionally happens that the flame is stifled and extinguished before the oxide falls off. To prevent this irregularity, or at least to reduce it to a minimum, there are two remedies:—

The one is to remove the oxide crust by means of rollers, and thus to keep the light fairly steady. The other is to use several tapes side by side, which tend to produce an even light, the momentarily small flame of one being compensated for by the simultaneous larger flames of the others.

Lamps with two, three, and six tapes were constructed and subjected to exhaustive trials; but in spite of the most exact regulation of the mechanical motor appliances a flame of even intensity could not be obtained, on account of the fresh difficulty presented by the inequality of the tapes, which excluded an equal raising of them severally; and when in a combination of several tapes one of them is in advance and another backward, it is, naturally, impossible to produce an even and continuous flame. Thus, although the magnesium light commends itself for signalling purposes by its great power and handiness, its employment, on the other hand, is excluded by its ever varying intensity, because a fluctuating light seen at a great distance might produce the impression of an intermittent obscuration, and it would be difficult to distinguish these casual effects from the obscurations used in signalling.

A further trial with a lamp of different pattern was also without results. In this lamp the magnesium is used, not in the form of tapes or threads, but finely powdered.

The signalling is done by blowing with bellows a certain quantity of powdered magnesium for long or short periods through a benzine flame, thus igniting the magnesium and producing a large and very intense light.

In order to ensure a rapid and unfailing ignition the powder is not blown by air alone, but with a mixture of air and benzine vapour. By this means the oxide formation at the burner is prevented, but there is still the difficulty of producing an even flame for the short period of 6 to 8 seconds, and the flame is so large (about 30 to 35 centimetres high and 4 to 7 centimetres wide), that it is difficult to concentrate it through a reflector in any fixed direction. When, therefore, the light is equal to

3,000 candle-power, it is not more clearly visible at great distances than is a small but well-concentrated light. There is, in addition, the high cost of magnesium to be considered, of which a considerable quantity is consumed when used in the form of powder.

VI. *Signals with Lime Light*.—Drummond's lime light affords another source of intense light. It is, as we know, produced from a mixture of oxygen and hydrogen gas directed on a small cylinder of lime, which is raised to a white heat and produces an intense light.

The production of such a light was formerly an inconveniently elaborate process. The oxy-hydrogen gases had to be produced initially and stored in gas holders, they had then to be compressed for field use into steel or copper reservoirs. The extraordinary spread of amateur photography in recent years has created a lively demand for strong sources of light, and has induced private firms to supply highly compressed oxygen in steel chambers. Ordinary coal gas can be substituted for hydrogen, and thus the production of lime light becomes a simple matter where gas works exist.

In order, however, not to be handicapped by the absence of gasworks, lamps are constructed in which the vapours of petroleum ether are consumed in contact with the stream of oxygen, which in conjunction with a lime pencil also gives a very intense light. A further improvement is made by using zirconia or compressed magnesia pencils instead of lime pencils, which are apt to be affected by moisture.

The former are dearer, but can be used in many cases where the lime pencils are useless.

According to experiments made by the Military Committee a lime light equal to 500 candle-power was obtained by the use per hour of 80 feet of oxygen and 160 feet of ordinary gas, the intensity of the light being more than doubled by using double the quantity of gas (1,150 candle-power). With the ordinary burners in use a more intense light could only be obtained by using considerably more gas, out of proportion to the effect, and therefore not economical.

The ordinary steel cylinders of commerce are 52 centimetres in length, 10 centimetres in diameter, and have a capacity of about 4 litres. The material being from 6 to 8 millimetres thick, they admit of being filled with oxygen under a pressure of 200 atmospheres, and can therefore receive up to 800 feet of gas, with a total weight of 8 to 10 kilogrammes. The consumption being from 80 to 160 feet of oxygen per hour, a reservoir of this kind is sufficient for a light of either 500 or 1,000 candle-power for 10 or 5 hours respectively. The weight of the lamp, the petroleum ether and other appurtenances being slight, it is possible to keep up a light of the above strength for 5 or 10 hours with an apparatus not exceeding 20 kilogrammes in weight. This is a trifle in comparison to the weight of an electric plant calculated to produce a similar effect, which requires either an apparatus of 50 Bunsen elements, or a dynamo with a petroleum motor of $1\frac{1}{2}$ -H.P. In the first case the weight would be about 400 kilogrammes, and in the latter 1,000 to 1,400 kilogrammes, *i.e.*, 20 to 70 times the weight of the lime light

