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The Means of Communication between Aeroplanes and the Ground

EDITED AT THE
ARMY WAR COLLEGE
SEPTEMBER, 1917

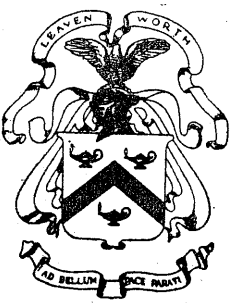
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WAR DEPARTMENT,

WASHINGTON, *September 14, 1917.*

The following pamphlet, "The Means of Communication Between Aeroplanes and the Ground," is published for the information of all concerned.

[311, A. G. O.]

BY ORDER OF THE SECRETARY OF WAR:

H. L. SCOTT,
Major General, Chief of Staff.

OFFICIAL:

H. P. McCAIN,
The Adjutant General.

WAR DEPARTMENT,
THE ADJUTANT GENERAL'S OFFICE,
WASHINGTON, *June 19, 1917.*

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BY ORDER OF THE SECRETARY OF WAR:

H. P. McCAIN,
The Adjutant General.

TABLE OF CONTENTS.

	Page.
The means of communication between aeroplanes and the ground	7
Wireless telegraphy	7
Sending and receiving of Hertzienne waves	7
Consonancy of the receiving antennæ with the sending antennæ	9
Wireless telegraphy in different sounds	13
Receiving in the microphone	15
Number of aeroplanes able to work simultaneously by combining the two processes	16
Radio officers for the air squadrons	16
Résumé of the idea of wireless telegraphy given in the preceding paragraphs	18
Visual signals	19
Rockets	20
Weighted messages	21
Audible signals	21
Wireless telephone	22
Means of communication from the ground to aeroplanes	23
Conclusion	24
Appendix:	
Wireless telegraphy section of the air squadron	25
Organization of wireless telegraphy—communications between the air squadrons and the command posts of the divisions and groups of divisions	26
Receiving on aeroplanes	27
Manual of position warfare for all arms—Translation of a German document:	
I. Infantry aeroplanes	28
1. Importance of the infantry aeroplane service	28
2. Duties of the infantry aeroplane	29
3. Employment and command of infantry aeroplanes	29
4. Means of communication	30
5. Method of carrying out the duties of infantry aeroplanes	32
6. Training of the troops	35
II. Captive balloons	36

THE MEANS OF COMMUNICATION BETWEEN AEROPLANES AND THE GROUND.

[Translation from a French official document of December, 1916, by the Army War College, September, 1917.]

Wireless telegraphy will be the method always employed whenever it is possible to use it, as experience has shown that it gives about ten times better results than any other (with the exception of the wireless telephone).

The methods employed in lieu of wireless telegraphy, when the latter can not be used, are visual signals, rockets, and the movements of aeroplanes. Wireless telephone and audible signals are also discussed in this pamphlet.

WIRELESS TELEGRAPHY.

Before demonstrating the advantages of wireless telegraphy and the best means of increasing its efficiency we will give a brief explanation of the apparatuses used by the aeroplanes and the batteries.

SENDING AND RECEIVING OF HERTZIENNE WAVES.

An electric current passes through the antennæ of a sending station. This current produces a disturbance in the surrounding ether in much the same way that a stone thrown into a lake sends out ripples which spread out toward the shore. Just as a cork floating on the water bobs up and down when reached by the ripples in our metophore, so, when the first wave sent out by the antennæ meets the antennæ of the receiving station, a like disturbance occurs; in other words, it produces an electric current. This is the current used to set the microphone in action, by means of which the wireless operator perceives the Hertziennes waves in the zone of his antennæ.

Let us go a little deeper into the working of these phenomena. When a current is sent through the sending antennæ it does not stop instantly with the cause that produced it. Just as a guitar string continues to vibrate after it has been struck, the sending antennæ continues an electrical vibration after receiving its first impulse. The current permeating it from end to end is followed by a countercurrent, then by a current in the old direction, and so on, until the vibrations die out like a cord of music. Each electrical vibration from the sending antennæ disturbs the surrounding ether as in the first instance, sending out a wave which follows on the heels of the preceding one. These waves all advance at a rate of 300,000,000 meters per second, like the light waves which only differ from them in the distance separating the successive waves. Therefore, if the number of vibrations of the sending antennæ is 1,000,000 per second, for instance, the waves sent out will succeed each other at an interval of a millionth part of a second, an interval during which these waves pass over $\frac{300,000,000}{1,000,000}$, or 300 meters. This interval between two waves represents what is called "wave lengths sent out by the antennæ." The wave lengths sent out by an antennæ of 1,000,000 electrical vibrations per second are, therefore, 300 meters. The light waves only differ from the Hertzienne waves by their length. The sending equipment of a wireless telegraph only allows it to send out waves on a scale varying from several thousands of meters down to a few thousandths of a meter, whereas the light waves are somewhere around a millionth of a meter.

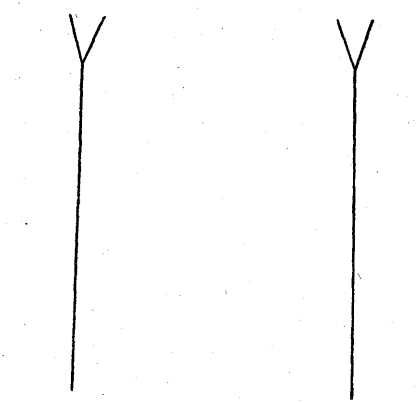


Fig. 1.

We have just seen how the sending antennæ, with a vibrating power of a million vibrations per second, can send out a series of waves separated one from the other by a distance of 300 meters. When these waves meet the receiving antennæ the same thing occurs as when the cork on a lake is lifted by each wave coming from the spot where a stone was thrown. When each wave from the sending antennæ strikes the receiving antennæ the latter receives an electrical current. Since the waves which strike the receiving antennæ succeed each other at a distance of 300 meters—that is to say, arrive at intervals of a millionth part of a second—the receiving antennæ, like the sending antennæ, will have an electrical vibratory power of a million vibrations per second.

CONSONANCY OF THE RECEIVING ANTENNÆ WITH THE SENDING ANTENNÆ.

If an electrical vibration is started in a sending antennæ, like the one of which we have been speaking, by sending a current and then leaving it to its own vibration, like the guitar string that has been struck, it can be shown that the length of the Hertzienne waves sent out are equal to four times the length of the antennæ. For instance, in order to send out waves of 300 meters in length, the sending antennæ would have to have a length of $\frac{300}{4} = 75$ meters. In practice, on aeroplanes, whose metallic mass is insufficient to form an electrical balance to antennæ of great length, the coefficient 4 only applies to short-length antennæ (30 or 40 meters). It decreases in proportion as the antennæ is lengthened, and is reduced to about 3 for a hundred-meter antennæ. This last will therefore send out waves of 300 meters.

In order to determine the most favorable length for a *receiving* antennæ, let us study the phenomena of these antennæ more closely. When this antennæ receives the shock of the first wave from the sending antennæ it is charged with an electrical current sufficient to produce a series of electrical vibrations similar to those produced by the current in the sending antennæ. If the receiving and sending antennæ are of the same length, the natural vibrations of the former set in motion by the first shock will, like the latter, be at the rate of a million vibrations per second. But in this case the vibrations, succeeding each other at an interval of a millionth part of a second from the first,

will coincide with the arrival of the succeeding waves from the sending antennæ, since the latter also reach the recurring antennæ at intervals of a millionth part of a second.

