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ANTI-AIRCRAFT GUNNERY.

(PROVISIONAL.)

ISSUED BY THE GENERAL STAFF.

SEPTEMBER, 1917.

(B17/542) 5000 10/17 H&S 4959wo

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AMENDMENTS TO "ANTI-AIRCRAFT GUNNERY, 1917."

Page 3.—*Insert* new definitions—

Present, Future.—The words "present" and "future" are used to define the condition of variables at the beginning and end respectively of the time of flight. For example, the Q.E. of a correctly laid gun is made up of the present angle of sight, the vertical deflection and the tangent elevation for the future position of the target.

Amend definitions to *read* as under :—

Angle of Tangent Elevation.—The angle which the axis of the piece, when laid, makes with the future line of sight.

Attack Angle.—The angle of sight at which a stationary target at a given height could be engaged with a given fuze setting.

Page 16.—*After* Chapter II, Section 13, *insert* new section—

SECTION 14.—ORDERS.

1. Orders for the engagement of a visible target should be given out by the Section (Gun) Commander in the following sequence :—

Target,
Nature of ammunition, if necessary,
Height,
Vertical deflection,
Lateral deflection,
Fuze, when a height-fuze indicator off the gun is being employed,
Order to fire, preceded by the number of rounds, if necessary.

2. When it is desired to indicate a target by ordering an angle of sight and bearing, the angle of sight will be ordered as shown in the following examples :—

30 deg.	"Angle of sight, three, 0."
45 deg.	"Angle of sight, four, five."

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The bearing will be ordered thus :—

176 deg. ...	...	"Bearing, one, seven, six."
260 deg. ...	...	"Bearing, two, six, 0."

3. Height will be ordered thus :—

18,000 ft. ...	...	"Height, one, eight thousand."
10,500 ft. ...	...	"Height, ten, five hundred."
9,250 ft. ...	...	"Height, nine, two, fifty."

The actual height should invariably be ordered. Such orders as "Raise," "Lower," "Add" or "Drop" will not be used.

4. Initial and fresh nett deflections will be ordered thus :—

"Up, three—right, four" (vertical deflection scale to be set at 3 deg. up, and lateral deflection scale at 4 deg. right).

The foregoing form of order will invariably be understood to mean that the deflections so ordered are required to be set on the scales as from the zero mark, whatever may be the deflections set on the scales at the moment the order is received.

5. When it is desired to set one scale at zero, while ordering a deflection to be set on the other scale, one of the following orders will be used—

"Vertical, zero."
"Lateral, zero."

6. Corrections to deflections during a shoot will be given out thus—

"One, more, up" (equals vertical deflection pointer moved from its present position through 1 degree towards "up").

"Two and a half, more right" (equals lateral deflection pointer moved from its present position through 2½ degrees towards right).

7. If at any time (*e.g.*, while waiting for a target to steady on a new course, or if it is thought that the deflections have been incorrectly set) it is desired to bring the deflection scales to zero, the order "Scales, zero" will be given. Subsequent orders will be in the form laid down in para. 4.

8. If deflection measuring instruments are in use, the spotting corrections will be given in the form laid down in paras. 5 and 6, above.

9. Fuze will be ordered thus—

Setting 8	...	...	"Fuze, eight."
Setting 18	...	...	"Fuze, eighteen."

10. Orders for the engagement of an invisible target by barrage fire should be given in the following sequence—

Bearing or map square.
Q.E. or height.
Fuze when necessary.
Order to fire, preceded by the number of rounds, if necessary.

Q.E. and bearing will be ordered as detailed for angle of sight and bearing respectively in para. 2, above. Height will be ordered as detailed in para. 3, above. Fuze will be ordered as detailed in para. 9, above.

11. In action, except where otherwise detailed in Gun Drills, the orders of the Section (Gun) Commander, if clearly heard by the numbers affected, will be acted upon at once without waiting for repetition by the No. 1.

12. The order board, where available, is used to check the orders passed verbally by the Section (Gun) Commander.

13. The position of a Section (Gun) Commander is near the jack post, where provided, or behind the gun or guns, in order to avoid the blast. When an order board or instruments separate from the gun are used, his position will be at those instruments or order board. If, however, the guns are firing at a low angle over his head, he may be compelled to move away temporarily to avoid the blast.

The Section (Gun) Commander should avoid making any attempt to save time by giving out a sequence of orders too hurriedly. A pause should be made after "Stop" is given and also between each separate order.

Page 24, Section 20, sub-section 2.—*Omit* second paragraph.

Substitute—

Small corrections to deflections will be made in the form laid down in Section 14, para. 6. When a considerable change of course is observed, the Section (Gun) Commander should start afresh, using the form of order laid down in Section 14, para. 4, proceeded by "Scales, zero" if necessary.

Page 45.—Under "Orders to gun," *delete* "*Fuze 22. Up 4. Right 4. Gun fire*," and *substitute* "*H.E.* (*or Shrapnel*). *Height 14,000. Up 4. Right 4. Fuze 22. 6 rounds. Fire.*"

Delete "*Fuze 18. Up ½. Left ½. Go on*," and *substitute* "*½ more up. ½ more left. Fuze 18. Go on.*"

Delete "*Stop. Up zero 1. Right zero 7. Go on*," and *substitute* "*Stop. Up 1. Right 7. Go on.*"

Page 46, line 11.—After "*Stop*" *insert* "*Scales, zero.*"

Lines 14 and 20.—*Delete* "Right" and *substitute* "Left."

Line 20.—*Delete* "*Fuze 18. Down zero 3. Right zero 2½. Go on,*" and *substitute* "*Down 3. Left 2½. Fuze 18. Go on.*"

Last line.—*Delete* and *substitute* "*3 more down. ½ more Right. Fuze 22. Go on. D. 6. Left 2. Fuze 22.*"

Page 47, line 2.—*Delete* "*Left ½. Go on.*"

Page 55.—*Delete* from line 7 to line 24 inclusive, and *insert*—

"4. Corrections to trajectory will be ordered in terms of height on the result of distant observation of groups of rounds."

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DEFINITIONS.

Angle of departure.—The angle which the line of departure makes with the horizontal plane, in other words, the quadrant angle plus the jump.

Angle of sight.—The angle which the line of sight makes with the horizontal plane.

Angle of tangent elevation.—The angle which the axis of the ~~gun,~~ piece when laid, makes with the future line of sight~~, provided there is no vertical deflection~~.

Attack angle.—The angle at which a target should be engaged at a given height with a given fuze.

Axis of the gun.—An imaginary line passing down the centre of the bore.

Calibre.—The diameter of the bore in inches measured across the lands.

Drift.—The constant deflection of the shell due to the rotation imparted by the rifling.

Fuze range.—The range in yards from the gun at which the given fuze will burst. (This varies at different angles of sight.)

Fuze range dial or scale.—A dial or scale marked in graduations of fuzes, and designed to correct automatically the tangent elevation required for a given fuze at varying angles of sight.

Jump.—The angle between the line of departure and the axis of the piece before firing. It is due to the vertical movements of the gun on firing, and for any gun differs according to the mounting and the charge used.

Lateral deflection.—The angle in degrees and minutes required to compensate for the lateral travel of the target, during the time of flight of the shell.

Line of departure.—The direction of the shell on leaving the muzzle.

Line of sight.—A straight line passing through the sights and the point aimed at.

Muzzle velocity.—The velocity in feet per second with which a shell leaves the muzzle.

Quadrant angle or quadrant elevation.—The angle which the axis of the piece makes with the horizontal plane.

Trajectory.—The curve described by the shell in its flight.

Vertical deflection.—The angle in degrees and minutes "up" or "down" required to compensate for the change in the angle of sight during the time of flight of the shell.

CHAPTER I.

General Tactical Considerations.

Section 1.—*The rôle of Aircraft and Anti-Aircraft Guns.*

1. Aeroplanes are employed in the following duties :—

(*a.*) Reconnaissance, including the taking of photographs.
(*b.*) Ranging of batteries.
(*c.*) Bombing raids on the lines of communication, supply depôts, &c.
(*d.*) The attack of enemy aircraft and captive balloons.
(*e.*) Various other duties (such as contact patrols) which are not classified under one of the above headings.

2. The rôle of the anti-aircraft gun is to assist our aircraft in preventing those of the enemy from carrying out the above duties.

The fire of anti-aircraft guns should therefore be directed :—

(*a.*) To prevent enemy aircraft flying at such a height over our positions that they can observe and photograph, range artillery, attack our balloons, drop bombs with accuracy or attack troops with machine guns.
(*b.*) To prevent enemy aircraft dropping bombs on vulnerable points situated at a distance behind our lines.
(*c.*) To compel enemy aircraft flying in formation to lose their stations and so render them more vulnerable to attack by our own aeroplanes.

Section 2.—Siting of Guns.

1. *In the field.*—A first line of defence of sections on mobile mountings should be placed in position at intervals along the line between 3,000 and 4,500 yards apart, that is, at such an interval as will enable each section to engage targets vertically above neighbouring sections and sufficiently far apart to obviate too many sections engaging the same target, and thus making observation difficult. These sections should be as near the front line as possible in order to engage enemy aircraft at the earliest possible moment. The actual distance cannot be laid down, as it depends on local conditions and may vary from 1,000 to 4,000 yards, but they should be usually as far forward as the line of the field batteries.

2. A second line of guns may be placed in the intervals about 5,000 yards behind those mentioned above so that hostile aeroplanes will not obtain immunity from shell fire after crossing the front line of guns.

3. In addition guns are required for the protection of localities, such as railheads, ammunition dumps, &c., and should be sited at least 2,000 yards away from the locality they are protecting.

4. *The defence of towns and areas by anti-aircraft guns.*—The arrangements for the defence of towns and areas by anti-aircraft guns must depend on the number of guns available and on political and military considerations. These considerations may demand the special defence of limited objectives in certain localities.

The grouping of guns in the defences must be governed to a certain extent by tactical considerations as to the probable lines of approach of the hostile aircraft, and by the possible co-operation with the Royal Flying Corps.

Section 3.—Mobile Guns.

1. The personnel should be trained in rapid changes of position, and lorry drivers must attain a high standard of efficiency, especially in driving over rough ground. Anti-aircraft guns will often be the only guns firing during the flight of enemy aircraft. The flash of the guns is conspicuous and the position is often located and shelled by enemy artillery. Arrangements should therefore be made for a number of alternative positions so that when one position is shelled the guns can come into action elsewhere. It may be necessary to split up the section, using single gun positions.