apparatus, which is a serious item in the matter of mobility. Furthermore, the handling and care of an electric plant is much more complicated and difficult than is that of the lime light, the use of which can readily be acquired by any man of average intelligence selected from the ranks.

Appreciating these advantages of the lime light, experiments were made with it, employing the reflector lantern mentioned in Sect. III., the projector of 60 centimetres diameter and the signal apparatus of Tyschen, which will be dealt with hereafter. The results obtained were that the signals were seen by day and in sunshine with a medium telescope at a distance of 24·5 kilometres (Kahlenberg and Eichkogel near Guntramsdorf).

With the reflector lantern the signals were just sufficiently distinct, but with the 60-centimetre projector very good, so good indeed that the signals could be distinguished with a binocular glass and even with the naked eye.

The light, however, had not the effect of the electric arc light, but appeared of a reddish-yellow colour. The atmosphere was fairly clear during the experiments, but by no means free of vapours.

The main purpose being to find a light which should be visible *by day* at distances from 14 to 25 kilometres, and even farther if possible, the maximum range by night was not ascertained; but it may be assumed from the results of prior experiments, with a small electric arc light, that lime light is effective at night to a distance of 47 to 50 kilometres.

The experimental employment of lights which are visible at long distances by day had a double purpose. Flag signals which, as has already been seen, are very suitable for day signalling, are combined with the disadvantage of being visible in all directions, and, from being so noticeable, they attract not only the attention of the enemy but also his fire; and therefore it is only possible to conceal the purport of messages by the employment of cypher, whilst it is impossible to conceal the fact that communication is being made. Signalling with lights, on the contrary, is difficult and often impossible, to detect by day, hence the process gives a better guarantee of secrecy. On the other hand, the range of flags is also more limited and extends only under favourable conditions from 25 to 37 kilometres.

The experiments with lime light were repeated in the Tyrol, but less favourable results were obtainable at 14 kilometres, the light being visible by day but not as distinctly as were the flags for reading purposes. Considering therefore the greater simplicity of flags, the Drummond light may be put out of question for such distances by day, and reserved only for very long distances exceeding 40 kilometres by night.

VII. *Signals with Electric Light*.—The most powerful source of light tried for signalling purposes was the electric light, which was used in two ways:—

- a. In the first method electric lamps were put into the apparatus illustrated in Figs. 3 and 4 and worked with a current of 6, 10, 20 and 40 amperes (800, 1,800, 5,000, 9,000 and 12,000

candle-power). Even with the weakest current the light was visible by day with a telescope up to 25 kilometres, and with 5,000 to 12,000 candle-power as far as 47·5 kilometres in daytime; but a trial over the points Kahlenberg-Sonnenwendstein on the Semmering Mountain, a distance of 80 kilometres, was unsuccessful both by day and night, on account of the atmosphere being insufficiently clear.

In these experiments the light was directed, as usual, by the mirror as accurately as possible upon the opposite station.

- b. The other method of signalling with electric light was by means of the comet-like beam of light reflected at night from a projector which is visible for relatively great distances. In these experiments the projector of the portable electric apparatus was directed towards the sky at an angle varying from 30° to 50° , and the beam of light visible in the atmosphere in all directions was observed from various stations.