The successive shocks that these waves give to the receiving antennæ have the effect of increasing its natural vibration, which was started by the shock of the first wave. In this case we say that the receiving antennæ is "tuned in with the sending antennæ."

This phenomena is similar to that produced when, on striking a guitar near another guitar, the string of the second guitar answers to the same note as that struck on the first guitar, setting it in vibration, whereas the other strings remain silent. We must obviously always endeavor to tune in the receiving antennæ with the sending antennæ, as it results in an enormous increase in the vibrations of the former.

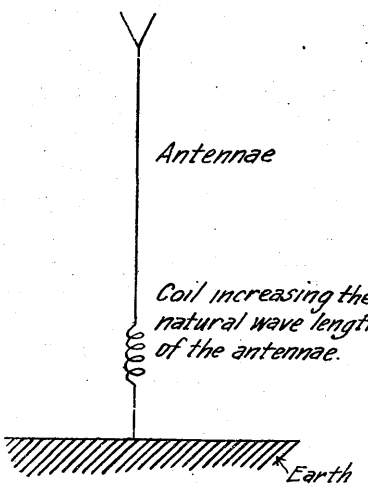


Fig. 2.

However, in view of the fact that it is necessary for all antennæ to be able to receive messages from all aeroplanes, it is possible, instead of having antennæ of corresponding lengths to those of the aeroplanes, to make use of contrivances shown later on to harmonize the receiving station with the sending station without its being necessary to change the length of the antennæ.

It can be shown that if we intercalate a coil of conducting wire between the antennæ and the ground it is equivalent to lengthening the antennæ, as far as the natural wave length is concerned. (Fig. 2.) It can also be shown that, inversely, if we intercalate a condenser we shorten the natural wave length. (Fig. 3.)

By combining these two devices—that is to say, by intercalating between the antennæ and the ground—a varying number of wire spirals of the same coil, together with a condenser whose surface can be changed by sliding one armature ahead of the other, we will succeed in obtaining an antennæ of varying natural wave length. (Fig. 4.)

The wave length is extended by intercalating the wire spirals of the coil and is shortened by diminishing the capacity of the condenser. We can thus "tune in" the receiving antennæ with any sending antennæ whatever, irrespective of the length of the

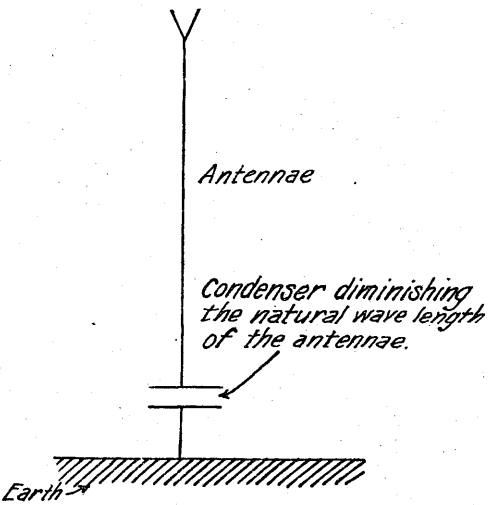


Fig. 3.

former. This consonance has been accomplished in such a way that if we vary the different natural wave lengths of the receiving antennæ while listening with the microphone of the latter for the messages of the sending station with which we desire to be in accord we will find that a decided strengthening of the signals in the receiving station will take place the moment they are in tune, a strengthening due, as we have seen, to the concordance of the successive impulses received by the antennæ from the passing waves with the natural vibration produced in the latter by the first wave shock.

We have just seen how a receiving station is "tuned in" with a sending station. This harmony has the effect of strengthening the signals from the sending station with which we are connected to the exclusion of all others, thereby obtaining the first method of "separating" it from all other aeroplanes telegraphing simultaneously and cutting out their disturbing influences.

If, for example, our receiving station is "tuned in" with a sending station with a natural wave length of 300 meters we would still hear the stations with natural wave lengths between 270 and 330 meters, for it is necessary that the wave lengths of two stations should differ by about 15 per cent in order that when harmonized with one of the stations we should not hear the other. For example, if eight aeroplanes are to be used simultaneously without conflicting it would be necessary for their sending stations to have natural wave lengths of 150, 180, 220, 260, 300, 360, 420, and 480 meters. (To obtain great wave lengths, we augment by intercalating a coil between the antennæ and the aeroplane. By this means, with antennæ of 120 meters, which, on an aeroplane, produce waves of not more than $120 \times 3 = 360$ meters, we can produce waves of 500 meters if necessary.)

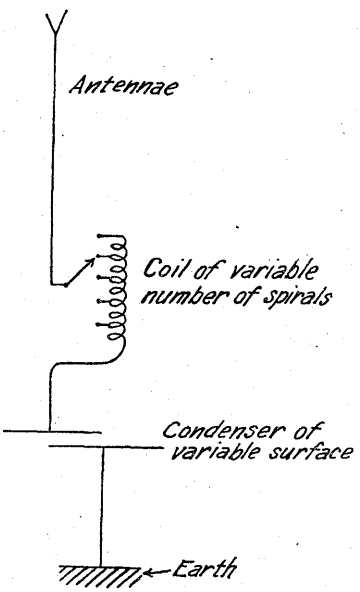


Fig. 4. Antennae of adjustable wave length

In view of what we have seen concerning natural wave lengths, it appears that the antennæ of aeroplanes should be one-fourth as long as their wave length. We can not have an antennæ of less than about 35 meters without weakening the power derived from the Hertzienne waves and reducing the

range of the machine too much. On the other hand, we can not have an antennæ of more than about 120 meters, for anything over that is liable to break when the aeroplane performs rapid evolutions. The range of wave lengths is therefore necessarily limited, as well as the number of aeroplanes able to work simultaneously, without conflicting, in a restricted zone like that of an army corps.

There is, fortunately, another method of separating the messages from two aeroplanes at the receiving station. Suppose, for instance, that two aeroplanes, with the same length antennæ and consequently the same wave length, are working simultaneously in the same zone. A receiving station "tuned in" with one of them will hear the other equally clear, but will be able to distinguish between them, provided the corresponding sounds in the two messages are in two different notes. With expert operators we may even use several aeroplanes of the same wave length sending in different notes. The operator would follow the message of any one amongst them in something of the manner in which the leader of an orchestra follows an individual instrument. This is the principle of the "musical spark" conceived by Col. Ferrie.

WIRELESS TELEGRAPHY IN DIFFERENT SOUNDS.

We will give a brief description of how these different notes are obtained.