2. As the state of the ground or other causes may prevent a change of position, dug-outs should be constructed near the guns in which the detachments may obtain cover when shelled. In some cases it may be preferable to withdraw the detachments 200 or 300 yards to a flank than to keep them in dug-outs at the gun position.

3. When gun pits are constructed they should be of sufficient size to allow the detachments to work freely.

Ready racks should be built into the sides of the pit at positions convenient for ammunition supply.

Protection can often be obtained by cutting into a bank or side of a hill.

In cases where guns are immobilized by being placed in gun pits, deep dug outs should be constructed for the detachments.

4. When the state of the ground prevents movement by motor lorry it may be necessary to dismount the gun and move it and its stores, ammunition, &c., to the selected position either with the aid of a G.S. wagon or light railway, or by hand.

A suitable platform can be made for a 13-pr. anti-aircraft gun with four pieces of timber, each about 13 feet by 9 inches by 9 inches.

5. In some cases bogie trucks or light railways are available for mounting anti-aircraft guns and carrying ammunition.

Section 4.—*Selection and occupation of positions.*

In the selection and occupation of positions the following points are important :—

(*a.*) An all round field of fire for the guns for angles of sight of over 10 degrees is desirable. This may not always be possible, but when working in sections guns can usually be placed so that one or other of the guns can engage an aeroplane in any direction.

(*b.*) The positions should not allow of direct observation from the hostile lines. The flash of guns is conspicuous at dawn and dusk and it may therefore be inadvisable at these hours to fire from positions which it is proposed to occupy during the middle of the day. Dark backgrounds such as rows of trees and valleys frequently in shadow should be avoided.

(*c.*) Places marked clearly on the map, such as churches, windmills, cross-roads, or points which are known to have been registered by hostile artillery should be avoided. Open spaces, provided they are screened from hostile observation at ground level, are recommended.

(*d.*) Close proximity to field and heavy gun positions, headquarters and dressing stations, should be avoided.

(*e*.) The position should allow ample room for the working of the detachments, and for the easy supply of ammunition.

(*f*.) Ammunition lorries should be kept under cover near the guns, 50 yards being considered an average distance. Care should be taken to avoid driving lorries up to a position during action, any movement being very conspicuous. If the position is too exposed to admit of this, dumps will have to be made as described in Section 10 (*g*).

(*g*.) There should be easy means of egress from the position. As a rule guns should be so placed that they can be moved straight out if a sudden change of position is necessary; alternative exits can often be constructed.

Section 5.—*Platforms for Anti-Aircraft Guns.*

Level platforms are essential. They must be constructed by the detachments from any material available and be kept constantly in repair if required for frequent use. A position which can be occupied when the ground is hard will often prove disadvantageous after heavy rainfall; this also applies to the approaches.

Section 6.—*Concealment.*

The position should be rendered as inconspicuous as possible, though arrangements for concealment should not interfere with the mobility of the gun. When work on a new position has been completed, the position itself should be made to resemble its surroundings by judiciously placed screens and "camouflage" work.

Lorries can be hidden by placing pieces of brushwood over the corners of the platform. Canvas placed round the lorries will also help to break up their general outline.

There should be no well defined pathways leading up to the position and the trampled space round the guns should be kept as small as possible. In dry weather the position should be sprinkled with water to lay any dust raised by the blast of the guns. A cloud of dust not only renders the position conspicuous but also interferes with the shooting.

Section 7.—Anti-aircraft guns in liaison with the Royal Flying Corps and other units.

Considerable assistance can be given to the Royal Flying Corps by informing them of the position of hostile machines. Information may be conveyed to machines already in the air by means of large arrows of white canvas placed on the ground and pointed in the direction of the enemy aircraft. A few rounds fired in the direction of the enemy aircraft, even if the hostile machines are slightly beyond the range of the guns, is of assistance to our machines.

The headquarters of anti-aircraft units should be in direct communication with the Royal Flying Corps squadrons, wings, &c., and if hostile machines cross our lines the fact should be notified as soon as possible to the Army Wing of the Flying Corps.

The following information should be given :—

(*a.*) Types of machines seen.
(*b.*) The number of machines.
(*c.*) Time at which seen.
(*d.*) Direction of flight.
(*e.*) Estimated height and map square over which seen.
(*f.*) Formation in which hostile aircraft is flying.

Information should also be sent if a hostile machine is seen doing persistent reconnaissance or artillery registration work, stating whether it is guarded by others. Wireless compass stations are employed by the Royal Flying Corps to determine the position of enemy aircraft; information obtained by this means should, when possible, be verified by anti-aircraft observers who can also inform the Royal Flying Corps at what height the hostile machine is working, this latter information being of great importance.

Unusual aerial activity over any particular area should be reported. Valuable information can sometimes be obtained from the comparison of the number of machines (hostile and allied) seen over a given sector in a given period. These numbers should accordingly be tabulated. Descriptions of new types seen should be forwarded as soon as they can be confirmed. Observed casualties to machines should be reported.

Anti-aircraft units can help other units in the identification of aeroplanes. This subject is most important for the personnel of field and heavy batteries.

Section 8.—Instruments.

Instruments should be grouped where they have a good field of view and where the results of the observations can be easily conveyed to the section commander.

Care should be taken not to place any delicate instrument near enough to the gun for the blast to affect it.

If instruments are used in positions likely to be shelled, the men using them must be trained in packing them up quickly and carefully. If this is not done, either the instruments will be damaged or the efficiency of the guns will suffer.

Instruments should as a rule be kept in a separate pit, communication to the gun being by telephone or voice, preferably the latter.

Section 9.—*Telephones.*

Telephone lines fall into two categories :—

(*a.*) Fighting lines.
(*b.*) Administrative lines.

Certain lines have to serve both purposes.

Under (*a*) are included lines joining up the two ends of the height-finder, lines to distant observing stations, and lines connecting the alternative positions of a section.

These lines should be laid and maintained by the battery.

Administrative lines, which should be laid and maintained by the Signal Service, usually connect the sections to the battery and group headquarters, and are used for various purposes such as arrangement of ammunition supply, &c., also they are usually the link between anti-aircraft units and the Royal Flying Corps.

These lines are of the greatest importance, and their general repair and maintenance require constant attention.

Section 10.—*Ammunition supply.*

1. *For mobile guns* :—

(*a.*) At least 250 rounds, *i.e.*, one lorry load of ammunition, must be kept with each section in addition to those already in the ammunition cases on the gun lorries.

(*b.*) The ammunition on the gun lorries must be kept with the fuzes set and with the cases marked so that shells set at any particular fuze can be easily found.

(*c.*) The ammunition in the lorry should be kept in the boxes. Fuzes should be set, and rubber caps replaced. In action the boxes should be open and cartridge clips, but not fuze covers, removed.

(*d.*) As soon as possible after firing, the ammunition boxes on the guns should be replenished with shell set at suitable fuzes. This may have to be done during the firing, but unnecessary movement round the gun position must be avoided.

(*e.*) Headquarters will take steps to ensure that fresh supplies of ammunition are sent up.

(*f.*) As regards getting up additional supplies of ammunition, the following points must be considered :—

(i.) The distance.
(ii.) The condition of the roads.
(iii.) Local traffic regulations.

(*g.*) In places where mobility is rendered difficult owing to the condition of the roads or other causes, "dumps" of ammunition should be made. These must be replenished as opportunity occurs. Whenever possible advantage should be taken of light railways. Guns operating with a mobile force must always exercise economy in ammunition owing to the probable difficulty of supply.

On a fine day after a spell of bad weather increased aerial activity may be expected, and the supply of ammunition should be arranged for accordingly.

The requirements may be as much as 1,000 rounds per forward section of guns per day.

2. *For fixed guns or stations* :—

(*a.*) Ammunition for fixed guns should usually be in four ready racks placed at intervals round the gun about four yards from it. A further supply should be kept in a local store or magazine.

(*b.*) The number of fuzes kept set at fixed gun stations depends on the amount and frequency of firing which may be expected. As a rough guide 200 rounds per gun may be taken as a suitable number.

The rubber caps should be replaced after the fuzes have been set and waterproof cement carefully applied round the edges.

(*c*.) The actual settings at which the fuzes will be kept depends on the nature of the equipment and the targets which may be expected. The object which must be kept in view is to avoid the probability of having to set fuzes during action.

CHAPTER II.

Principles of Attack.

Section 11.—*The two natures of target.*

An aeroplane offers a very fast moving target which can change its course in a few seconds. It is very small and often extremely difficult to see.

It is necessary to predict the course of the target, and corrections should be made as soon as an aeroplane shows signs of changing its direction.

Targets presented are of two distinct natures :—

(*a*) *Those visible some time before coming into range.*

In these cases there is usually ample time to obtain initial deflections and height by means of instruments.

(*b*) *Those which appear suddenly within range.*

Targets of this nature have to be engaged with the least possible delay, and the section commander must rely largely on his powers of estimation for initial deflections and height. For this reason officers must endeavour to perfect themselves in the making of these estimations.

The tendency in shooting at aeroplanes is to employ too low a height or in other words too short a fuze throughout the series. A burst below the target has no material effect and seldom any moral effect.

Unless a good range or height finder is available (that is, unless the data as regards the height of the machine can be fairly accurately established), the fewer changes of fuze the better.

Mechanical means for correcting fire are always liable to breakdown, and officers should be prepared at any moment to carry on by their own observations.

Section 12.—*The chief variable factors.*

In anti-aircraft gunnery the three chief variable factors are :—

1. *Vertical deflection*, or the amount of change in the angle of sight during the time of flight of the shell.
2. *Lateral Deflection*, or the lateral travel measured in degrees during the time of flight of the shell.
3. *Range.*

A change in direction by the target will affect any one or all of these factors, and an aeroplane is easily capable of making such a change during the time of flight of the shell.

These factors must be considered in relation to the question of time ; aeroplanes usually offer a target for a short time only, and fire must be brought to bear on them with as little delay as possible. Extreme accuracy in calculating any of the above variables should not therefore be attempted if it involves material loss of time ; and in all cases of calculation the criterion must be whether, with the particular target which has to be engaged, the extra accuracy gained is worth the time lost. This does not mean that incorrect methods of engaging targets should be employed, but that it may be necessary on occasions to estimate heights and deflections in preference to obtaining them accurately from instruments.

Section 13.—*Fire Control.*

If more than one hostile machine is within range of a section, the fire of both guns should be directed on the target which is of the greatest tactical importance at the moment. Two-seater observation machines should be engaged in preference to single-seater scouts. If a hostile machine is at such a high angle that guns cannot fire because of the dead angle, the guns should be traversed round so that fire can be opened as soon as the target is in bearing again. No other movement should be allowed near the guns which will be liable to disclose the position.