During the first experiment of this kind the apparatus was placed in the yard of the electro-technical factory of Bruckner, Ross & Co., Baumgasse, Vienna, III., whilst observing stations were fixed at the Schmelz, the Kahlenberg, in Kaiser-Ebersdorf, Klosterneuburg, Korneuburg, Mödling, Baden, Felixdorf, Wölldorf, Wiener-Neustadt, Hainburg, and Neulengbach. The light was worked with various currents, viz., 12, 25, and 50 amperes (2,000, 7,000, 18,000 candle-power) with the result that the signals were seen to a distance of 42 kilometres (Wölldorf, Wiener-Neustadt).

Secrecy is, of course, out of question in this method, which necessitates the use of a cypher code. On the other hand, there is the advantage that these signals travel, so to speak, round the corner, *i.e.*, they are effective between stations hidden from one another by intervening heights and mountains, as is the case between Vienna and Neulengbach, where in spite of a chain of mountains the signals were seen.

Other experiments at ranges of 40 to 100 kilometres were not successful, owing to the state of the atmosphere.

The explanation of such signals being visible over the tops of intervening high mountains is that the beam of light directed upwards, although it has to traverse the atmosphere and although it continuously loses illuminating power owing to its divergence, yet the absorption in the higher regions is small. This will be understood on referring to Fig. 5.

When the beam strikes the clouds (as shown at *W* in Fig. 5) and lights them up the signals become more prominent. This result was observed at trials in Baden and Ansbach.

It may be taken for granted that special apparatus for this method will not be adopted, but a search-light apparatus may occasionally be made as an accessory for signalling purposes.

VIII. *Signals with the Light of the Sun.*—By far the most distinct signals can be given by means of the heliograph. A heliograph of a simple and suitable construction is that made by Bayer and Bessel (Fig. 6).

It consists of an ordinary plain mirror SS , which can be revolved in both horizontal and vertical directions around the axes aa and z . Opposite to the mirror is a short tube R , firmly fastened to the bed uu and provided with a lid T .

Inside of the tube are cross-hairs. The whole can be fastened to a stand by the screws mm .

The method of using the apparatus is as follows :—

The mirror is placed so that the opposite station can be seen through a small spot O , scraped out at the back of the mirror, and the tube R , in alignment with the cross-hairs. This done, the lid T is turned down and the mirror then moved in both directions until the light is reflected into the tube R and in the exact direction of the opposite station. The signals are made by obscuration either with a card or a special appliance. Some apparatus are constructed to admit of a vertical change of direction of the mirror by a key, when the light goes up, and is invisible at the opposite station, the mirror falling back into the original position on releasing pressure on the key.

Experiments made by the Military Committee in 1874 and 1875 gave a range of 54 and as high as 95 kilometres; the latter between Schneeberg and Hundsheimerberg near Deutsch-Altenberg; in daytime, of course, as sunlight is the first condition.

The larger the mirror and the more exact the adjustment, the better the effects.

A heliograph of the Mance system combining both these advantages is shown in Fig 7. It is the same in principle as that of Bayer and Bessel's, only the mirror SS and the sighting arrangement VV are mounted on separate stands, which allows of tenfold increase of distance between mirror and sight, and therefore ensures a more exact alignment on the opposite station. The mirror is also larger. The place of sighting tube is taken by a disc VV , with a circular opening and cross wires. As in the former, the sight is taken through a small hole in the mirror and over the cross, the mirror being so adjusted that the reflected light falls in the opening of the disc and a concentric halo of light r, r, r, r appears on the margin. By pressure of a key T the mirror is elevated to a slight angle, and the obscuration effected.

When the sun is at the operator's back, a second mirror is required, also movable in all directions, and by a double reflection the desired direction is given to the light. It is best that the auxiliary mirror should be the larger one, as otherwise the whole area of the first is not lighted up.

Although the heliograph is very effective, its employment must be limited, as clear days and sunshine are essential, and it often happened during the experiments that clouds were hanging over one or the other station, and made communication impossible.

The heliograph is employed most successfully in cloudless Egypt, and in India, where it is much used by the English troops.

A further drawback is that the heliograph can only be used in the open, and can scarcely be placed in the interior of a casemate, which is possible with other signalling apparatus using artificial light.