The electrical impulsions necessary to put the antennæ of the sending station in vibration are obtained in the following manner: The antennæ is insulated electrically from the bulk of the aeroplane, and attached to one of the poles of an electric generator whose other pole is attached to the bulk of the aeroplane. The antennæ is terminated by a metal ball in front of which successively pass the points of a metal star, which is fastened to the axis of the machine and turns with it. This star is electrically connected to the bulk of the aeroplane. In short, the antennæ and the star are each attached to a pole of the machine, and consequently each time that the point *b* of the star passes close to metal ball *a*, which terminates the antennæ, a spark is struck between the ball and the star. (Fig. 5.) This spark sends an electric current through the antennæ, which then continues to vibrate and to throw out in its turn a succession of Hertzienne waves. These waves strike against

the receiving antennæ, as we have seen above, thereby starting the electrical vibrations, which jar the vibrating plate of the microphone. A succession of waves in this way produces a sonorous vibration in the plate.

When the succeeding point passes close to the ball a second spark is struck, a new succession of waves are thrown into space by the sending antennæ, and a second vibration of the microphone plate is produced in the receiving station by the second succession of waves.

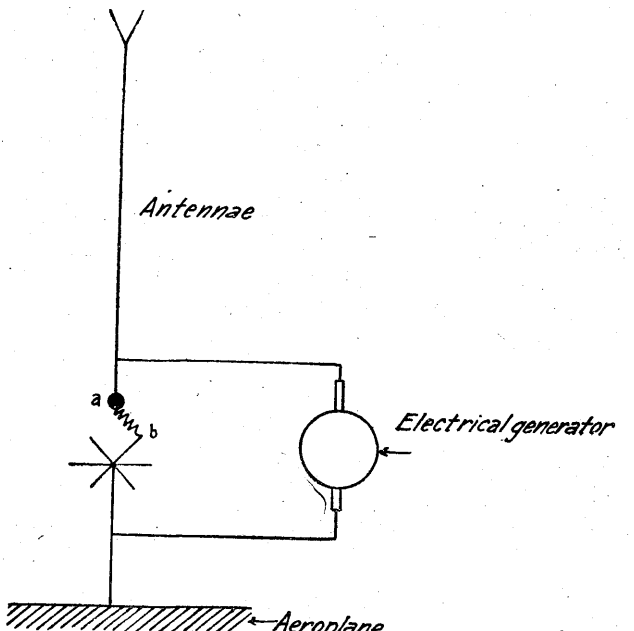


Fig. 5.

Each succession of waves in this way produces a sonorous vibration in the microphone plate.

If the generator of the aeroplane, and, in consequence, the star fastened to its shaft, makes 50 revolutions per second, and if the star has n branches, the pitch of the sound heard in the microphone will be of 50 n vibrations per second. By using stars with from 6 to 24 points, we obtain as many notes as there are different stars.

RECEIVING IN THE MICROPHONE.

In order to complete this explanation, it is necessary to show how a succession of waves produces a vibration in the microphone plate of the receiving station.

We have seen that, between the antennæ and the ground, there is a coil B_1 which is traversed by the vibrations produced in the antennæ by contact with the succession of waves from the sending antennæ (fig. 6).

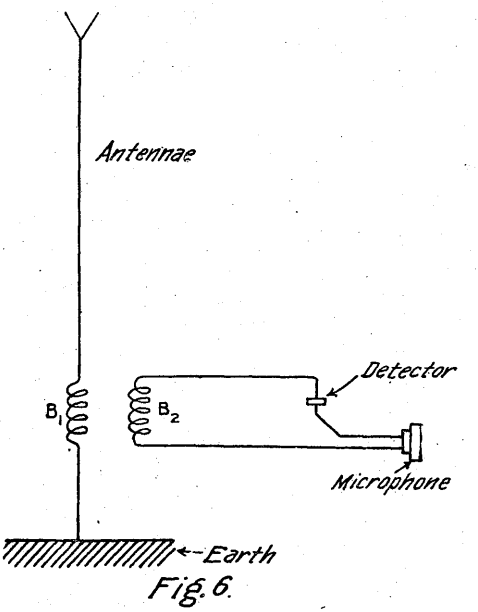


Fig. 6.

This coil B_1 in its turn acts as an antennæ and emits a succession of waves which strike a neighboring coil B_2, at the end of which the microphone is connected. This coil B_2 is in turn set in vibration, and the alternating currents running through it also run through the microphone. These currents would not set the microphone plate in vibration if the *detector* was not placed between the coil and the microphone. The rôle of the detector is as follows: The vibratory currents running through the coil B_2 change direction at each semivibration. The detector only allows the currents to pass in a given direction, in the

same way as the clapper placed in the pipe of a suction pump only lets the water pass in one direction. Now, although the vibratory currents have no effect on the microphone plate, the current directed by the detector draws this plate as long as the current lasts and allows it to return to its normal position when the current ceases, in this way setting up a vibration for each succession of waves that cross the receiving apparatus.

NUMBER OF AEROPLANES ABLE TO WORK SIMULTANEOUSLY BY COMBINING THE TWO PROCESSES.

If, therefore, we use five different notes for each one of the eight wave lengths at our disposal, for example, we can work about 40 aeroplanes (8×5) simultaneously in a zone with a radius of 10 kilometers without their conflicting. (Ten kilometers represents the maximum range of an aeroplane station.) This obviously requires a radio personnel who thoroughly understand their business, for, amid the cacophony made by 40 aeroplanes telegraphing simultaneously, it is necessary to understand the handling of the receiving station perfectly, and to have a practiced ear to be able to "tune in" the antennae with the antennae of the aeroplane with which we wish to be connected. *The proper working of a wireless telegraph depends above all on the quality of the operators in the receiving stations.* This is why we can not take too much pains to recruit the operators, as well as the auxiliaries of all branches, from among men whose profession renders them particularly fitted for this work—that is to say, from among electricians and students of technical schools whose habit of handling electrical machines and whose theoretical knowledge makes them particularly fit to understand the theory and use of a receiving station. A technical training of several weeks, at the very least, will be barely sufficient to ground this personnel.

RADIO OFFICERS FOR THE AIR SQUADRONS.

It has therefore been judged necessary to provide each air squadron with a radio officer, whose duty will consist solely of insuring the proper working of the sending stations of the air squadrons *and the receiving stations depending on it.* He will exercise a strict technical supervision over the personnel of the receiving stations, and at the same time complete their instruction on the spot.

By next spring each air squadron will be provided with its own radio officer, who will be charged, under the orders of the radio officer of the Army Corps, with the perfect transmission of information, beginning with the aeroplane observer down to the aerial officer of the receiving station, for all aeroplanes in his squadron.

As far as the batteries and command posts are concerned, the duty of the radio officer will consist of periodic visits to the wireless stations, to verify the choice of their position, the details of their mounting, and the ability of the operators. He will aid the latter by his advice. In case the wireless gets out of order, he will at once repair to the station in question, so as to take the proper measures for putting it in order.

In order to test the ability of the operators belonging to the battery, the radio officer will assist in the adjustment of the receiving apparatus and the receiving of messages from aeroplanes. He will complete, by judicious criticism on the spot, the instruction which it is impossible under the existing system to carry far enough in the schools.

He will establish calibrating curves for each aerial, which will allow the operator to prepare the adjustment of his receiving apparatus in advance, the moment he is notified by telephone of the wave length of the aeroplane with which the battery is to be adjusted. This precaution will save the operator much complicated testing, which, without these curves, is absolutely necessary in adjusting the receiving with the sending apparatus.