CHAPTER III.

Section 15.—*Vertical and Lateral Deflections.*

Method of calculation.—The means of calculating vertical and lateral deflections are essentially the same ; and the results are obtained either by mechanical means or estimation.

The mechanical means are as follows :—

(*a.*) A graticuled telescope and stop watch.
(*b.*) An instrument which measures angular velocity, such as the Wilson and Dalby, or Brocq apparatus.

(*a.*) *Graticuled telescope and stop watch.*—These instruments have been practically superseded by the Wilson and Dalby instrument. The method of employment is to time the travel of a target between two graticules a known distance apart. Thus by a simple calculation the amount of travel during the time of flight of the shell for a given fuze can be determined.

The graticuled telescope may however still be of use in estimating the relation between vertical and lateral deflections for a given target.

Thus if the target moves ½ degree vertically while moving horizontally across the space between the graticules (*i.e.*, 2 degrees) then the vertical movement is a quarter of the lateral movement. Again, where there is a background of moving clouds behind the target deflections, especially very small lateral ones, are extremely hard to estimate. In such cases the graticuled telescope will be found of use as a guide to the real direction of the travel of the aeroplane.

(*b.*) *The Wilson and Dalby instruments.*—Each instrument consists of a sighting telescope and a speedometer device with a dial indicator, the one giving horizontal readings and the other vertical. The telescope is kept on the aeroplane by turning a handle actuating the speedometer. According to the rate at which the handle is turned to keep the telescope laid on the target, the pointer gives a reading on the dial corresponding to the time of flight. Good results are obtained for initial deflections, but in the event of an aeroplane frequently changing its course it will become necessary to disregard the readings until the target again assumes a constant course.

The Brocq apparatus.—This instrument is designed to give direct readings of the necessary deflections, without having to transpose them to a time of flight scale. The handles which actuate the sighting telescopes are geared to magnetos. The current generated by turning the handles is modified to allow for the time of flight by passing it through a resistance which can be varied according to the fuze range. The resultant current passes on to give direct readings for deflections on two dials. Most of the inherent errors of the tachymetric system are allowed for in this apparatus by counter balancing one against another.

Section 16.—*General considerations about deflections.*

1. Vertical and lateral deflections can sometimes be estimated by eye with fair accuracy, but this requires much practice. The general considerations which determine the amount of these deflections are as follows :—

(*a.*) *The speed of the target.*—This is affected directly by the direction and the velocity of the wind.

(*b.*) *The time of flight of the shell to the target.*

These two factors represent the travel of the target as regards the calculation of deflections. As will be shown later in calculating "fuze range" (*see* Chapter IV.) the time taken in putting on corrections, loading the gun, &c., must also be considered.

(*c.*) *The height of the target.*—For the same range the higher the target the greater will be the vertical deflections required for the same amount of travel.

2. The two natures of deflections must always be considered together; as an increase of vertical deflection generally represents a decrease of lateral deflection and *vice versâ.* For instance, a directly-crossing target will require lateral deflection and no vertical; while a directly approaching or receding target will require vertical deflection and no lateral.

A target approaching or receding obliquely at an angle of 45 degrees will require about two-thirds of the full lateral and vertical deflections respectively.

A target approaching or receding obliquely at an angle of 60 degrees requires half the full vertical deflection and seven-eighths of the lateral.

A target approaching or receding obliquely at an angle of 30 degrees requires half the full lateral deflection and seven-eighths of the vertical.

The above cases are considered with reference to the deflections required for a directly approaching or crossing target respectively. (*See* deflection charts for targets travelling at 80 miles per hour.)

The horizontal angle made by the intersection of the path of the target and the line gun-target may be called the "presentation" of the target. This angle will vary between 90 degrees in the case of a directly crossing target and 0 degrees in the case of a directly approaching or receding target.

The presentation on which deflections should be based is the mean between that at the moment of firing and that when the shell bursts.

3. For purposes of estimating deflections, aeroplanes may at present be divided into three classes as regards speed :—

(*a.*) Fast machines, 100 miles per hour and over.
(*b.*) Medium machines, 80 miles per hour.
(*c.*) Slow machines, 60 miles per hour.

Although linear velocities are difficult to calculate, the difference between the three classes of target can be distinguished with practice.

Section 17.—*Vertical deflection.*

Vertical deflection tends to increase as the target approaches. The amount depends to a large extent on the height of the target and on its speed.

A rough guide for estimating vertical deflections for a target directly approaching or receding at 80 miles per hour is as follows :—

(*a.*) *For* 13-*pr.* 9 *cwt. and* 3-*inch* 20 *cwt.*—At fuze 22 (*i.e.*, long range) the vertical deflection in degrees is one tenth of the angle of sight plus 1.

(*b.*) At fuze 14 (*i.e.*, medium range) and under, the vertical deflection in degrees is about one tenth of the angle of sight.

Examples—

(*a.*) Height, 10,000 feet. Angle of sight, 30 degrees. Range = 6,500 yards.

$$\text{V.D.} = \frac{\text{Angle of sight}}{10} + 1 = \frac{30}{10} + 1 = 4 \text{ degrees.}$$

(*b.*) Height, 9,000 feet. Angle of sight, 45 degrees. Range=4,500 yards.

$$\text{V.D.} = \frac{\text{Angle of sight}}{10} = \frac{45}{10} = 4\tfrac{1}{2} \text{ degrees.}$$

For fast or slow machines a proportion of the above results should be taken.

It is often found, even if the sights are accurately set, that a zero deflection will not produce bursts on the line of sight. This may be due to wear of the gun, barometer pressure, temperature, wind, variation in fuzes or to other causes. A few preliminary rounds should be fired at a distant object such as the moon.

Such rounds must be economically employed and should only be fired on days when shooting is probable and if weather conditions, &c., have changed.

A false zero can thus be established for each gun of a section or battery which will ensure the guns shooting the same as regards elevation.

On mountings (such as the 13-pr. 9 cwt., Mark IV.) with a movable pointer on the "up" and "down" scale the pointer can be set to the new zero.

Another method is to alter the vertical deflections for each gun until bursts are obtained on the line of sight as viewed over the sights themselves. These tests can only be carried out if the direction in which the rounds are fired is at right angles to the constant equivalent wind, as a head or following wind has the effect of causing a shell to burst above or below the line of sight respectively. In the case of a wind of 40 f.s. this may amount to as much as a degree.

Section 18.—*Lateral deflection.*

As a rough guide, the following rule may be employed for targets moving directly across the front:—

For 13-*pr.* 9 *cwt. and* 3-*inch* 20 *cwt.*—

At long ranges. Lateral deflection in degrees = one-tenth of the speed in miles per hour.

At medium ranges. Lateral deflections in degrees = one-tenth of the speed in miles per hour less one degree.

At short ranges. Deflections of about three-quarters of those used for long ranges will be required.

Example.—

The lateral deflection required for a machine travelling at 80 miles per hour.

(*a.*) At long ranges $= \frac{80}{10} = 8$ degrees.

(*b.*) At medium ranges $= \frac{80}{10} - 1 = 7$ degrees.

(*c.*) At short ranges $= \frac{80}{10} \times \frac{3}{4} = 6$ degrees.

The direction and strength of the wind must be taken into consideration, and an aeroplane can be taken as having its true speed plus or minus the component of the wind speed, according as it is moving with or against the wind. A machine going down wind may be travelling so fast as to require a deflection of over 12 degrees.

The result of the wind acting on the projectile also requires consideration. In estimating the total deflection necessary the effect of the wind on the projectile must be deducted from that of the wind on the aeroplane.

Section 19.—*Difficulties in determining deflections.*

1. The main difficulties of anti-aircraft shooting are due to changes in speed or direction by the aeroplane during the time of flight of the shell.

These changes may de due to—

(*a.*) Changes in angular velocity due to the speed of the target even when keeping a constant course. At long ranges this change is not great during the time of flight of the shell.

(*b.*) Attempts on the part of the pilot to avoid the fire of the guns.

The best chance of obtaining effect on an aerial target is with the first burst of fire, and every effort should accordingly be made to eliminate errors in the preliminary calculation of deflections and fuze range.

2. *Initial deflections.*—The charts at the end of the book show the initial deflections necessary when engaging aeroplanes travelling at 80 miles per hour and at various heights.

The deflections applicable to any particular gun must be committed to memory.

3. To use the chart it is necessary to imagine the figure in the form of graticules in a telescope, and having arranged it so that the target is in the centre, to note along which line (or presentation) the target will fly to the circumference.

The power of judging presentations is easily acquired after a little practice. The presentations which are the most difficult to judge accurately are those over 70 degrees, but an error of 10 degrees makes very little appreciable difference to deflections at these presentations.

Section 20.—*Corrections to deflections when deflection instruments are not available.*

1. If an aeroplane remains within range after the first burst of fire, fresh corrections can be given in certain cases from the observed position of the bursts. These bursts may show the actual corrections necessary for a new burst of fire or may, at any rate, give an indication of what is required.

The actual error in deflections as seen from the position of the bursts can be given as a correction if—

(*a*.) The aeroplane is keeping a constant course.

(*b*.) The range is not changing to any great extent during the time of flight of the shell.

(*c*.) The range is fairly long.

2. Owing to rapid changes in presentation of the target large corrections to deflections have often to be made, such as when an approaching target becomes a receding target, or a target moving to the right turns and becomes one moving to the left.

When small corrections to deflections are made, they should be ordered in degrees or half degrees and added to, or subtracted from, existing deflections on the scales, but for considerable alterations of course of target or when for other reasons the gun commander wishes to start afresh, use should be made of the word zero, which implies that the correction is to be made from zero. To change from an "Up" deflection to a "Down" deflection, the order should be given "Down zero . . . degrees." Similarly in changing from a right to a left deflection, the order becomes "Left zero . . . degrees."

3. Owing to the rapid change of presentation of an aeroplane target, even whilst moving on a constant course, the necessary corrections to deflections may be resolved into two distinct components, viz. :—

(*a.*) Corrections due to errors in estimating the height, speed, wind, &c.

(*b.*) Corrections due to the change of course, or presentation, of the target.

6. It is necessary to realise that it is not sufficient to correct the error actually observed, as such a correction will not bring the subsequent bursts on the line of sight. The presentation of the target, even on a constant course, is constantly changing, entailing a change in the amount of angular measurement through which the target will fly during the time of flight of the shell. Such changes must be taken into account practically every 30 seconds.

