CHAPTER 3

RADAR AIDS TO GUNLAYING IN BOMBER AIRCRAFT

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LIST OF ILLUSTRATIONS

GENERAL PRINCIPLES OF AGLT

Introduction

1. AGLT (Airborne Gunlaying in Turrets), formerly called Village Inn, is an ultra short wave radar equipment installed in heavy bombers. Its primary function is to provide the rear gunner with accurate information about the position of an enemy fighter. The directional properties of the system are such that the gunner can open fire at an unseen target with an accuracy of about half a degree. Under conditions of good night visibility the equipment may be used in a less ambitious way—the gunner using radar to find the location of the attacking fighter, but relying on visual aid for firing the guns.

2. AGLT has two subsidiary functions. In the first place it warns the gunner and air-crew that an aircraft has been picked up in the AGLT beam. This is achieved by the injection of a warning note into the intercommunication system whenever an aircraft is within 4,000 feet of the bomber and inside the beam. The warning note is of the pipping type and varies with the range in the same way as that used in Monica.

3. The second subsidiary function of AGLT is connected with the operation of the Mk. II C gyro gunsight, which is used with AGLT. The gyro gunsight is a form of predictor which calculates the allowance that the gunner has to make in order to hit the target. The sight is automatic, but normally has to have the target range fed into it by an optical range finder which is operated by pedals. When AGLT is used the range correction is obtained from the radar equipment and the sight becomes fully automatic. It can be used in this way either by night or by day. This last function of AGLT may be summarised by stating that the equipment provides automatic range for the Mk. II C gyro gunsight.

Scanning system

4. AGLT is installed in powered gun turrets. The scanner is covered by a perspex dome and is mounted at the base of the turret as shown in fig. 1. It rotates in azimuth with the guns when the turret is turned. The scanner is connected to the gun elevating mechanism by a parallel linkage so that it follows the gun movement in elevation. The aerial is a small dipole mounted near the focal point of a 16-inch parabolic reflector. The dipole is mounted eccentrically and is spun by an electric motor at 2,000 r.p.m. This causes the axis of the beam to follow a conical scan with a vertical angle of 11 degrees. The aerial is fed from a 9·1 cm. magnetron transmitter through a coaxial cable, and half-microsecond pulses are radiated at a p.r.f. of 660 per second.