The amount of efficiency of the wireless telegraph, which is determined according to the number of aeroplanes able to work together with the least conflict, will be largely dependent on the intelligent use of the means here mentioned to facilitate its action. It is to be remarked that the successful employment of these methods does not depend exclusively on the wireless telegraph service, but also in a large degree on the good will shown by the other services in giving their assistance, either in facilitating the recruiting of the personnel, or in assisting the officers to obtain an effective control of the receiving stations.

If we stop to consider that the amount of information which the other branches of the service require of the Aviation Corps is growing with the rapidity of aviation itself; that, in spite of the immense strides made, the corps is still very far from

satisfying all these demands; and that the only means to insure the transmission of the bulk of this information is wireless telegraphy, we will realize the extreme importance of making every effort to develop this means of communication to its utmost extent, *which is only possible with the concurrence of all those who have occasion to use it.*

RÉSUMÉ OF THE IDEA OF WIRELESS TELEGRAPHY GIVEN IN THE PRECEDING PARAGRAPHS.

1. *Sending.*—The antennæ is attached to a pole of a generator. The other pole is attached to a metal star which revolves before

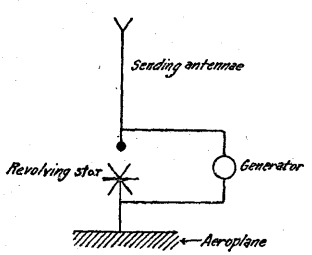


Fig. 7

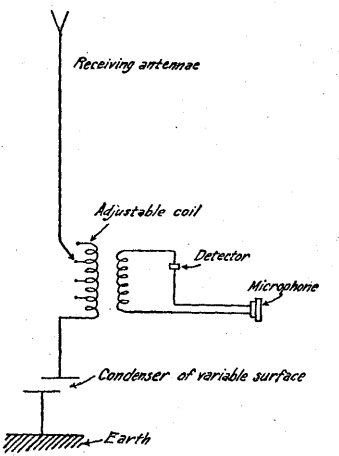


Fig. 8. Simplified receiving station

the metal ball terminating the antennæ. As each point passes, a spark is struck between the point and the ball. At each spark the antennæ vibrates and throws out a succession of waves whose wave length equals four times the length of the antennæ. (Fig. 7.)

2. *Receiving.*—When a succession of waves strike the receiving antennæ each wave produces an electrical vibration in the antennæ. (Fig. 8.) Also, under these successive impulses, the antennæ sets up a vibration according to the extent of its own wave length.

When the receiving antennæ is "tuned in" with the sending antennæ, its "natural" vibrations and the "artificial" vibra-

tions coming from the succession of waves mutually agree and strengthen each other. An increase of sound is then perceptible in the microphone which serves to distinguish the signals from the sending station with which we are trying to "tune in."

The receiving antennæ is "tuned in" with the sending antennæ by lengthening its natural wave length by means of a coil of conducting wire or by shortening it by means of a condenser in order to give it the same wave length as the sending antennæ. Each succession of waves causes the microphone plate to vibrate, and the number of vibrations in this plate corresponds to the number of sparks struck between the sending antennæ and the revolving star. By changing the number of points in these stars we obtain as many different notes as there are stars. If we use eight different wave lengths, with five different sounds for each wave length, we will have 40 different emisions at our disposal.

VISUAL SIGNALS.

At the present time visual signals are made with a searchlight whose rays are kept directed on the receiving station by the observer during the entire course of manipulation. We are striving to simplify the work of the pilot and the observer by replacing the searchlight by a 1,000-candlepower lamp furnished with a simple reflector and placed on the wings. The light signals made by this lamp can be seen by all posts within a radius of approximately 1,500 to 2,000 meters.

In any case, visual signals only lend themselves to a small number of operations, as they oblige the aeroplane to keep close to its receiving station and to fly low. Moreover, the sending of visual signals requires a great deal of care and attention on the part of the aeroplane observer and the receiving personnel, for in order to distinguish the dots from the dashes it is necessary to work on an extremely regular cadence. In short, the slow pace at which these signals have to be sent, in order to be understood, only permits the sending of very simple messages. In fact, it takes about *ten times longer* to send a message by visual signal than by wireless telegraphy.

Visual signals should therefore be reserved for operations which do not permit the use of wireless telegraphy because of the absence of a receiving station at the point with which we wish to communicate. This is the case, for example, in fire for

adjustment of trench mortars, in signaling to the Infantry or to the advance command posts, and, finally, in signaling during open warfare to other units momentarily without a wireless station. Visual signals are also useful during night flights to enable the aeroplanes to be recognized by friendly troops and to inquire whether the landing area is free.

In résumé, visual signaling will always have a much smaller range of usefulness than wireless telegraphy; but it should not be neglected, as it is capable of rendering valuable service under certain circumstances. The most interesting practical example that can be given of its use is that of the two fires for adjustment of trench mortars executed in midbattle during the Battle of the Somme by Capt. Amondson and Capt. Fèrre. It is easy to execute the adjustment of a single gun or of a battery in this manner, provided the adjustment is executed by salvos, which require only very simple signals for each observation. An Infantry aeroplane can also give certain information to an advance command post, on condition that simple signals agreed upon be used for this and that they limit themselves to the most important information.

Visual signals may have a much larger use in open warfare, where the land wireless stations will be less numerous and less well erected than at present, and this is the reason why it is necessary to practice the use of them at once, even in those sections where their immediate use can not be foreseen.

ROCKETS.

Rockets fired by the aeroplane observer are used at the present time by Infantry aeroplanes for making certain requests, as, for example, asking the fire line to stake out the first line by signals agreed upon in advance (panels, lights, and searchlights).

Signaling by rockets has the disadvantage of being illusive and of often passing unnoticed by those infantrymen whose eyes are not constantly fixed on their aeroplane. This explains the effort being made to replace them by audible signals, which do not present this drawback. (Sometimes the firing of a rocket is preceded by a cadenced machine-gun fire in order to attract the attention of the infantrymen for whom the signal is intended.)

Rockets, combined with the movements of aeroplanes, were used at the beginning of the war for fire adjustment by aero-

planes. It may be that in open warfare this practice will be renewed in the case of batteries which have lost their antennæ or have damaged their wireless apparatus. But visual and audible signals, which allow the sending of more detailed information than is possible in signaling with rockets or by the movements of aeroplanes, will generally be considered preferable.

WEIGHTED MESSAGES.

The dropping of weighted messages, with a pennant attached in order to show their dropping place, is especially used by Infantry and staff aeroplanes to send detailed information to the command posts on the aspect of the battle field when this information can not be sent by any other method. This includes, for example, accurate sketches of the positions reached by our troops, information of the enemy formations still holding out, of enemy defenses impeding our advance, of enemy barrage fire with indication of the batteries responsible for the barrage, and details on the condition of our units and of those of the enemy, etc. By this means aeroplanes can also carry orders from the command posts of Army corps or of divisions to the advance command posts which have no telephone connections.

In short, the use of weighted messages, already extensively supplementing the insufficient means or want of communication with the advance lines, will become still more extensive in open warfare, when this want will be felt even more.

AUDIBLE SIGNALS.