IX. *Signalling Telescopes*.—In the before-mentioned signal lanterns, mirrors are required to reflect and concentrate the light, but a similar effect can be obtained by means of signalling telescopes with glass lenses. Neglecting the consideration of the varying transparency of the air, the success of optical signals depends not merely on the intensity of the light and on the size of the reflecting mirror, but also on the dispersion, which is a material factor. As we shall prove elsewhere, the theoretical condition that rays of light proceeding from the focus of a concave mirror or glass lens may be sent forth in a bunch of exactly parallel rays is practically unattainable, because this would require the concentration of the source of light into a mathematical point, whilst in reality every flame, and every light produced artificially, has a certain area, which is greater in proportion to its power. Every apparatus, therefore, sends forth the rays, not parallel, but diverging at a slight angle. In apparatus with concave mirrors this angle varies between 2° and 10° , and can only be reduced to $1\frac{1}{2}^\circ$ under most favourable conditions. But in employing telescopes the bundle of rays can be concentrated to 20 or 30 minutes, and, therefore, it is clear that an apparatus with a dispersion of 2° throws its light upon a surface thirty-six times as great as an apparatus with a dispersion of only 20 minutes.

Using in both cases the same source of light, the concentrated light of the latter would be thirty-six times clearer to the distant observer than that of the former.

The construction of telescopes, as represented in Figs. 8 and 9, rests upon this idea. Any telescope with large objective will answer; it requires no alteration, but is only provided with the astronomic ocular glass, that is, with a powerful magnifier with small focal length. In front of the ocular an ordinary petroleum lamp *L*, or any other source of light, as intense as possible, is placed.

The rays taken up by the ocular *O* (Fig. 10) unite in the point *P*, which, however, is not the focal point, the light not being at a distance, but, on the contrary, very close to the ocular lens. But the point *P* must be the focal point of the objective lens to satisfy the condition that the rays proceed from the objective lens in a direction as nearly parallel as possible. It is naturally impossible to obtain exact parallelism, for however small the concentration of the light at the point *P* may be, it is far from being a mathematical point, but the dispersion decreases in proportion to the decrease in focal length of the ocular.

A concentration of the rays down to 20 minutes is obtained with telescopes, but the advantage in respect of theoretical intensity is considerably reduced because oculars of small focal lengths have also a small diameter, and therefore receive only a comparatively small fraction of the rays from the lamp, the remainder being lost for signalling purposes. As a rule a second terrestrial telescope *BB*, placed upon the same stand with the signalling telescope *SS* (Fig. 9) is used in the adjustment of the signalling instrument, and for observing the opposite station. The better the source of light, and the larger the objective, the greater the effect of the instrument.

A suitable proportion between the focal length and the diameter of the object and ocular lenses is essential. In practical experiments with telescopes the results were not particularly satisfactory on the whole. An instrument with non-achromatic object lens of 20 centimetres diameter (90 centimetres focal length) carried signals to a distance of 25 kilometres by night, visible to the naked eye, but at the very limit of discernment; and the signals from a smaller telescope of 5 centimetres diameter (80 centimetres focal length) could be read at night with a binocular glass at the same distance, the angle of dispersion being 20 minutes in the former and 30 minutes in the latter. An ordinary petroleum lamp of 10 candle-power was used. In daytime, however, the signals in both instances were not visible at 9.5 kilometres, not even with a good telescope.

A trial was then made to increase the distinctiveness of the signals by using an electric lamp, a so-called semi-incandescent lamp on Reynier's system. Such a lamp (Fig. 11) consists of a thin carbon pencil KK of about the thickness of a knitting needle, resting upon a small wheel V of retort carbon. The pencil is enclosed in a metal case $h h$, and a small weight g presses it downwards.