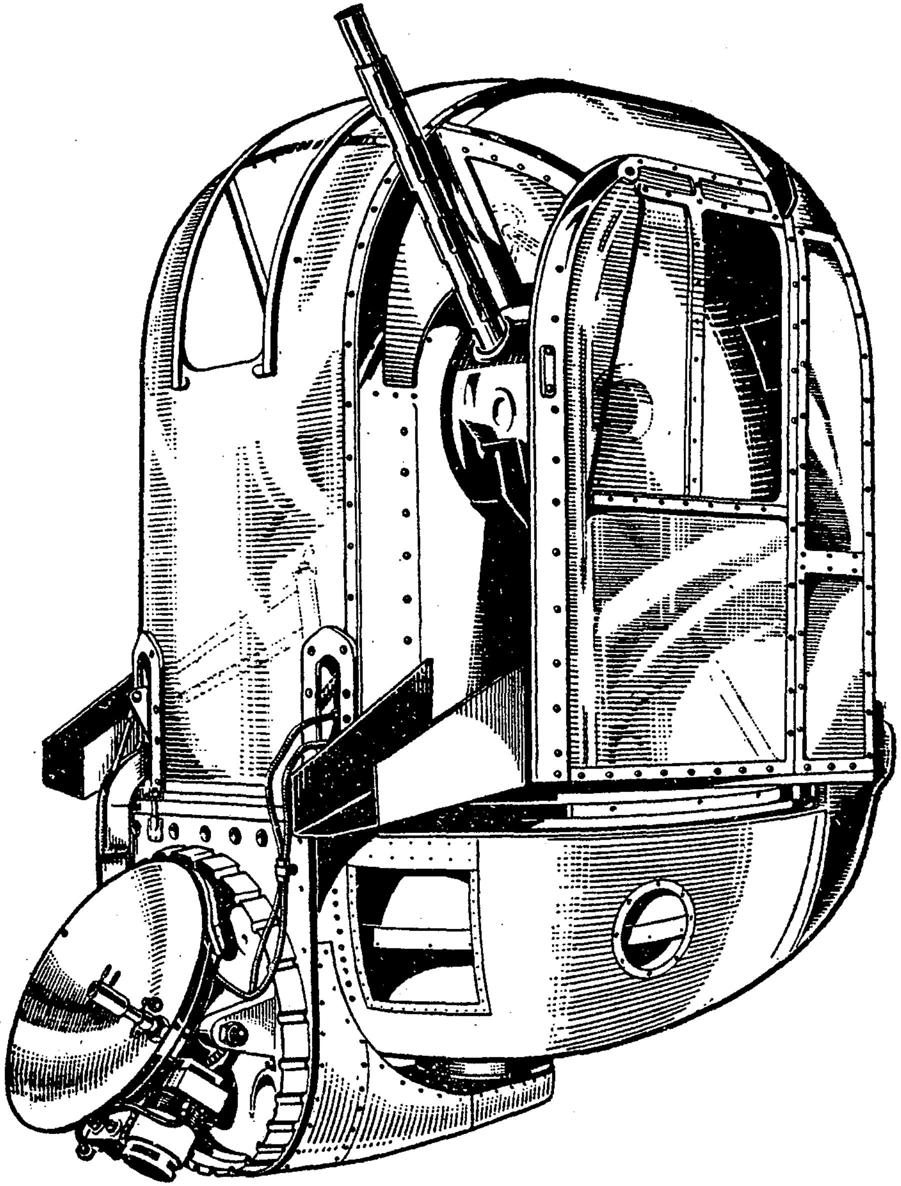


Fig. 1.—Rear gun turret with AGLT scanner

5. The beam is about 17 degrees wide at half-amplitude and one might therefore expect to be able to pick up an aircraft approximately within a 30-degree cone. In fact, the sensitivity is sufficient to enable aircraft to be picked up over a 35-deg. cone in most cases. Aircraft can be detected by the rear gunner over most of the rear hemisphere, since the axis of the beam can be scanned over ± 85 deg. in azimuth and ± 45 deg. in elevation. This form of search involves manual control of the turret and is tedious, but it need not be normally employed since most aircraft fitted with H2S are also fitted with Fishpond, which has a coverage over the whole of the lower hemisphere.

6. The maximum range of AGLT is artificially restricted to 4,000 feet. This range was chosen in order to limit the number of casual contacts from friendly bombers and to eliminate ground returns. The minimum range of the system is about 500 feet.

Display system

7. The direction of the enemy aircraft is indicated by the movement of a bright spot on a cathode ray tube. This form of display is sometimes known as a spot indicator. The displacement of a bright green spot from the centre point of the tube gives a measure of the bearing and elevation of the attacking aircraft. Usually the operator of a radar equipment looks directly at a cathode ray tube, but in this case the image of the spot is projected into the gunsight through an optical system containing mirrors and a convex lens. The display unit therefore consists of a cathode ray tube with an attached optical system. The complete unit, which is called the collimator, is shown in fig. 2. The collimator is mounted on the right-hand side of the gunsight with the axis of the tube vertical and the screen facing upwards. Fig. 3 is a sketch of the sight with the collimator attached.

8. The Mk. II C gyro gunsight is a reflector sight. The aiming point is seen by the gunner as a bright spot in the centre of a circle of diamonds as shown in fig. 4(a). The aiming point which is produced by reflection is called the graticule.

9. When a gun is provided with a fixed sight, the gunner must allow for the movement of a target by aiming in front of it; and must allow for the effect of gravity on the bullet by aiming slightly above the target. In firing from a moving aircraft other allowances must be made which are discussed later. The Mk. II C gunsight is, however, a predictor sight, the graticule moving about under the influence of a gyro and an electromagnetic system. The allowance is computed electrically and the graticule is automatically offset from the fixed aiming point by the correct amount. This simplifies gunlaying to a considerable extent.