Audible signals are made by means of a siren or a claxon or by two compressed-air trumpets. This last method seems the best, as in these days trumpets have a greater range, and also they have two notes—deep and shrill—permitting a better combination of signals than is possible with the other instruments. For example, the deep notes can be considered as dashes and the shrill notes as dots in the Morse code.

On the ground a trumpet has a range of about 1,000 meters, which is increased by using an amplifier. An effort is being made to increase the range still more by a "sound selector," which intensifies the perception of the trumpet notes to the exclusion of all outside noises, such as cannonading. This selector, which has not yet been perfected, has been given some interesting trials.

Since sound signals from the air encounter no obstacles from the time they leave the aeroplane until they reach the receiving station, the trumpet range will doubtless be superior to what it is on the ground. We have already mentioned that audible signals have the advantage over visual signals and rockets of attracting the attention of those for whom they are intended without the necessity for a constant watch on the aeroplane from which the signal is expected. Moreover, audible signals give rise to fewer errors and are easier to understand than visual signals, since the ear is a quicker organ of perception than the eye.

Trumpets have already been successfully used by an Infantry unit at the time of the Chilly attack on the Somme in asking for barrage fire in front of the conquered position.

WIRELESS TELEPHONE.

Wireless telephone from the aeroplane to the ground presents enormous advantages over telegraphy, as it constitutes a much more rapid and complete form of communication, allowing the giving of important details in a few words, which could not be given by telegraphy on account of the length of time required for transmission. It will, therefore, be very valuable for any duty requiring rapid action on the part of Artillery or of the staff. It permits the aeroplane observer to give the signal for barrage or neutralizing fire at the moment of an attack, with as much precision and rapidity as a battery commander observing the enemy from an ordinary observation station connected by telephone with his battery. It permits the rapid sending of detailed information to the command post by an Infantry aeroplane concerning the condition of their troops and the aspect of the battle field.

The summary idea here given will show how much can be expected from an intelligent use of this means of communication. Unfortunately, from the technical viewpoint, there are some serious difficulties. These difficulties chiefly arise from the danger of conflicting, which is much greater than with wireless telegraphy.

The trials up to date have shown that it is easy to telephone from an aeroplane to the ground, even at great distance, provided we are not troubled by wireless telegraphy messages. But the moment we attempt to use the wireless telephone and

wireless telegraphy together, it is quite another matter. Although it is possible to distinguish easily messages from several aeroplanes telegraphing with the same power on the same wave length, provided they are on different notes, it is practically impossible to distinguish two simultaneous conversations by wireless telephone on the same wave length.

Moreover, telephone messages are much less strong than wireless telegraphy messages for the same power of aeroplane station, and the danger of their conflicting is therefore greater. These obstacles might possibly, however, be partially overcome, first, by limiting the use of the wireless telephone to aeroplanes whose duty would most require this improved method of communication, confining it, for example, to one aeroplane per army corps. In this way we will avoid having aeroplanes provided with telephones conflicting with each other. To avoid conflict with aeroplanes carrying wireless telegraph, longer wave lengths will be reserved for the telephones than for the telegraphs—lengths of from 570 to 700 meters for instance, if the aeroplanes carrying wireless telegraph stop at 500 meters. (The wave emission used in the wireless telephone is accomplished by means of an apparatus founded on slightly different principles from those discussed above. The successive series of waves is replaced by a succession of uninterrupted waves. With antennæ of 120 meters, these apparatus enable us to obtain wave lengths over 500 meters.)

MEANS OF COMMUNICATION FROM THE GROUND TO AEROPLANES.

Panels are convenient, since the signals can be left on the ground until the observer has thoroughly understood them. They are also rapid, since the observer can take in the message at a single glance. On the other hand, they have the disadvantage of being seen by enemy aeroplanes.

Searchlight signals are more difficult to use than the preceding, since they are less quick to attract the attention of the aeroplane observer and are slow and more difficult to make out without making mistakes. On the other hand, they have the great advantage for the advance lines of not being seen by the enemy.

Signal lights serve to mark a line. They quickly attract the attention of the aeroplane observer and do not remain on the ground like the panel signals in case our troops retreat. On

the other hand, they attract the attention of the enemy and lend themselves to attempts on the enemy's part to confuse our signals.

Wireless telegraphy.—Although this means of communication can not be used in the present warfare, on account of the conflict and errors to which it would subject the great mass of messages sent out by aeroplanes carrying wireless telegraphs, it will render important service in open warfare, when it will be impossible, on account of the lack of telephone lines, to establish any previous detailed understanding between the aeroplanes and the staff. By this means the staff can question its aeroplane observer to a certain extent or send him on new or urgent duty. The danger of conflicting would not be too great in this case, as an organization with a necessarily less perfect wireless system in its moving units will probably not allow such a large number of aeroplanes to work simultaneously as at present. Moreover, it can be arranged that only the staff aeroplanes are to carry receiving stations on board, and that they are to communicate only with the more important command posts. (See Appendix.)

CONCLUSION.

To put these various means of communication into action and get appreciable results requires constant intensive training not only of the personnel who are to use it (aeroplane observers, telegraph operators, and signalers) but also the unit commanders who are to use the information derived from these different channels. It is necessary that these commanders, having studied the practical operation, should understand exactly what can be expected of each method, when the use of each is preferable, and what errors are liable to occur as a result of their respective limitations. Moreover, as these means of communication are all very rudimentary, and do not adapt themselves to detailed explantions, it is necessary to circumvent this defect by having a clear and perfect understanding between the aviators and those employing them. It is, furthermore, necessary that this understanding should accord as exactly as possible with the spirit of the regulations, so that the inevitable changes of station which occur between aviation units should not threaten the destruction of the service and render it impossible for the relieving units to carry out their mission.

All these conditions make it necessary that extensive practice be engaged in between aviation units and the various elements of the army corps. This practice must be under the control of the superior commander charged with coördinating the methods used and adapting them to circumstances without sacrificing on this account their general character laid down by the regulations.

APPENDIX.

WIRELESS TELEGRAPHY SECTION OF THE AIR SQUADRON.

Up to the present date, December 1, 1916, a wireless telegraphy section has been assigned to each army corps. It is commanded by a lieutenant, having under him the wireless operators of the air squadrons attached to the army corps, the command posts, the batteries, and the trench stations or the staff stations.

The development of wireless telegraphy, which will soon allow us to have from 80 to 100 antennæ per army corps and from 4 to 6 squadrons, at least in the attacking sections, makes the increase of wireless telegraphy sections imperative. One officer per army corps can not answer for the supervision of such a large personnel and so much material, especially when it is so widely dispersed.

It has therefore been decided to create a wireless telegraph section per air squadron, under the command of a lieutenant having under him the air-squadron sappers and the antennæ operators attached to the air squadron.

The wireless telegraphy sections of the air squadrons of a group of divisions will be under the command of the radio officer of the group.

There are two ideas in this reorganization—first, to unite the sending and receiving mediums under a single head; second, to station the officer in charge at the point where all the information concerning the working of the wireless naturally gathers—at the point which it reaches the quickest and where all the telephone lines from all receiving antennæ terminate—that is to say, at the squadron.

The squadron commander becomes, by the natural order of things, responsible for the transmission of information, starting from his aeroplanes down to the antennæ officer. In case the wireless gets out of order, the battalion and group commanders apply to him, and he gives the necessary instructions to his wireless telegraphy lieutenant.