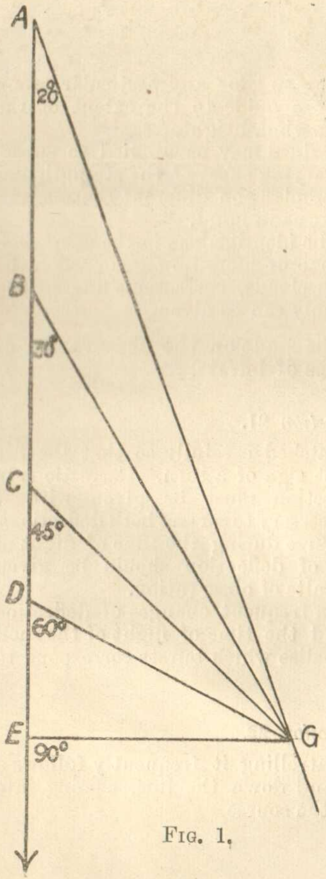


Fig. 1.

G represents position of a 3-inch 20 cwt. gun, and A B C D E the course of a target travelling at 80 miles per hour. Suitable deflections are shown for the various presentations (compare chart). The target is at extreme range at A.

The necessity for corrections will easily be seen, *i.e.*, L D changes from Left 3 to Left 7. V D changes from Up 4½ to zero.

A target travelling at 80 miles per hour will go from—

A to B in about 60 seconds.
B to C in about 40 seconds.
C to D in about 25 seconds.
D to E in about 30 seconds.

The corrections found necessary for any particular group of bursts can only serve as a guide to the extent of the original errors in estimating wind, height, &c.

The information thus obtained may be applied to subsequent corrections, but the varying effect of the strength and direction of wind on the aeroplane on different courses, and on the projectile, must be borne in mind.

When the bursts cannot be identified, as in the case when several guns are engaging one or more targets, or when the aeroplane is flying through clouds, corrections due to the presentation of the target only can be given.

Corrections should not be made on the observation of single bursts but of groups of bursts.

Section 21.

The target should be watched carefully so that the fire may be corrected at the first sign of a turn. Corrections to vertical and lateral deflection must be given without hesitation. It is usually necessary to correct both deflections. If a machine changes its course during the time of flight of the shell further changes of deflection should be given without waiting for the results of observation.

Care must be taken when frequent changes of deflection are ordered to keep in mind the time of flight of the shell or it will be difficult to realise which bursts correspond to which set of deflections.

Section 22.

When an aeroplane is patrolling it frequently follows a fairly constant course up and down the line, coming into range for a certain part of the course.

The first time an aeroplane comes into range it should be engaged in the ordinary way. If it returns on the same course again the knowledge of the corrections which were necessary at various points on its previous flights should be taken advantage of.

If an aeroplane is pursuing an irregular course (*e.g.*, moving in small circles) a few rounds fired without any lateral deflection appears to be the best plan.

Section 23.—*Effect of Errors in Fuze Range on Deflections.*

A large error in "Fuze Range," *i.e.*, getting bursts far short or far over, will upset calculations of lateral and, to a less extent, of vertical deflections.

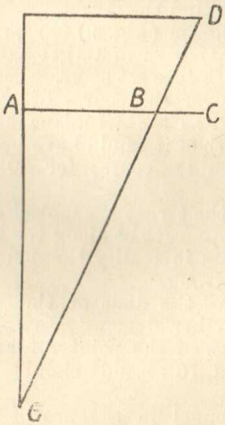


Fig. 2.

Example—

A gun is fired at fuze 22.

The real range is, say, 5,000 yards corresponding to fuze 15.

(13-pr. 9 cwt.) Time of flight for fuze 22 = 24 seconds.

Time of flight for fuze 15 = 14 seconds.

In estimating the deflection the time of flight of 24 seconds has been allowed for, but in reality the shell crosses the path of the plane after 14 seconds and then continues its course for 10 seconds before bursting.

The aeroplane also continues on its course for 10 seconds thus travelling through a larger lateral angle.

The burst which corresponds to the correct angular deflection appears behind the target.

In the above diagram (Fig. 2) G represents the position of the guns A, B, C path of target 5,000 yards from G. The shell is fired with fuze set at 22.

The shell passes over the course of the target (A, B, C) after 14 seconds just as the aeroplane is at point B (*i.e.*, if the shell had burst then it would have been correct for line) it then continues on its course for 10 seconds, bursting finally at point D.

In the meantime the target has moved to position C.

The burst at D appears to be along the line G, B, D and to be behind C, whereas in reality the deflection was correct, but the fuze range wrong.

An examination of the dials of the Wilson and Dalby instrument will further demonstrate this fact for which purpose the readings of the pointer for times of flight of, say, 22 seconds and 16 seconds should be taken and the difference noted.

In training personnel in the use of these instruments attention must be drawn to the necessity of taking readings corresponding to the time of flight of the shell for the range of the target.

Section 24.—Aeroplanes losing or making height rapidly.

The normal guides to this estimation of vertical deflections depend on the assumption that the target is travelling at a fairly constant height and speed, so that any marked change of altitude should at once be taken into account.

When, for instance, an aeroplane is turned back by anti-aircraft fire it will probably increase its speed either by using the full power of its engines or by diving, and the necessary down deflections will become correspondingly greater. Down deflections for a given fuze range tend to be larger than corresponding up deflections.

Section 25.—Effective bursts.

When engaging enemy aircraft it should be borne in mind that an effective shrapnel is not one that bursts on the line of sight, but slightly above it; the bursts should therefore be kept about $\frac{1}{4}$ degree above the line of sight.

CHAPTER IV.

Fuze Range.

Section 26.—Calculations based on height of target.

1. In dealing with the question of fuze range all calculations are made on the assumption that the aeroplane will be flying at a fairly constant height during any short period of time. Given the height of an aeroplane, the range to it at any

moment can be found from the height and the angle of sight. The assumption, however, that the target keeps at an exactly constant height is not strictly true; and also errors are possible in the methods of calculating a height at a given moment. In addition there are errors due to ballistics. In order, therefore, to allow for and absorb any such errors, a zone system is employed. This consists of firing a number of rounds at a given fuze, and continuing until it is certain that the target has passed out of the zone created by these bursts.

2. A zone is, however, not to be regarded as a barrage or wall of fire into which the target must fly (such as is set up when firing by quadrant elevation), but rather as a series of rounds each of which is a potential hit.

It will be seen, therefore, that as the methods of calculating the height of targets become more accurate, and when the ballistic errors are compensated for, the number of rounds fired at a given fuze will be less, and hence the extent of the zones smaller.

3. Generally speaking, the employment of zones absorbing large altitude errors can only be justified by sufficient volume of fire being established to fill the zone.

4. The initial problem is thus to find the height of the target.

Section 27.—To find the height of the target.

The height of an aerial target can be found—

(1.) Mechanically by some form of height-finder.
(2.) Mechanically by means of a range-finder.
(3.) By rough estimation by eye.

1. Height-finders are designed to obtain direct calculations of the height of an aerial target.

They depend for these calculations on angular readings being taken to the target from either end of a base of predetermined length.

Under favourable circumstances results of considerable accuracy can be obtained. In order to ensure this it is essential that not only should the personnel be carefully trained in the precise drill of the instrument, but also, that they should be constantly practised on friendly aircraft, and that the instruments themselves should be accurately adjusted at frequent intervals.

In conjunction with certain forms of height-finder a device can be used for comparing the height of the shell bursts with that of the target, the principal being the use of additional sighting wires so as to obtain simultaneous readings on the target and the bursts.

There are several considerations which affect the use of the height-finder.

(*a.*) If a long base be employed the readings will be more accurate than with a short base, but the difficulty arises of pointing out the target to both ends of the base. Owing to the loss of visibility this difficulty increases as the base is made longer.

(*b.*) In the case of a fixed height-finder a survey of the base has to be made which requires a considerable amount of time.

(*c.*) With several machines in the air, it is very difficult to ensure both ends of the base laying on the same aeroplane.

(*d.*) Telephone wires are always liable to breakage, especially in shelled areas.

2. Range-finders may be used indirectly to obtain the *height* of an aerial target. The range to the target is first found and then converted mechanically to height.

When suitably mounted, range-finders give good results and they possess the advantage that the difficulties of pointing out targets to a distant base are avoided.

3. Ability to estimate the height of aeroplanes is very important and needs much practice. Every series should be considered from this point of view until the eye acquires the faculty for this estimation.

Normally aeroplanes may be expected to fly at heights varying from 6,000 to 18,000 feet, with a mean of about 15,000 feet.

During extensive operations the average height may be expected to be considerably lower.

Estimating angles of sight.—The estimation of angles of sight to objects in the air should be practised. It may be of great use in pointing out targets quickly.

When once the height of an aeroplane has been read or judged, the question of when to open fire at a given fuze depends on the angle of sight and the vertical deflection.

Section 28.—*To find the ballistic height and height error.*

1. The "ballistic height" is the height which must be employed on the height fuze indicator, in order to ensure the trajectories reaching the correct height.

The correction which it is necessary to make to the observed height should be checked from time to time as described below (*see* also Section 17).

To arrive at the ballistic height, certain fuzes are selected and fired from a gun laid at certain quadrant elevations. These fuzes should burst at definite heights, provided the meteorological conditions are normal, and provided the muzzle velocity of the gun has not been reduced by wear or altered by other circumstances such as temperature of the charge. The actual height of the bursts is measured by means of a height finder, and the difference between the actual height and the height at which they should burst is called the "Height Error." This height error is proportionate to the height. Thus, if a shell which should burst at 12,000 feet is observed to burst at 11,000 feet the height error at 12,000 feet is 1,000 feet low or 8·33 per cent., and the ballistic height will be roughly 13,000 feet; it can thus be assumed that the height error at 6,000 feet would be 500 feet low and the ballistic height would be roughly 6,500 feet.

2. In order to ensure getting the correct ballistic height, it is necessary to select fuzes and quadrant elevations that will give a burst at the highest part of the trajectory, as the height of the burst is not then affected by any variation in the time of burning of the fuze.

3. The fuzes and quadrant angles, also normal times of burning for a burst at 12,000 feet and at 8,000 feet should be obtained from the range table.

For the 13-pr. 9-cwt., they are as under :—

Height in feet.	Fuze.	Q.E.	Time of flight.
		° ′	secs.
12,000	20	51 18	24·4
8,000	18	38 20	19·7

N.B.—These Q.E's. assume that there is no jump.