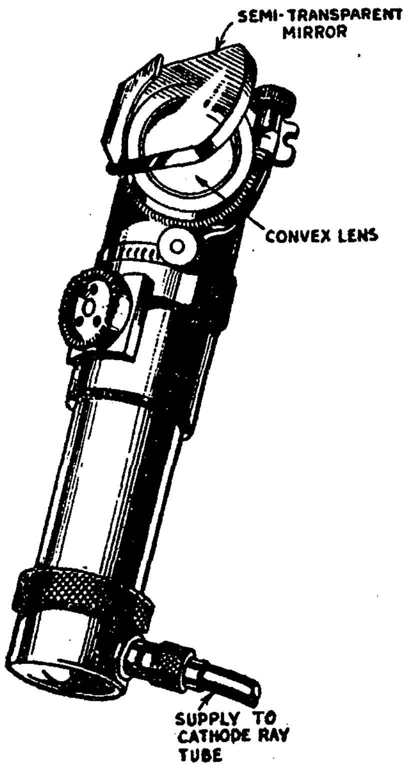


Fig. 2.—AGLT collimator

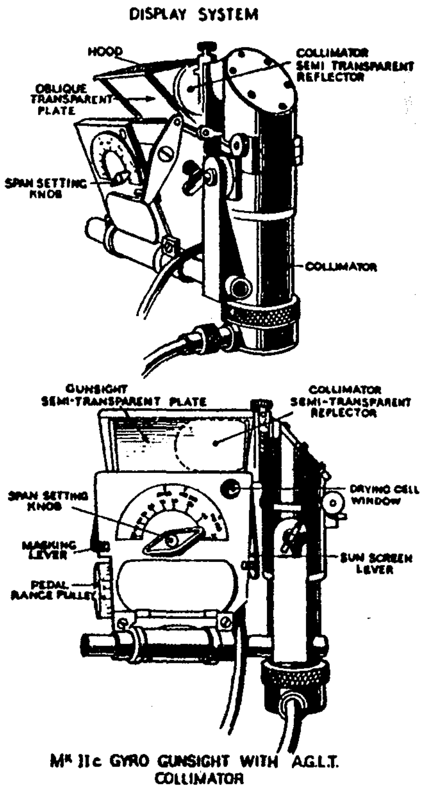


Fig. 3.—Gyro gunsight with AGLT collimator

When firing during the day, the gunner simply moves the guns to keep the aircraft encircled by the graticule with the central aiming point superimposed on the target. For night firing, the image of the AGLT green spot is observed in place of the target aircraft, and the guns are moved so that the green spot is central in the graticule, *see* fig. 4. In this way the gunner is able to keep his gunsight graticule lined up on an invisible target by regarding the image of the cathode ray tube spot as the target.

10. When operating, either during the day or at night, range is automatically fed into the gunsight computer from the AGLT receiver. The gunner therefore has no ranging difficulties when the sight is used in conjunction with radar equipment. It is convenient, however, for him to be aware of the approximate range of a target without having to look away from the gunsight, so that he may know when to open fire. In visual firing, the appearance of the target is sufficient for this purpose.