Another important part of the duty of a wireless telegraphy lieutenant consists in the constant supervision of the professional efficiency of the antennæ operators, this recruiting and grouping of the latter having been seriously neglected up to the present. He should, in the course of frequent and periodical inspections, assist at the fire for adjustment of the batteries, advise the radio personnel, and eliminate the more inefficient among them. He will also assist the battalion and group commanders in placing their wireless stations, which is extremely important in obtaining satisfactory results, since the sites must be free from surrounding obstacles and sheltered from humidity and the concussion of gunfire.

ORGANIZATION OF WIRELESS TELEGRAPHY—COMMUNICATIONS BETWEEN THE AIR SQUADRONS AND THE COMMAND POSTS OF THE DIVISIONS AND GROUPS OF DIVISIONS.

In view of open warfare, it is necessary that these communications be established at once. The distance separating the various command posts and the air squadrons from each other has the effect of prohibiting the use of telephone communication at the present time. At least they can not be established until after several days' occupation of the same position. The lack of rapid and constant communication tends to paralyze aviation during this period. To remedy this as much as possible it has been decided to provide each squadron and each command post with a complete wireless telegraph outfit, chiefly including a *generator group* of approximately one horsepower (gasoline motor and continuous-current generator); a *converter group*, including a continuous-current motor and a continuous-current generator with two collectors for feeding the sustained wave of the receiving wireless station. The wireless station also includes a receiving station with an amplifier. These stations use a wave length of between 600 and 1,000 meters, so as not to be troubled by the messages sent out by aeroplanes (the army corps aeroplanes send on a length between 100 and 500 meters and those of the high-power heavy artillery between 500 and 700 meters).

These highly perfected stations can not be heard by any of the battery stations and they can use a very restricted scale of wave lengths without a conflict resulting. On the other hand, they require the use of operators very superior to the average employed at the battery stations.

As soon as the squadrons and command posts have been provided with these stations they will insure permanent communication between the various elements without any interference with communications from aeroplanes resulting.

RECEIVING ON AEROPLANES.

At the present time we have several receiving stations on board of aeroplanes which work perfectly. But we can hardly put them into general use as yet, since it would be to the detriment of communications from aeroplanes to the ground, and this is of paramount importance in view of the fact that each aeroplane is an observer which informs the command post, while the latter, having come to an understanding with the aeroplane before the flight, has very little to say to it. In open warfare the case will present a different aspect, for, either on account of the absence of telephone lines or on account of the want of landing areas in the vicinity of the command posts, only a partial understanding can be reached between the command posts and the aeroplane before the flight. There would then be every advantage for the command post of a division or group of divisions to be able to question its aeroplane or send it on urgent duty by means of wireless telegraphy. It is also probable that the number of adjustment aeroplanes will then be less great than during the present periods of artillery preparation, if for no other reason than that of the difficulties of establishing an understanding between the batteries and the squadrons. The chances of conflicting being thereby diminished, we may then consider receiving on aeroplanes at first limiting it to the command aeroplanes which may make the greatest use from it.

However alluring this improvement may be, we must not consider using it on all aeroplanes at once, as the difficulties attending its accomplishment are such as to endanger the present organization. It is only in the course of event, as we gradually overcome the difficulties of manufacturing the apparatuses, of training observers (who should become actual wireless operators) and in perfecting our radio personnel, that we may possibly attain the general practice of receiving on aeroplanes. At the present time this device could probably be used to perfect the tactics of aeroplanes of pursuit. Experiments are being made concerning this.

[Translation of a German document.]

MANUAL OF POSITION WARFARE FOR ALL ARMS.

PART 6.

COMMUNICATION BETWEEN INFANTRY AND AEROPLANES OR CAPTIVE BALLOONS.

[January 1, 1917. Issued by the Chief of the General Staff of the Field Army. Berlin, 1917.]

I. INFANTRY AEROPLANES.

1. Importance of the Infantry Aeroplane Service.

It is of the greatest importance for commanders and the artillery to have constant information, in the course of a battle, as to *the progress of the infantry fighting, the position of the foremost infantry lines, and any of the enemy's measures which may have been detected.*

In consequence of the increased effectiveness of artillery fire, transmission of information from the front line to the rear, in spite of the increase of and improvements in the means of ground communication, is becoming more and more difficult. For this reason, the infantry, when heavily engaged, is often unable to obtain the requisite effective support from the higher command and the artillery, ground which has been gained with difficulty has been lost again, and the enemy's successes are liable to acquire a dangerous extension.

In many cases *the infantry aeroplane* (contact patrol) can render valuable services to the infantry in this respect. Flying at a low altitude, the airman is able to define with great accuracy, on the map and by photography, the situation of the front lines as revealed to him by the signals of the troops, and can also, by means of preconcerted signs and signals (see appendix), transmit reports from the infantry, and the result of his observation of the enemy's movements, quickly and safely to the

rear. *Proper cooperation between infantry aeroplanes and the troops will thus provide the infantry with an additional means of reconnaissance and communication.*

2. Duties of the Infantry Aeroplane.

(*a*) *Determination of the position of our own front line.*—The main duty of an infantry aeroplane, in every flight that is undertaken, is to determine and keep under observation the position of the front line. In any case communication must be established with the infantry by means of signals. Even if the front line has undergone no modifications, the consciousness of being in communication with the aeroplane strengthens the *morale* of the infantry.

(*b*) *Transmission of tactical reports from the front line and from battalion and regimental headquarters to the rear.*—The heavier the fighting, whether in attack or defense, the greater becomes the dependence of the infantry upon the aeroplane for the transmission of its reports. By means of the arrangements for communicating with the infantry, the infantry aeroplane is able to transmit to the rear, in the shortest possible time, all reports of special importance as to the course of the action and the conditions in the front line. It is particularly important to forward immediately any requests of the infantry for barrage fire.

(*c*) *Tactical reconnaissance in the sphere of the infantry action.*—Thorough familiarity with all details of his sector enables the infantry airman, in addition to his other duties, to carry out very detailed tactical reconnaissance. From observation of the artillery fire upon the front line, with regard to the fall of the rounds and the volume and general direction of the fire, as well as from observation of concentrations, movements, and bringing up of reserves in the enemy's trenches, the object and direction of hostile attacks can be recognized and, by an immediate report, can be nipped in the bud.

3. Employment and Command of Infantry Aeroplanes.

On the principal fighting fronts, special aeroplanes will be allotted to the infantry divisions as infantry aeroplanes. Their number will depend upon the nature of the fighting, and their employment will be determined by the flight commander concerned, who will receive his instructions from divisional headquarters.

It may be found necessary, in order to enable the infantry aeroplanes to carry out their duties even in the face of hostile aerial activity, to assign special aircraft for their protection. Applications in this respect should be made to the commander of the aviation troops or to the wing commander.

4. Means of Communication.

A. COMMUNICATION FROM THE GROUND TO THE AEROPLANE.

(*a*) *Cloth signals.*—These cloths are colored white on one side and dark on the other (for use in snowy weather); those used at battle headquarters are 2 feet 7 inches by 8 feet 2 inches, and those employed in the front line 2 feet 7 inches by 3 feet 3 inches. It is advisable to stiffen the narrow sides by wooden battens and to keep the cloths in cases as a protection against dirt.