To find the height error or ballistic height, the gun should have a preliminary round fired from it, as the first round usually gives abnormal results.

4. The gun must be carefully laid at the Q.E. shown, then loaded and the Q.E. again tested, and immediately fired. If the round is left in the chamber of a hot gun for

some time before it is fired, an abnormal result may be obtained.

The time of burst of the fuzes should be taken with a stop watch and recorded.

5. At least three rounds should be fired at each fuze setting and several readings taken with the height finder on each burst ; the mean of such readings should be recorded. If any reading varies very much from the others, it should be regarded as an abnormal round and not recorded.

Readings should be to the nearest 100 feet.

Section 29.—*Methods of obtaining fuze range when height fuze indicators are available.*

1. The general principle should be to engage enemy aircraft with short bursts of rapid fire (say, 4 to 6 rounds per gun) all fired with the same fuze setting, then to stop and reopen fire with a fresh burst fired at a suitable fuze setting, either immediately or after an interval.

2. In selecting the fuze to employ during a burst of fire the object should be to ensure that the first rounds burst in front of the target and the last rounds behind the target, that is provided the height, &c., have been correctly estimated.

3. Even if the height has been over- or underestimated by about 700 feet, this procedure should ensure that one out of a burst of six rounds per gun will be fired with the correct fuze range to the target.

These short bursts ensure that fire is kept under control and is not continued at a fuze range which must have become too long or too short.

Also, owing to the short life of anti-aircraft guns, it is important to limit the number of rounds fired, and this is best effected by firing in short rapid bursts.

4. There are two methods of arriving at the correct fuze to employ during these bursts of fire.

Method (I.) Having determined the correct ballistic height of the target, obtain the correct fuze setting from a height fuze indicator.

Method (II.) First determine the range and then deduce the correct fuze setting from the range.

5. Method I. should be considered the normal method, and should always be employed, except when the target is flying at very low altitudes.

Aircraft flying at heights of under 5,000 feet should be engaged by Method (II). The majority of height-finders are not constructed to work at under 4,000 feet or under 15 degrees angle of sight, and the results given at low angles of sight are not of an accuracy sufficient to determine the correct fuze from a height fuze indicator, *e.g.*, at 11 degrees angle of sight and at a height of 4,000 feet an error of 500 feet in the height will correspond to an error of four fuze lengths with a 13-pr. 9 cwt. gun.

6. For all targets at 5,000 feet or higher Method (I) should be employed, and section commanders should be forbidden to guess or estimate the fuze from the range. If a range finder is used it should only be used as a means of estimating the height.

7. When neither height finder nor range finder are available, or in cases where enemy aircraft appear suddenly within range, section commanders should estimate the height and obtain a fuze from the height fuze indicator; the height can be corrected subsequently, when accurately obtained, or from observation.

8. Whichever method is employed, it is essential that "dead time" should be taken into consideration, that is the

interval which elapses between the fuze setting being read off the height fuze indicator (or in Method (II) the range being read) and the gun being fired. This may be taken to be about 5 or 6 seconds.

If this interval is not taken into consideration, and the ballistic height has been obtained, the first round of the series will burst behind the target, and each subsequent round at the same fuze length will burst still further behind, provided there is any vertical deflection necessary.

9. There are various methods for allowing for this "dead time," and a simple way of doing so with the existing pattern of height fuze indicator is to exaggerate the vertical deflection when applying it to the indicator.

If for the longer fuze lengths, the vertical deflection ordered is multiplied by $1\frac{1}{2}$, and for the shorter fuze lengths by 2, before being applied to the indicator, the effect will be not only to allow for the 5 or 6 seconds "dead time," but to make a slightly greater allowance which will ensure the first round of a series bursting slightly in front of the target.

It can be calculated that the effect of applying these exaggerated vertical deflections to the indicator, will be to indicate a fuze length which will give a correct burst for the third or fourth rounds of a series, under normal conditions.

10. This method of allowing for "dead time" and arriving at the suitable fuze length to employ during a short burst of fire, is equally applicable to targets approaching or receding, directly or obliquely.

When from observation (distant or otherwise) it is apparent that the majority of the bursts are all too short or too long, the correction must be applied to the height which will automatically lengthen or decrease the fuze lengths employed.

This should be the only method of altering the fuze length.

11. In the case of Method (II), until some instrument can be designed which will measure the rate of change of range, the only practicable method of arriving at the correct fuze from the range, appears to be to tabulate the fuze length to employ in the case of approaching, crossing and receding targets, worked out for an average speed (like 80 miles an hour) and for an average height such as 3,000 feet. These can be printed on a small card and given to the operator of the height fuze indicator, who can be employed in Method (II), to translate ranges into fuzes for the section commander.

12. In either method the section commander should stop the fire after an interval of from 15 to 20 seconds, or as soon as the target alters its course, and obtain a new fuze setting as described above.

Section 30.—*Method of obtaining fuze range when no height fuze indicators are obtainable.*

The following factors must be considered when determining the fuze range :—

(*a.*) *When to open fire at a given fuze.*

For tactical reasons approaching targets have, as a rule, to be engaged at maximum ranges ; in certain cases, however, it may be permissible to allow the target to come into medium range before fire is opened. Then owing to the greater accuracy of the gun and the shorter time of flight of the shell the fuze range can be more accurately determined.

The angle at which the target should be engaged at a given height and with a given fuze is called the "attack angle," and the following simple tables show the attack angles for various heights and fuzes for the following guns :—

The tables correspond to the equipment in use and should be memorised by the officers and senior N.C.Os. of Anti-Aircraft units.

They are, however, merely for guidance when no fuze height indicators are available.

13-*pr.* 6 *cwt.* *Fuze* 80.

Height of target in feet.	Attack angle, fuze 22.	Attack angle, fuze 16.
4,000	12	16
6,000	18	25
8,000	24	32
10,000	30	40
12,000	36	52

N.B.—As a rough guide for a 13-pr., 6 cwt. for a given height the attack angle at fuze 22 = three times the number of thousands of feet in the height.

For a given height the attack angle at fuze 16 = four times the number of thousands of feet in the height.

13-*pr.* 9 *cwt.* *Fuze* 80.

Height in feet.	Attack angle, fuze 22.	Attack angle, fuze 16.
5,000	14	18
7,000	20	24
9,000	25	32
11,000	32	40
13,000	38	48
15,000	47	60
17,000	58	...

3-*inch* 20 *cwt.*

Height in feet.	Fuze 80· Attack angle, Fuze 20.	Fuze 85.	Fuze 80. Attack angle, Fuze 16.	Fuze 85.
4,000	10	11	12	12
6,000	15	16	18	18
8,000	20	21	24	25
10,000	25	26	30	31
12,000	30	32	36	37
14,000	35	38	42	45
16,000	40	45	48	52

As a rough guide the attack angle for the 13-pr. 9 cwt. at fuze 22 and the 3-inch 20 cwt. at fuze 16 is three times the number of thousands of feet of the height of the target.

The attack angle for the 3-inch 20 cwt. at fuze 20 can be obtained by dividing the number of hundreds of feet in the height by four.

(*b.*) *How long to continue firing at a given fuze.*

The zones employed are designed to absorb a certain altitude error. At a given height this error is absorbed by firing between certain limits of angles of sight. Fire must be continued at the same fuze between these limits, unless the results of distant observation make a correction necessary. In actual practice bursts of fire should not exceed six rounds per gun without making corrections.

(*c.*) *How much to shorten or lengthen the fuze when the target has passed through a given zone.*

This depends on the limits of altitude between whic the zones are employed. If these limits are great the angles of sight which the zones absorb will be found to include several fuzes.

If the target is flying very fast towards or away from the guns the "dead time" will have to be allowed for.

To establish new zones when no fuze height instrument is available, or when targets are at low altitudes, the following rough rule may be taken as a guide for long ranges :—

For a slow target edging in towards the guns drop two fuze lengths.

For a medium-paced target or obliquely approaching target drop four fuze lengths.

For a rapidly-approaching target drop six fuze lengths.

If the target is receding the fuze lengths will be increased by corresponding amounts.

Section 31.—*Laddering.*

With two or more guns together there are various methods of utilising the increased volume of fire to the best advantage. Of the three variables in anti-aircraft gunnery, fuze range is the hardest to calculate accurately. The zone system allows for this, but only at the expense of intensity of effective fire, owing to the fact that at any definite height only a few effective shell can be expected from a single gun.

Better results can be obtained when several guns are employed by a system of laddering fuzes. This in its simplest form consists in firing the guns at different fuze lengths for the same angle of sight. This, however, does not produce an equal effect at all ranges.

If a larger number of guns than a section are concentrated together the additional volume of fire should be employed in increasing the density of the zone rather than the space covered by the fire. In certain cases the sights of the guns may be set differently : about half a degree of difference is sufficient. This gives the burst of fire a certain amount of vertical and lateral dispersion.

Section 32.—*Quadrant elevation ranging.*

This method is useful for—

(*a.*) The protection of observation balloons by day.

(*b.*) Firing at night without searchlights.

It is designed to produce a barrier of fire the bursts of which are all on the same height. The line is obtained by laying direct on the balloon or at night in direction of the sound or on the probable line of approach, whilst the elevation is found by giving the quadrant elevation to produce bursts at a given height.

The protecting barrage should give bursts near the balloon, so that attacking aircraft will have to fly through the barrage, which can be moved to meet the lines of attack. Shrapnel should be employed, as high explosive, the effect of which is largely radial, might damage the balloon.

In night firing tactical consideration may be of assistance in judging from what direction an aerial target may be expected. Aeroplanes by night use rivers, roads and other landmarks to steer by. The probable direction of approach of a hostile plane may sometimes be anticipated by the consideration of such landmarks.

CHAPTER V.

An Example of Ranging.

This example is designed to show the procedure in a section of 13-pr. 9 cwt. anti-aircraft guns. It is also applicable to other natures of anti-aircraft guns with the necessary modifications to orders, including deflections.

(*a.*) From the time a hostile machine is seen until fire is opened.

(*b.*) During the firing.

The aeroplane is supposed to follow the course A, B, C, D, as shown, Fig. 3. It is sighted at point A, the observer being with the guns at point G.

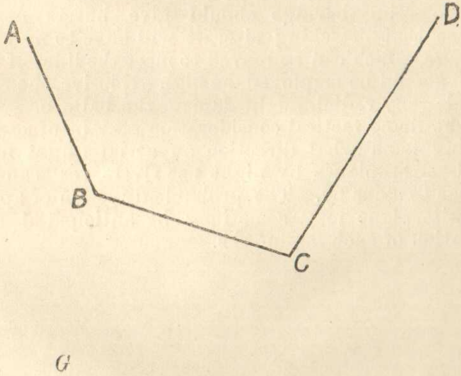


Fig. 3.