When an electric current is led from " a " into the metal case by h and the contact brush S into the carbon K and back by rb , portions of K and r become white-hot, and a specially intense light is generated at the point of contact c between the wheel and the carbon pencil; and as this light has a limited area, it appeared most favourable for use with signalling telescopes. The experiment was made in daytime, 12 large Bunsen elements being used in feeding the lamp, which produced a light of 50 to 60 candle-power. The results on account of the unfavourable condition of the weather being unsatisfactory, the experiment was not repeated, the care of so many Bunsen elements being too complicated for practical use. Using petroleum light the telescopes gave less distinct signals than the simpler and cheaper reflector lanterns, and therefore experiments with telescopes were abandoned, their adjustment being difficult and requiring much practice and technical knowledge, and on that account they were found less suitable for employment in fortresses.

X. *Mangin and Tychsen Apparatus*.—Mangin's apparatus is very practical, as also is another form of the same, improved in some details, by Tychsen. This apparatus (Figs. 12 and 13) consists of a square prismatic steel case $abcd$, on the front face of which a large bi-convex glass lens LL is let in. In the focus of the lens there is either a petroleum lamp R , in Fig. 12, or sunlight is used, as in Fig. 13, for which purpose a plain mirror SS is used which reflects the light upon a lenticular system ee, e_1e_1 , producing a concentration of light at the focal point R . If necessary, an auxiliary mirror S_1S_1 can be added.

The lamp or sunlight concentrated at R is, with a small angle of dispersion, thrown on the opposite station through the lens LL . A telescope is used for the adjustment of the apparatus and for observing the signals from the opposite station; this is enclosed in the case $abcd$ (not seen in Figs. 12 and 13), and its optical axis is parallel to the axis of the lens LL . The case has a partition, $W'W'$, with an

opening OO , which can be closed at will with a shutter K , by pressing a knob. By this arrangement the signals are worked. The apparatus rests upon a three-legged stand, and can be moved in a horizontal as well as a vertical direction.

The flap d in front serves as protection against sun and rain.

The Tychsen model is constructed to use besides petroleum and sunlight also electric and lime light. It is also produced in various sizes with object lenses of 10 centimetres diameter in the so-called Cavalry apparatus, and of 14 centimetres diameter for field and fortress use.

Practical trials with the smaller Mangin model using petroleum light gave a range by day, using a telescope, of 4 kilometres and 25 kilometres at night; by using sunlight the range was 12 kilometres for the naked eye, and 25 kilometres, but indistinct, with a telescope.

The results of trials with the larger Tychsen model were as follows:—

a. With lamplight.

By day with the telescope, indistinct at 12 kilometres, and with the naked eye invisible at 4 kilometres; at night with the naked eye barely visible at 25 kilometres, but distinct with telescope.

b. With limelight (500 candle-power).

By day indistinct with the naked eye at 12 kilometres, but visible at 24·3 kilometres with telescope.

c. With sunlight.

At 25 kilometres good with the telescope, but indistinct with the naked eye.

It is thus seen that both models when using lamp or lime light are inferior to the simple reflector lantern, but have the advantage of being able to work with sunlight and to obtain a range of 25 kilometres by day.

XI. *Balloon Signalling.*—Captive balloons—capacity, 100 to 150 cubic metres—are used and lighted and obscured by electricity conveyed along the cable holding them.

An experiment was made in Belgium with a balloon of 4·5 metres diameter. It was allowed to ascend 90 metres. It was seen well at night at 4 kilometres, but absolutely invisible at 18 kilometres.

Another method is to direct a search light upon a captive balloon.

The system is impracticable on account of difficult arrangements, can only be used in calm weather, and the results are not satisfactory.

XII. *Concluding Remarks.*—The above detailed apparatus may be taken as the most important types for land service, and it has been shown that a variety of implements exist for signalling, both by day and by night, to a distance of 25 kilometres. But for greater distances—say 40 to 80 kilometres—possibly often required for military purposes, we have only the heliograph and large concave glass mirrors with electric light, both of which can only be used under certain conditions; the former only with a clear sky, the latter if electric apparatus be at hand and suitable transport be obtainable.

Both of these conditions can only exceptionally be met.

It appears desirable, therefore, to make further improvements in signalling apparatus for long distances, which task will be the object of

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further experiments by the Military Committee. In conclusion, there is another circumstance to be considered, *i.e.*, the atmospheric condition, which is of first importance in all kinds and methods of visual telegraphy.