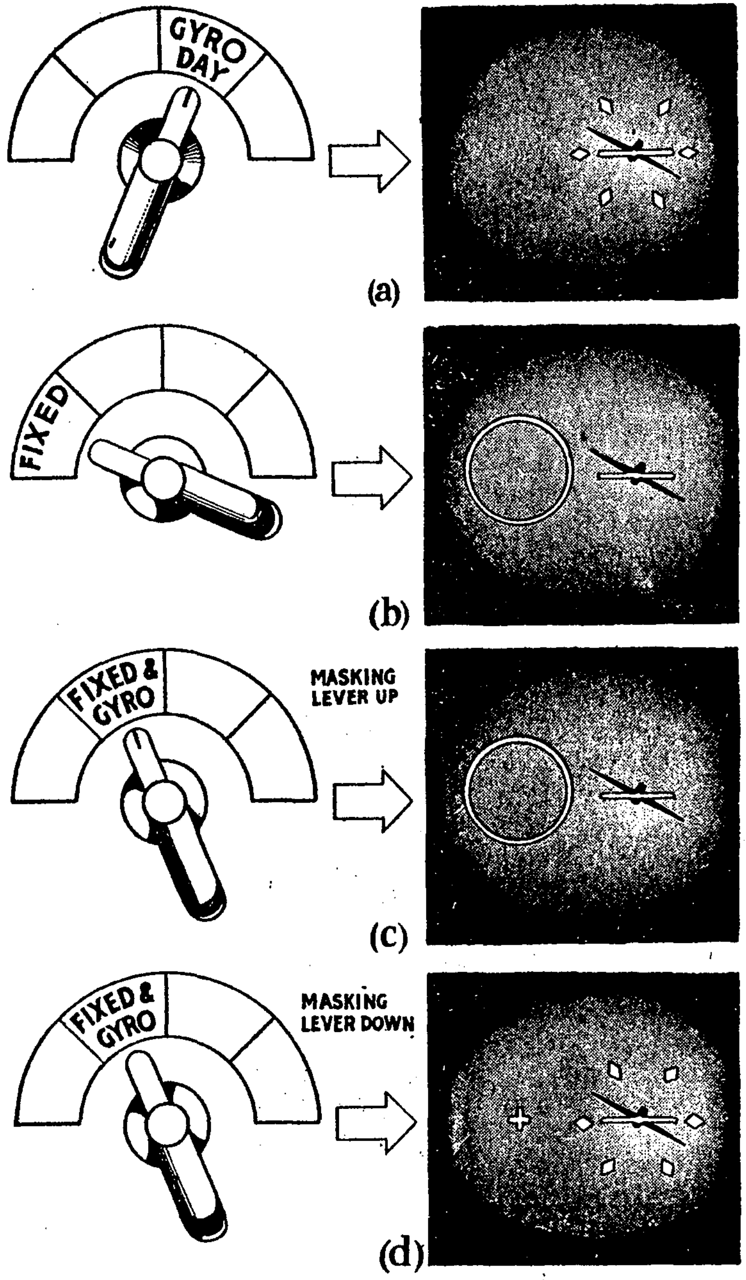


Fig. 4.—Gunsight display with visual contact

For blind firing, the difficulty is overcome by making the spot grow wings to give the gunner an approximate idea of range. The length of the wings is about equal to the projection in the gunsight of an aircraft with a wing-span of 120 ft. The wings, however, do not grow at a steady rate as an aircraft approaches. They lengthen gradually at first and then rapidly at about 500 yards, which is a suitable range for opening fire.

11. This arrangement has a number of advantages. In the first place it allows the rear gunner to change instantly from radar to visual aiming. This is important because there will probably be many occasions on which the rear gunner can aim visually when he has been directed to the right position by radar. Another reason for needing a quick transition is that the gunner will want to know whether the enemy aircraft is returning his fire. He will also want to see if his own ammunition is hitting the target and causing "strikes" which are often visible at night. Finally, he will want to see if the enemy is on fire. All these operations would be difficult if the gunner had to focus his gaze continuously from the distant target to the near image on a cathode ray tube. Another advantage of the projection system employed in the display is that it simplifies checking the radar equipment. When AGLT is flown in the daytime with a target aircraft, both spot and aircraft can