Section 33.—*Procedure on the aeroplane being sighted.*

(*a.*) The machine is identified as being hostile by the section look-out and the alarm given.

(*b.*) The detachments man the guns while the officer commanding the unit confirms the fact that the machine is hostile.

(*c.*) The target is pointed out to the layers and to all concerned. (This includes the personnel of the Height-finder and the Distant Observing Stations.)

Case 1.—It is assumed that there is sufficient time to obtain readings of instruments for deflection, fuze range, &c., and :—

(*a.*) The height-finder gives a reading of 14,000 feet. The pointer of the height fuze indicator is set at this height a correction being made, if necessary, for the height error. If the range-finder was in use a reading of 9,000 yards at an angle of sight of 30 degrees might well be expected. This could be converted to height by a special instrument or by using the formula $H = \frac{R \times O}{\cdot 20}$ where R is the range in yards, H, the height in feet and O the angle of sight.

(*b.*) Readings of the Wilson and Dalby instrument are taken. When fire is about to be opened, these readings are given to the guns (as the target is approaching the guns fairly rapidly it might be advisable to add half degree to the Wilson and Dalby instrument for vertical deflection). An exaggerated vertical deflection is also put on the height fuze indicator.

Case 2.—It is assumed that there is no opportunity for the use of the height-finder or deflection instruments.

An estimation of the height of the machine is made (say 14,000 feet).

It is judged to be approaching at a medium speed (say 80 miles per hour).

It is desired to engage the target as soon as possible, *i e.*, fuze 22.

The attack angle for fuze 22 at a height of 14,000 feet is about 42 degrees (rough rule—attack angle for fuze 22, 13 pr. 9 cwt. in degrees = three times the number of thousands of feet in the height).

Applying the rough rule for obtaining vertical and lateral deflection we have

$$\text{V.D.} = \frac{\text{Angle of sight}}{10} + 1 = \frac{42}{10} + 1 = 5 \text{ degrees.}$$

(to nearest ½ degree)

$$\text{L.D.} = \frac{\text{Speed in m.p.h.}}{10} = \frac{80}{10} = 8 \text{ degrees.}$$

The presentation of the target is about 30 degrees ; hence about half the full lateral deflection and nearly all the vertical deflection will be needed.

This gives V.D. = 4 degrees. L.D. = 4 degrees.

These deflections and the height are ordered.

In either case the order to load and fire is given as soon as an intersection is obtained on the fuze curve by the pointer on the height fuze indicator.

Section.	Orders to gun.	Resulting deflections, &c.
	Fuze 22. *Up* 4, *R* 4. *Gun fire.* After 6 rounds per gun. *Stop.*	F. 22. Up 4. R. 4. Fire is continued for 6 rounds per gun. Bursts are seen ½ degree low and 1 degree to the right of the line of sight. The position of these bursts is an indication of the corrections needed. Cumulative corrections may be given. The fuze range will also have altered as shown on the height fuze indicator.
	F. 18. *Up* ½. *L* ½. *Go on.*	F. 18. Up 4½. R. 3½. The lateral deflections are beginning to increase owing to the tendency of the target to become a crossing one. (Change of presentation.)

The aeroplane reaches course B and turns on to the point B. C. Wilson and Dalby instrument readings are taken, and these may be given as deflections without alteration, as the range is not changing rapidly. The same fuze range might be employed. Corrections from zero should be given.

Section.	Orders to gun.	Resulting deflections, &c.
	Stop. Up zero 1. *R. zero* 7. *Go on.*	F. 18. Up 1. R. 7. Bursts are seen about 2 degrees above the target and about 4 degrees to the left of it. These should be neglected, as they are bursts corresponding to the deflections given when the machine was on course A. B.

Section. Orders to gun.	Resulting deflections, &c.
Fuze 16. *Go on.*	F. 16. Up 1. R. 7. Fuze range is altered to fuze 16.

Bursts are seen correct for line and elevation, but the distant observer reports short. The inference from this is that the height of the target has been underestimated. Fuze range is now altered on a basis of a height of 15,000 feet (*i.e.*, 1,000 feet more. This affects the corresponding fuze ranges by 1 or 2 fuze lengths).

Stop	Target turns at C and proceeds on course C D. The Wilson Dalby readings are taken and show Down 3 R. 2½. These readings may be given to the guns, as although the vertical deflections tend to get less at long ranges yet the speed of the target may be increasing.
Fuze 18. *Down zero* 3. *R. zero* 2½. *Go on.*	F. 18. D. 3. R. 2½. The fuze range is increasing. The target dives suddenly. Readings on the height fuze indicator will be useless until a new height is obtained.
Stop	Estimation for fuze range and deflections should be used. Cumulative corrections may be given.
F. 22. *Down* 3.	F. 22. D. 6. R. 2.

Section.	Orders to gun.	Resulting deflections, &c.
L. ½.	*Go on* ...	As soon as the machine has passed through the fuze 22 zone, fire is stopped. If the machine has kept a fairly constant height the fuze height indicator would show when the target was out of range.
	Stop	As soon as it is certain that the machine is not turning back towards the guns, or that there is no other hostile machine near, the detachments may be withdrawn.

CHAPTER VI.

Distant Observation.

Section 34.—*Distant Observation in General.*

1. Under suitable conditions corrections for fuze range may be made by observations from different stations. In the field, telephones have so far been found to be the most practical method of transmitting the observations, which must be conveyed instantaneously, or they are useless.

Several stations are needed, each with a definite zone allotted in which observations are to be made.

Observation should be made on groups of bursts and not on single bursts.—Experience has shown that it is not practicable to report the amount "short" or "over" of any particular burst, nor, owing to variation in the time of burning of the fuze, would the information be of value when received.

The general tendency of the fire "over" or "short" or "high" or "low" is all that can be expected, and the resulting correction should be given to the guns in terms of height.

Section 35.—Special Difficulties of Distant Observation.

The problem of distant observation of fire is not an easy one, and demands a considerable amount of intelligence on the part of the officer or non-commissioned officer carrying it out. For instance, a target visible to the guns may be invisible to the distant observer on account of clouds, &c., or with two or more machines in the air it may be difficult to indicate which one is being engaged even if the bursts are near the target.

During the time of flight of any particular round, the target may turn and fly in a different direction, so that a round which would have burst correctly had the target continued on its course, may quite possibly burst as much as 2,000 yards away from it, should the target turn in the opposite direction just after the gun fires. A distant observer, who did not realise this, would report this round as "Far Over" or "Far Short," and the section commander, not knowing to which particular rounds the observation applied, would not be in a position to make a suitable correction.

For this reason, it is not advisable to get distant observation from any but trained observers.

Distant observers should be instructed never to send any observations unless they are sure that the target has continued on the same course during the flight of the shells observed.

CHAPTER VII.

The Identification of Aeroplanes.

Section 36.—*General Instructions.*

1. The duty of a look-out man is to be able to identify aeroplanes at considerable ranges (up to 10,000 yards). Small details of manufacture are accordingly of little importance.

2. Men under instruction should be taught to make rough drawings of various types of machines. This can be done well enough to show the main features of a type without the draughtsman having any particular talent. The aspects of an aeroplane wnich are simplest to draw and which show all the necessary features are as follows :—

(*a.*) The view as it passes overhead. This shows the shape of the tail and wing tips and also if there is a stagger.

(*b.*) The side view. This shows if the wings are staggered and also the shape of the rudder.

(*c.*) The approaching or receding view. This shows if the wings have extensions or dihedral and also the number of struts on each side of the fuselage.

3. Men should be taught to consider what features of a machine can be seen from the various "presentations" it may offer to the observer.

4. The importance of efficient look-out work in anti-aircraft batteries and sections should be emphasised. Good look-out work not only improves the efficiency of a unit, but it also lessens the work of the men not on duty. It should be

a point of honour for look-out men not to allow a single aeroplane to appear during their tour of duty without it being identified.

5. The same type of machine has often a very different appearance according to the variation of its "presentation" to the observer. Each type must be considered from the following points of view, when—

(*a*.) Directly approaching or receding.
(*b*.) Obliquely approaching or receding.
(*c*.) Crossing.

6. When it is desired to identify a type actually in the air, it must be watched during its whole flight.

7. Visits to aerodromes should be arranged, if possible, especial attention being given to machines in the air.

8. No officer or man of an anti-aircraft unit in the field can be considered efficient until he can identify all the types of machines flown on his particular sector of the front, or at least recognize their nationality.

9. Owing to the fact that the design of aircraft changes rapidly no details of aeroplanes are included in this book. These will be found in S.S. 162, "Notes on Identification of Aeroplanes," and also in the silhouette plates issued from time to time.

CHAPTER VIII.

The Attack of Airships.

Section 37.—*Characteristics of Airships as Targets.*

Airships differ from aeroplanes as targets for artillery fire in the following respects:—

(*a*.) They are far larger. (The latest type of Zeppelin is about 670 feet long, with greatest breadth of 70 feet.)

(*b*.) Their normal cruising speed is 50 to 60 miles per hour, though when the airship is not loaded with bombs, &c., and has a favourable wind, speeds up to 90 miles per hour, have been attained.

(*c*.) Airships have not the capacity of aeroplanes for sudden turns and changes of direction. They can turn easily, but only slowly as compared with aeroplanes.

The main difficulty of attacking airships by night is the lack of visibility.

In addition to the darkness, there may also be low-lying fog and mist.

At night it is difficult to use mechanical measuring instruments, or to estimate degrees. Also under cover of darkness airships can sometimes drift over their objective by taking advantage of the wind, in which case no indication is given of their position by the noise of engines, &c.

Section 38.—*Deflections in Attack of Airships.*

The question of lateral and vertical deflections is considerably simplified by the relatively low speed of airships as well as by their size, which allows a certain latitude in the calculation of deflections. A crossing Zeppelin subtends two degrees or more at 6,000 yards.

Owing to the size of the target, the same deflections will be suitable at all fuze ranges for a given height, and a proportion of these deflections should be taken for a faster or slower moving airship.

The following may be taken as a rough guide for the deflections necessary for engaging airships travelling at 50 miles per hour :—

(*a.*) For 3-inch 20-cwt. gun.—Vertical deflection varies from 3 degrees at 14,000 feet to 2 degrees at 6,000 feet. Lateral deflection varies from 4 degrees at 14,000 feet to 2½ degrees at 6,000 feet. A mean vertical deflection of 2½ degrees and lateral of 3 degrees is sufficient for memorising purposes.