By placing the cloth signals, stretched to their fullest extent, about 55 yards apart, especially at salients and reentrants of the front line, its outline can be defined. To avoid attracting the enemy's attention, they must be displayed from the slope of the trench which faces away from the enemy.

They can be used in certain combinations to convey tactical information. (See appendix.)

As against the disadvantages arising out of the difficulty of displaying the cloths under hostile fire, and of the possibility of confusion being caused by their nonremoval, must be set the fact that they are easily recognized from an aeroplane, can be unmistakably reproduced in a photograph and, when once extended, obviate the necessity for continuous observation on the part of the aeroplane.

(*b*) *Signal lamps.*—Signal lamps (infantry signaling apparatus and special aeroplane flash lamps) are used for sending certain flash-light signals to the aeroplane.

Much practice is required for their operation; it is no simple matter for the aeroplane, when hampered by difficult flying conditions and the incidents of the battle, to take the signals so sent. This means of communication is, therefore, not so reliable; moreover, the messages can not be reproduced photographically.

(*c*) *Flares.*—The front line can be outlined by means of white or red magnesium torches or flares. The flares or torches must be lighted at the bottom of the trench or in shell craters,

if possible against a dark dackground and screened from the enemy. If much smoke is produced they will attract the attention of the enemy, and must, therefore, only be used exceptionally by the troops in certain circumstances (attack). In the absence of smoke, they are difficult to see from an aeroplane and can not be photographed.

When used, they must be arranged with a certain amount of regularity (groups of two or three flares or torches, distance between the groups 55 to 110 yards).

Signaling from the front line must be confined to the display of cloth signals, flashes by signal lamps, and the use of flares.

Cloth signals (see appendix) and Morse signals (see appendix) on the signal lamp can only be used for the conveyance of information from points situated farther in rear (from the company commander upward).

B. COMMUNICATION FROM THE AEROPLANE TO THE GROUND.

The infantry aeroplane is distinguished by long black, white, and red pennants at the outer extremities of the lower plane and flies at a lower altitude than other aircraft. The infantry aeroplane possesses the following means of communication with the ground:

(*a*) *Light-pistol cartridges.*—To enable itself to be identified by the divisions to which it is allotted as their infantry aeroplane and as a request to them to display their cloths the aeroplane will discharge colored-light signals when near the front line. (See appendix.)

Atmospheric conditions and the position of the sun may render it difficult to recognize and distinguish between the different colors; repeated signals, moreover, can not be made, as but few cartridges can be carried.

(*b*) *Machine-gun fire.*—Failing any other means of attracting the attention of the troops, short bursts of machine-gun fire can be delivered; in the same way, several series of rounds from the machine gun have proved a useful method of giving the "understood" signal or the "call" signal of units.

There is danger of such signals being misinterpreted and of the aeroplane running short of ammunition if engaged by an opponent.

(*c*) *Signal lamps.*—Infantry aeroplanes are equipped with signal lamps to enable them to give the "understood" signal

and to repeat Morse messages sent from the ground. These lamps can also be used to transmit reports received from below to such command posts in rear as are unprovided with wireless stations and at which it is inadvisable to drop the report.

(*d*) *Wireless apparatus.*—Each division has a wireless receiving station for the receipt of urgent messages requiring instant action; the infantry aeroplane must report to this station, using certain wave-lengths and the preconcerted "call" signal. *Demands for barrage fire, in particular, must be transmitted by wireless.* It is the duty of divisional headquarters to cause the necessary telephone lines to be constructed, to keep them disengaged while the infantry flight is in progress, and to detail a skilled operator to work the telephone at the wireless station, in order that these demands may be transmitted, without any delay, to the proper quarters.

(*e*) *Dropping reports.*—As reports which are dropped by means of the "*Rauchmeldepatrone*" (smoke indicator) very rarely fall quite close to the command post concerned, it is advisable only to drop them in those places where there is a certainty that the enemy's fire will not prevent a search for the reports. In any case a report should be repeated by telephone as soon as the aeroplane has landed.

5. Method of Carrying out the Duties of Infantry Aeroplanes.

General observations.—The infantry is confronted by the twofold difficulty of identifying immediately, out of the large number of aircraft visible, its own aeroplane, which usually appears unexpectedly, and of often having to display the necessary signals to the aeroplane in circumstances of the greatest difficulty and under heavy hostile fire.

Goodwill, vigilance, consciousness on the part of the troops that the aeroplane always comes on their service alone and for their advantage, and, if necessary, the issue of drastic orders and the display of severity by commanders, will enable many imaginary difficulties to be surmounted.

The airman, by complete disregard of personal danger, by flying at a very low height and in bad weather, must prove to the troops that they can rely on him in their difficulties. Where confidence is mutual, excellent results will be obtained.

Measures to be Taken Previous to Establishing Communication.

TROOPS.

1. Certain observers will be posted, at all points where signals are to be made, to keep aircraft under constant observation.

2. The signaling apparatus is always to be kept in readiness by the operators.

AIRMAN.

1. Previous to starting, the observer will be informed by the General Staff officer of the division as to the situation in the front line.

2. He will communicate the time of his intended departure to the divisional wireless station.

3. It may occasionally be advisable to inform the troops by wireless or by telephone.

The Process of Establishing Communication.

TROOPS.

1. As soon as the observers recognize an infantry aeroplane they will keep a sharp lookout for the anticipated light signals.

2. As soon as the call signal of the division is recognized, the troops in front line, company commanders, battalion and regimental headquarters, will display the cloths, or report by flash lamp, flares, or cloths as to the tactical situation.

In signaling with the flash lamp it must be remembered that the aeroplane will devote its attention first of all to the front-line and company commanders, then to battalion headquarters, and, last of all, to regimental headquarters.

3. The signals will be displayed or repeated until the aeroplane has given the "understood" signal or has obviously departed.

4. Signaling is completed, but the aeroplane will be carefully observed as long as it is in sight.

5. If the troops should see that, owing to its being involved in an air fight, the aeroplane is unable to receive the signal, or that the aeroplane is withdrawing temporarily but unmistakably, the signals are to be taken down and not again displayed till the aeroplane again asks for them.

AIRMAN.

1. The aeroplane will appear at such a height as, in view of weather and other circumstances, will enable the troops to identify it with certainty (generally speaking, between 550 and 1,100 yards). It can be recognized by long pennants at both ends of the lower planes. Unless the airman disposes of other means of attracting attention by sound, he can do so by means of short bursts of machine-gun fire.

2. To signify its desire to get into communication with the —th Division, the aeroplane will discharge the light signal forming the call signal of the particular division.

3. The airman will photograph the front line and its signals. Should circumstances require a sketch of the front line to be brought back *at once*, the airman will draw it on a section of a large scale map, or on a photograph. If he happens to detect a remunerative target, he should report it by wireless, giving the map square or number. It is not his duty to observe fire.

4. When the airman has received all the signals he will give the "understood" signal by repeating the signal given on the ground, by flashing the "understood" signal with the addition of the sector letter, or by light-pistol signals. Urgent reports are to be dropped at headquarters or sent by wireless. They should be sent in the following order: Front line, company commanders, battalion headquarters, and regimental headquarters, beginning from the right of each battle sector.