When it is said that an apparatus has such and such a range, the expression only holds good for a certain degree of transparency of the air and the kind of light used, both of which vary under circumstances without it being possible to give in figures the exact transparency of the air or the influence of sunlight.

Irrespective of dense fog (such as, for instance, the well-known and notorious London fogs) which can attain such a density as to make it impossible to see objects at 2 metres, there are various degrees of transparency even when the atmosphere is apparently clear. At short distances, in streets and open places of a town, these differences are not noticeable, but they are at long distances, when they play a most important rôle.

The limits of transparency of what is considered a clear atmosphere may be defined by considering that the outline and contours of mountains may be seen as distinctly at 80 to 90 kilometres on perfectly clear days as at 3 to 4 kilometres on hazy days, a variation of 20 to 30 degrees.

A layer of fog 10 metres in thickness absorbs as many rays as an 8,000 times thicker layer of clear air.

[Here follow notes on the unsuccessful attempts to measure the transparency of the air.]

Background.—Not less important for the distinctness of day signals is the effect of contrast between the colour of the signalling instrument and the background. The darker the background, the clearer and more visible at longer distances are the signals. For this reason light signals are more distinct under a cloudy sky than in bright sunshine, and are naturally best at twilight or in complete darkness, when the contrast is greatest.

The dependence of the distinctness of signals on variations in the condition of the atmosphere, on the varying contrast effect, and on the greater or lesser degree of expertness in the use of the telescope, explain the many often contradictory opinions on apparatus, whereby good and effective instruments are frequently discredited.

It cannot be denied however that signalling, in spite of defects and disadvantages, offers a good and often indispensable auxiliary for many military purposes; and its study should, therefore, not be neglected.

See Table showing results of experiments.

TABLE OF RESULTS OF TRIALS OF VARIOUS SIGNALLING ARRANGEMENTS.

Types of Signalling Apparatus.		Source of Light.		Ranges in Kilometres at which Signals were seen.				Remarks.
Description.	Diam.	Description.	Candle-Power.	By Day.		By Night.		
				With the naked Eye.	Through a Telescope.	With the naked Eye.	Through a Telescope.	
Small Signal Telescope .. 5 c.m.		Paraffin Lamp	10	0	4	?	25	Bad weather.
Small Signal Telescope .. 5 "		Semi-Incandescent Electric Lamp	50	?	?	?	(weak)	
Large Signal Telescope .. 20 "		Paraffin Lamp	10	0	4	25	25	
Mangin Lantern 10 "		Paraffin Lamp	10	0	4	(very weak)	(good)	
Mangin Lantern 10 "		Sunlight	?	12	25	12	25	Not tried by night.
Tychsen Lantern 14 "		Paraffin Lamp	12	0	(weak)	(very weak)	(good)	
Tychsen Lantern 14 "		Sunlight	?	25	25	—	—	
Tychsen Lantern 14 "		Limelight	500	(weak)	(good)	?	?	
Ebner Lantern 30 "		Paraffin Lamp	6	0	12	25	25	
Reflector Lantern 30 "		Paraffin Lamp	12	0	(weak)	(good)	(very good)	
Reflector Lantern 30 "		Semi-Incandescent Electric Lamp	50	?	25	(good)	(very weak)	
Reflector Lantern 30 "		Limelight	500	12	25	?	?	
? ? ? "		Magnesium Tape	600	(weak)	(good)	?	?	
? ? ? "		Magnesium Powder	3000	12	25	?	?	
Projector 60 "		Paraffin Lamp	40	(very good)	(good)	?	?	
Projector 60 "		Limelight	500	?	25	25	47	
Projector 60 "		Electric Arc Light	800 to 9000	(good)	(weak)	(good)	(very weak)	
Projector 60 "		Electric Arc Light	800 to 9000	25	47	47	80	
Heliograph of Bayer & Bessel ? "		Sunlight	?	(good)	54	(good)	(?)	
					(weak)	—	—	