(*b.*) For 13-pr. 9-cwt. and 13-pr. 6-cwt. gun.—The vertical deflection varies from 3½ degreee at 14,000 feet to 2½ degrees at 6,000 feet. The lateral deflection varies from 5 degrees at 14,000 feet to 3½ degrees at 6,000 feet. A mean vertical deflection of 3 degrees and lateral 4 degrees may be taken for memorising.

(*c.*) For 12-pr. 12-cwt. gun.—The vertical deflection varies from 3 degrees at 14,000 feet to 2 degrees at 6,000 feet. The lateral deflection varies from 4 degrees at 14,000 feet to 3 degrees at 6,000. A mean vertical deflection of 2½ degrees and lateral of 3½ degrees is sufficient for memorising.

The vertical deflections are calculated for directly approaching and receding targets, the lateral for directly crossing targets. For oblique targets a proportion of each will be required, *e.g.*, with a presentation of 45 degrees two-thirds of each full deflection will be necessary.

Section 39.—*Fuze Range.*

Fuze range is based on the assumption that the airship will be flying at a fairly constant height during the series, though, in point of fact, sudden changes of altitude on fire being opened are to be expected.

The height of the target can be obtained by the use of height-finders, range-finders, or by estimation.

Height-finders should give accurate results, but the personnel working them need special training in night work.

Airships are capable of attaining a height of 24,000 feet, but cannot stay at this height for long periods.

Fair results can be expected by assuming that the average height is approximately 12,000 feet, and a rough estimation can be made by assuming the length of the airship to be 225 yards. The angle it subtends should be considered in conjunction with the angle of presentation at the moment.

Once the height of the airship has been established the question of fuze range can be solved by the use of the height fuze indicator.

After the first burst of fire the attack should be continued as far as possible on the results of distant observation, and the change of fuze range as shown on the fuze height indicator.

The accuracy of this method depends largely on the presentation of the target at the moment.

Section 40.—*Tracers.*

When shells with tracers are used observations should be confined to the position of the bursts.

Section 41.—*Ammunition.*

1. Airships are peculiarly vulnerable to incendiary attack.

High explosive and shrapnel can be used for general destruction of material, and in certain cases may produce an incendiary effect. There are, however, incendiary shells specially designed for the attack of airships.

These are known as A.Z. (Anti-Zeppelin) shell.

The flash from the fuze is transmitted through a central tube in the shell and ignites a small quantity of powder. This fires the igniting composition and the incendiary composition in the body. The base of the shell is blown out and a flame is emitted through the base of the shell. This flame lasts for about 15 seconds and gives tracer effect.

It is essential that this ammunition should be stored separate from other ammunition.

2. Only two fuze settings are necessary, as follows :—

	Fuze A.	Fuze Z.
3-inch 20 cwt. Fuze T. 185. ...	4	10
Other anti-aircraft guns T. 180 ...	5	10

The periods during which these fuzes respectively should be used are tabulated as follows :—

3-inch 20 cwt.	Fuze "A"	When the fuze indicator reading does not exceed Fuze 13.
"	Fuze "Z"	When the fuze indicator reading exceeds Fuze 13.
18-pr.	Fuze "A"	When the fuze indicator reading does not exceed Fuze 13.
"	Fuze "Z"	When the fuze indicator reading exceeds Fuze 13.
13-pr. 9 cwt.	Fuze "A"	When the fuze indicator reading does not exceed Fuze 14.
"	Fuze "Z"	When the fuze indicator reading exceeds Fuze 14.
12-pr. 12 cwt.	Fuze "A"	When the fuze indicator reading does not exceed Fuze 14.
"	Fuze "Z"	When the fuze indicator reading exceeds Fuze 14.

3. A distant fire observer is necessary to report whether the trajectory passes above (high) or below (low) the target.

The height and vertical and lateral deflections are ordered, the necessary tangent elevation being kept set on the fuze range dial according to the fuze shown on the height fuze indicator.

4. Corrections to trajectory will be ordered in terms of *vertical deflections* according to the observation received from the distant observer as to the relation of the flaming trajectory to the target.

Sufficient time must be allowed for the result of one correction to vertical deflection to be signalled before making a fresh correction.

5. Corrections should be bold to commence with in order to try and obtain a bracket, for example :—

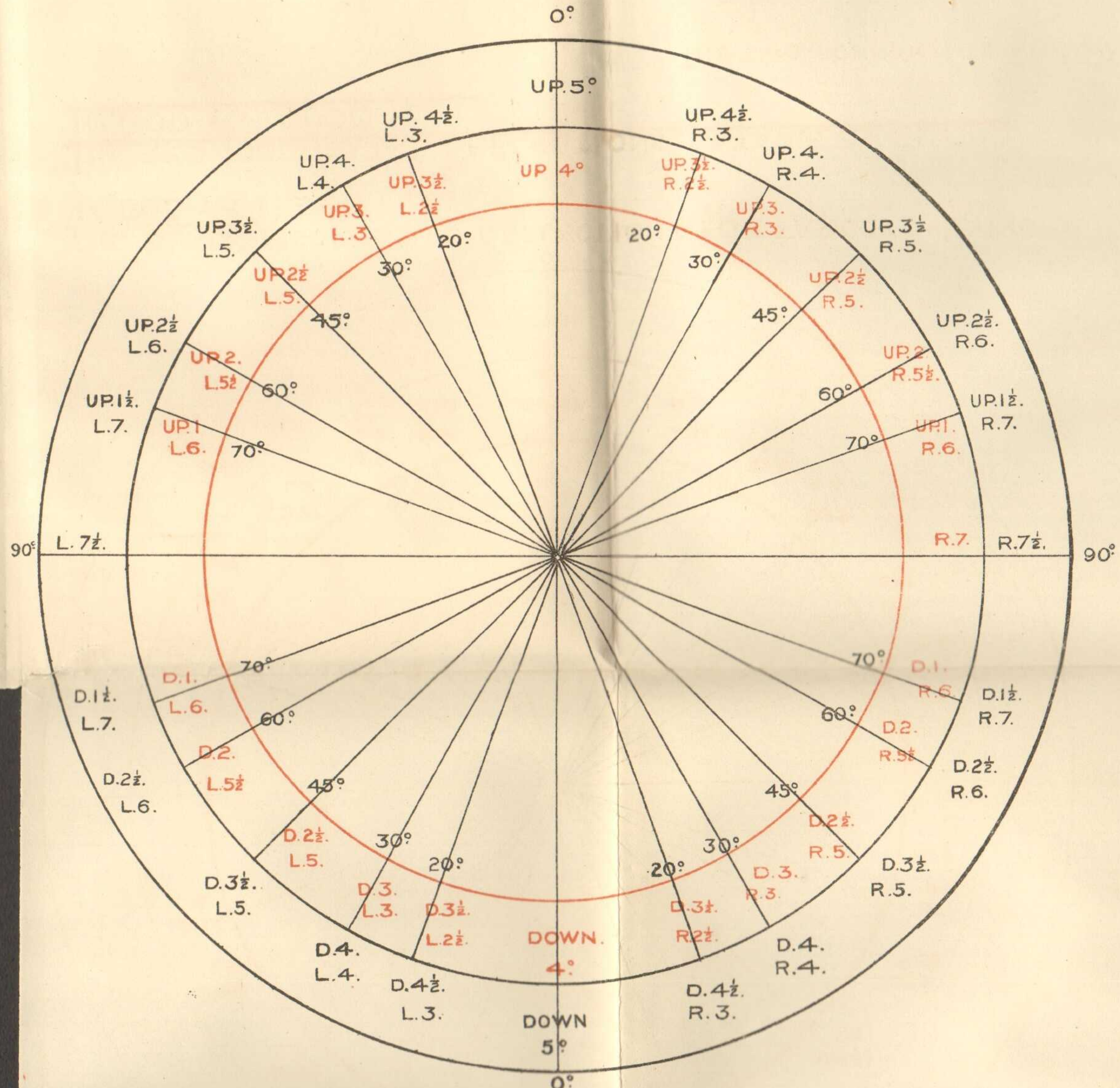
Distant observation received.	Correction ordered.
High.	Down 2°.
Low.	Up 1°.
Low.	Up ½°.

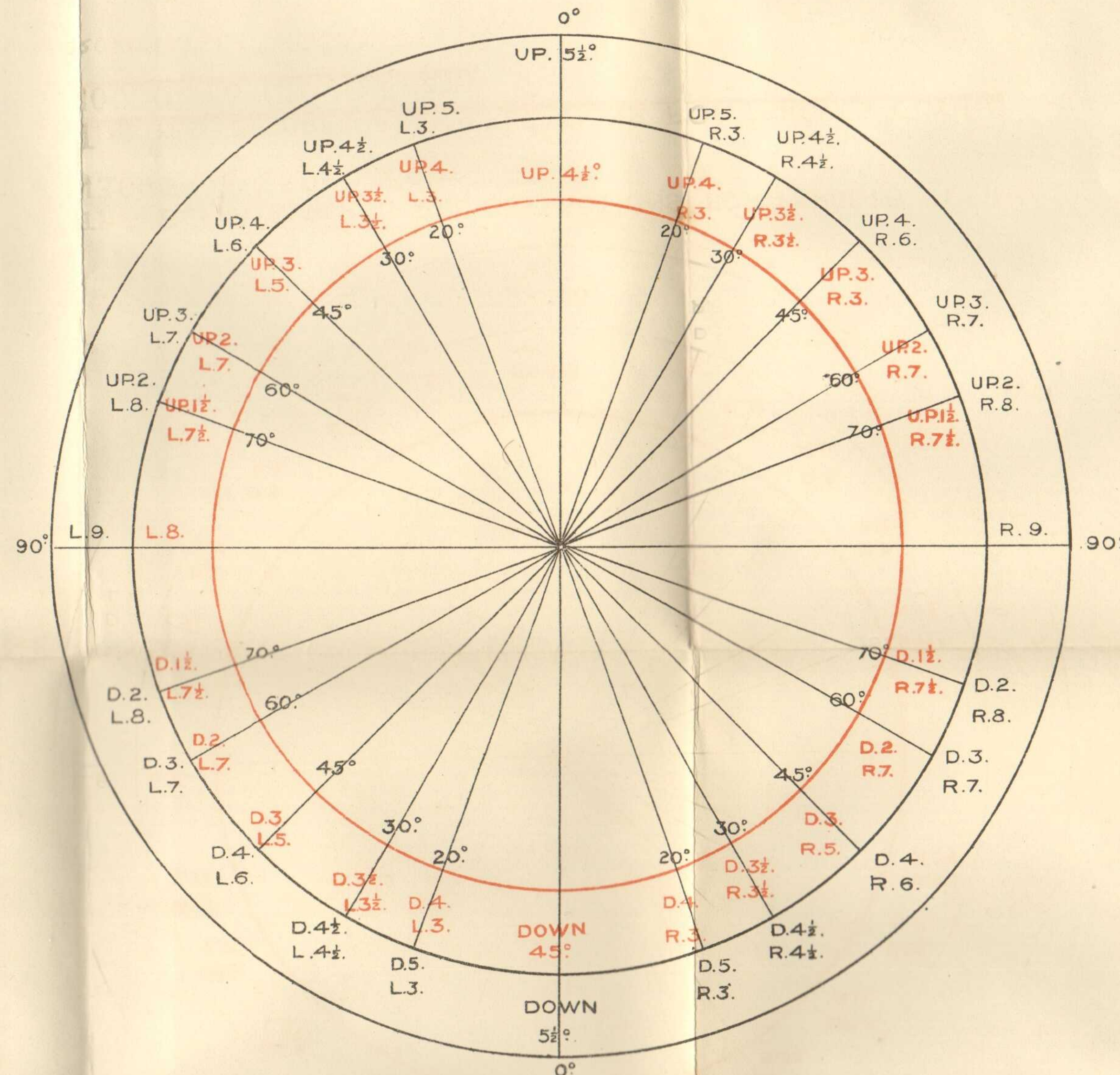
It is possible if the height of the airship is very much under or over estimated, that the vertical deflection may run off the scale, in which case a fresh height should be ordered.