Signals made with the flash lamp are to be repeated until the "understood" signal is given from below.

It is most important to forward *at once* requests for *barrage fire.*

5. The result of the flight is invariably to be dropped at divisional headquarters or regimental battle headquarters, as the case may be. The report will be supplemented by telephone immediately after landing. Photographs are to be sent on to the regiments concerned as soon as possible. It will be advisable at times for the aeroplane to land temporarily at a special landing place near divisional headquarters, in order to complete verbally the report which has been transmitted by wireless or flash lamp.

6. Training of the Troops.

The training must conform to the regulations. Arbitrary modifications are forbidden, as they lead to confusion, and, possibly, disaster to the troops.

Officers of all ranks must make every effort to insure that troops are thoroughly trained in this most important duty.

It must be explained to the troops that their fear of hostile aeroplanes is exaggerated; that the visual signals and individual soldiers can not be seen from aeroplanes at a great height; and that the light of the signal lamps is only visible to the aeroplane with which they are in communication. Every officer, noncommissioned officer, and man must be sufficiently acquainted with the regulations to enable him to act independently.

Officers of the flying troops who have been trained as infantry airmen should, as far as possible, be detailed to carry out this training.

Each method of signaling will be practiced as a drill.

The men must be regularly drilled in displaying the cloths, lighting the signal flares, and reading light signals and flashes from the aeroplane, *under service conditions*, as it is by no means easy to display the cloths and receive the signals under fire.

The men operating the signal lamps must be taught, above all else, to signal clearly and distinctly and not too hurriedly. They must be taught to follow the movements of the aeroplane with the lamp, and to continue the repetition of the signals until the aeroplane gives the "understood" signal or repeats the "call" signal.

Individual training must be followed by regimental training under war conditions, in which aeroplanes should take part.

To make the training more *realistic* trenches must be available where the men can operate the appliances, wearing their field service kit and equipment and in the posture they would be forced to adopt in actual fighting. The aeroplanes taking part in the training must, as they would do in reality, only fly over the position for a short time and withdraw temporarily, as if owing to prevailing wind conditions and the exigencies of aerial warfare.

II. CAPTIVE BALLOONS.

Captive balloons may be assigned to divisions for important operations in which, as "*infantry balloons*," they can, to a limited extent, replace or supplement the infantry aeroplane.

Their employment depends largely on weather conditions (storm, fog).

The infantry balloon carries a conical pennant on the basket and accepts signals as long as the pennant is flying.

The signal apparatus is used for communication from the ground to the baloon and *vice versa*, but it must be borne in mind that if the basket is very unsteady many light signals will be missed. At night the balloon works like an ordinary signal station and must frequently send out flashes to facilitate "aiming" in its direction. The signals to be made with the signal apparatus are identical with those laid down for infantry aeroplanes.

The balloon observer reports by telephone to the different battle headquarters. The report should be supplemented later by a sketch.

Continual practices between balloons and the front lines are necessary; the principles of training laid down in Section I, paragraph 6, hold good with the necessary modifications.

APPENDIX.

Signals to be used in communication between Infantry and Aeroplanes.

A.—FROM INFANTRY TO AEROPLANE.

No.	Message.	Morse signals by signal lamp, or wireless.	Cloth signal.	Light-signal (signal-shots).	Remarks.
1	Foremost infantry line.	Light shown for 20 seconds.		White or red light.	The white cloth signals are spread out taut about 55 yards apart on the front edge of the trench if possible.
2	Here is a regimental battle headquarters.	By special arrangement, *e. g.*, the regimental No., or regimental No. with letters added.			In heavy snow 
3	Here is a battalion battle headquarters.				 Only to be shown if the position of battle headquarters has been changed.
4	We hold the line....	Light shown for 20 seconds.		Only to be displayed at command posts of company commanders and upward.	This signal must always be made to the aeroplane even if there is no change.
5	We are about to advance (ready to attack).	M A — — . —			It also means "lift artillery fire for our own attack."
6	Enemy is preparing to attack.	B — . . .			It also means "enemy is attacking."
7	Barrage fire.....	S . . .			It also means "request annihilating fire on the enemy trenches."
8	Barrage fire nearer our own line.	F N . . — . — .			It also means "artillery is firing on our trenches."
9	Lift artillery fire....	F . . — .			Only to be used in cases of extreme urgency.
10	Support necessary...	U . . —			

Signals to be used in communication between Infantry and Aeroplanes—Continued.

A.—FROM INFANTRY TO AEROPLANE—Continued.

No.	Message.	Morse signals by signal lamp, or wireless.	Cloth signal.	Light-signal (signal-shots).	Remarks.
11a	Enemy has broken through on our right.	R . — .		Only to be displayed at command posts of company commanders and upward.	
11b	Enemy has broken through on our left.	L . — . . .			
11c	Enemy has broken through in our center.	M — —			
11d	Enemy has broken through in our center and on our right.	M R — — . — .			
11e	Enemy has broken through in our center and on our left.	L M . — . . — —			
11f	Enemy has broken through on our right and left (center holding on).	R L . — . . — . .			
11g	Front line lost.....	O — — —			
12	Counter-attack has failed.	G I — — . . .			
13	Hostile attack repulsed.	A B . — — . . .			
14	Understood.....	Light shown for 5 seconds.			

B.—FROM AEROPLANE TO INFANTRY.

1	I want to get into communication with the—				
	First division (from the right).	.....	.....	One white and one red light.	
	Second division (from the right).	.....	.....	One green and red double star.	If the light signal ammunition is bad, one green and one red light.
	Third division (from the right).	.....	.....	Two white and one red light.	
	Fourth division (from the right).	.....	.....	Two green and red double stars.	If the light signal ammunition is bad, one green and one red light.

Signals to be used in communication between Infantry and Aeroplanes—Continued.

B.—FROM AEROPLANE TO INFANTRY—Continued.

No.	Message.	Morse signals by signal lamp, or wireless.	Cloth signal.	Light-signal (signal-shots).	Remarks.
2	Understood.....	Light shown for 5 seconds, or repetition of the signal received from the ground.	.....	Two red lights.	
3	Barrage fire.....	S . . . (adding the number of the sector).	.....	.....	To be repeated until barrage fire is opened.

REMARKS.

1. If the "call" signal (B1) for a division is given, small cloth signals are to be put up (A1) in the front line; messages are to be sent from command posts with large cloth signals (A2—14).
2. All signals should be repeated or left in position till the "understood" signal (B2) is given, or the aeroplane withdraws.
3. It is advisable when giving the signal "understood" in Morse, to preface it always by the pre-arranged call signal of the unit.
4. Wireless messages "in clear" are not allowed.
5. Dimensions of the small signal cloths are 2′ 7″ × 3′ 3″, of the large cloths 2′ 7″ × 8′ 2″. They are strengthened on their narrow sides by wooden battens; they should be kept in cases, as a protection against dirt. The cloths are colored white on one side and dark on the other for use in snow.
6. The signals contained in lists A and B are universal. Other signs must only be used by agreement, on each occasion, with the troops in line.