Corrections to lateral deflection will be ordered on the observations from the guns of the point where the flaming trajectory crosses the line of sight "gun——target."

The necessary alterations to both vertical and lateral deflections must also be made in accordance with any change observed in the "presentation" of the target.

3" 20 Cwt. | Deflection Charts. for Speed of Target. 80 M.P.H. | 13-Pr 9 Cwt.





The BLACK figures are deflections for targets flying 14,000 to 16,000 Feet.

The RED figures are deflections for targets flying 10,000 to 14,000 Feet.

The BLACK figures are deflections for targets flying 13,000 to 15,000 Feet.

The RED figures are deflections for targets flying 10,000 to 13,000 Feet.

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The two components at 30° are approximately the same.

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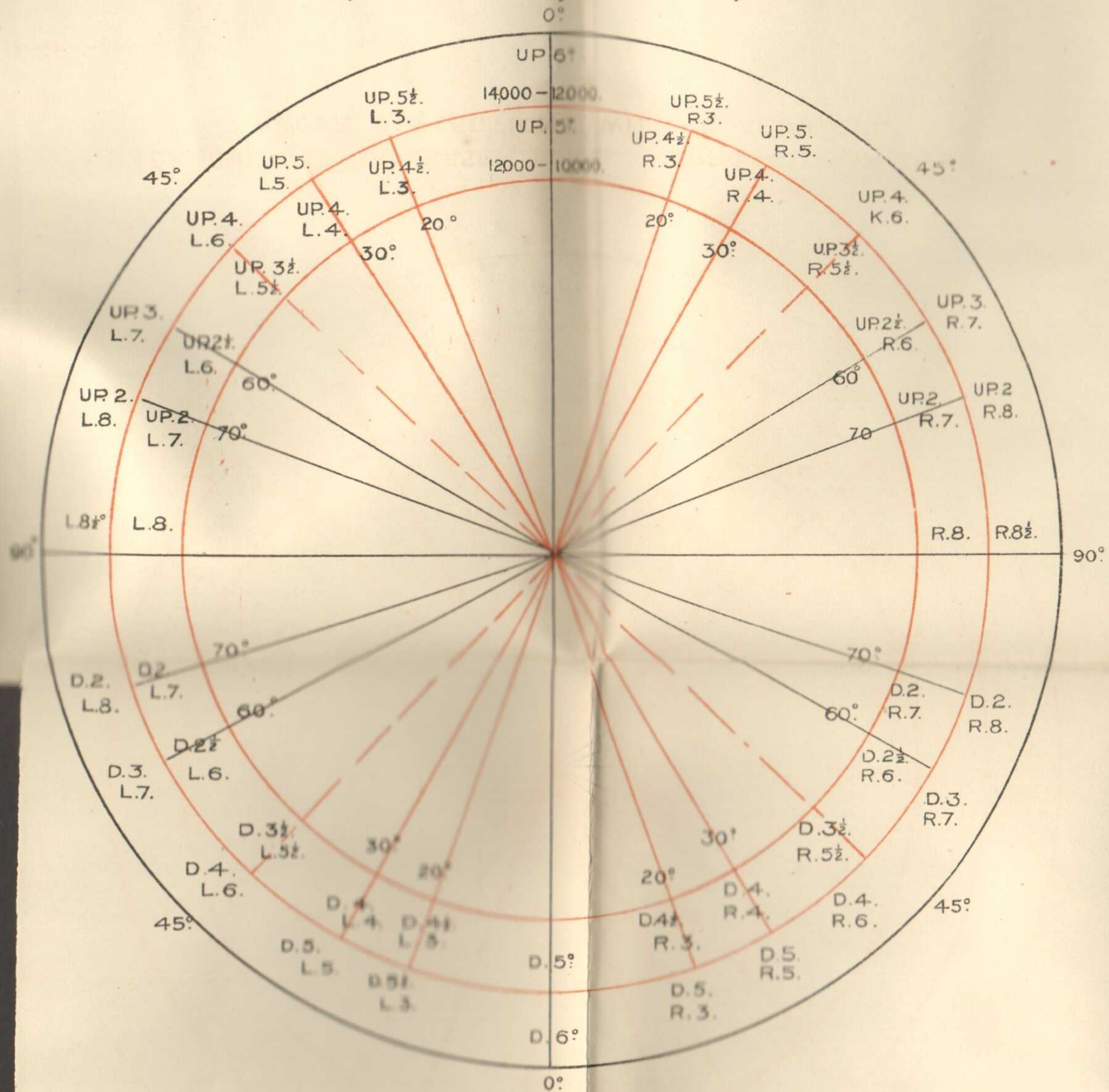
Deflection Chart.

— 18-Pr Q.F. —

Speed of Target 80 m.p.h.

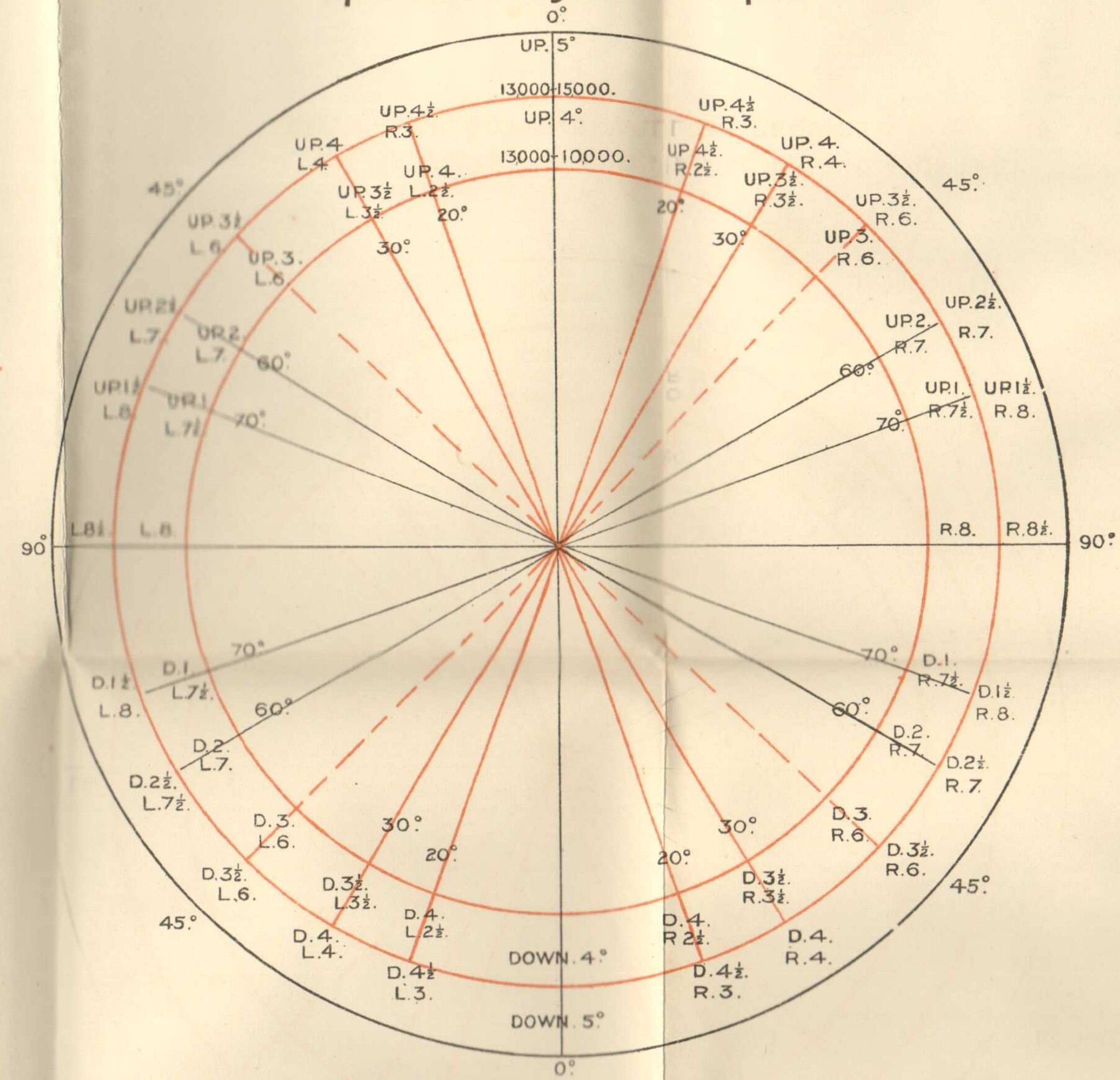


For greater or lesser speeds a proportion of the above deflections will be required.

Deflection Chart.

— 12-Pr 12 Cwt —

Speed of Target 80 m.p.h.



For greater or lesser speeds a proportion of the above deflections will be required.

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