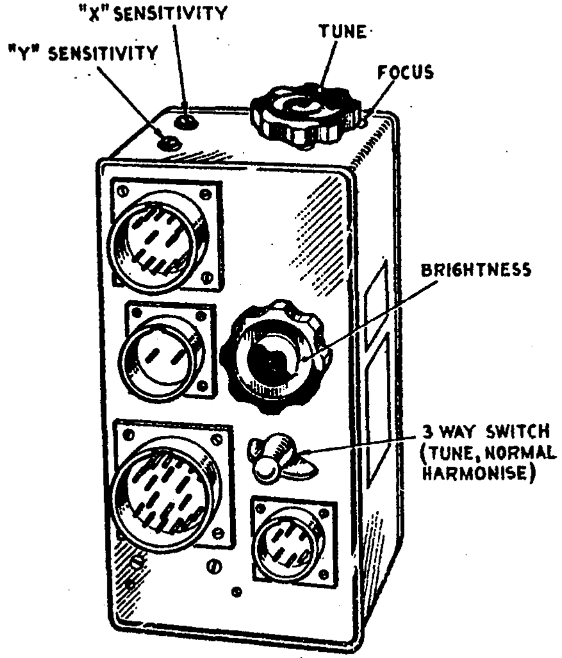
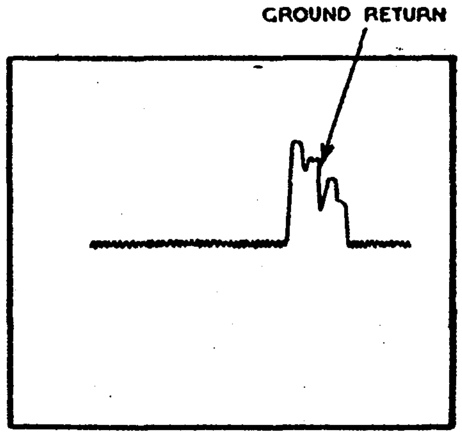


Fig. 5.—Gunner's control unit

be seen in the sight at the same time. If the system is operating satisfactorily the cathode ray tube spot can be seen within about half a degree of the target aircraft. Hence the harmonisation and sensitivity of the radar equipment can be checked with great ease.

Operation

12. The navigator is responsible for switching on the H2S and AGLT equipments. The PEDAL/RADAR switch in the turret is placed in the RADAR position to ensure that automatic range information is fed to the gunsight computer. The AGLT controls which are available to the operator are three in number, and are situated on the gunner's control unit, fig. 5. The intensity of the cathode ray tube spot may be varied by means of a brightness control. A similar control is provided on the gunsight for adjusting the intensity of the graticule. The gunsight selector switch is turned to the GYRO-DAY position. Height and airspeed are set in, and these require resetting should an appreciable change take place. Should the gunner wish to check the tuning of the AGLT receiver a switch on the control unit is rotated to the TUNE position. The cathode ray tube spot is then replaced by a horizontal range timebase which is reflected into the sight, *see* fig. 6. The guns are depressed, and a tuning knob adjusted until the ground returns appear at maximum amplitude.



Range timebase reflected into gunsight for tuning on ground return

Fig. 6.—Gunsight view of range timebase

13. When the receiver is tuned as described, the switch is returned to NORMAL and the spot reappears. It should be coincident with the centre of the graticule when the turret is stationary and there is no target within range. If attack is probable the gunner searches by moving the guns in azimuth and elevation in a regular manner. Usually he may confine his attention to the region behind and above the aircraft because the Fishpond equipment gives warning of attack from below. Should the Fishpond operator observe an aircraft, he informs the gunner of the approximate direction of attack. If the range of the target is greater than 4,000 ft. the gunner will see no change in his gunsight, except that during movement of the turret and guns and for about a second afterwards, the graticule will appear to move in a direction opposite to the direction of motion of the guns and turret.

14. When the target comes within range of the AGLT equipment three things happen. The cathode ray tube spot starts to grow wings, and a choppped-up 1,500 cycle per second note is heard by all the crew on the intercommunication system. This note consists of pips at about two second intervals. In addition, the spot moves to a position where it is collinear with the target and the gunner's eye. The gunner must now move the turret and guns so that the centre spot of the graticule follows as closely as possible the projection of the spot. By doing this he is feeding information into the gyro gunsight. As the fighter aircraft approaches, the wings continue to grow larger, and the pips heard in the intercommunication system grow more frequent, until at 500-ft. range the total wing-span extends over about 11 degrees, and the pips are occurring at a rate of about six a second.

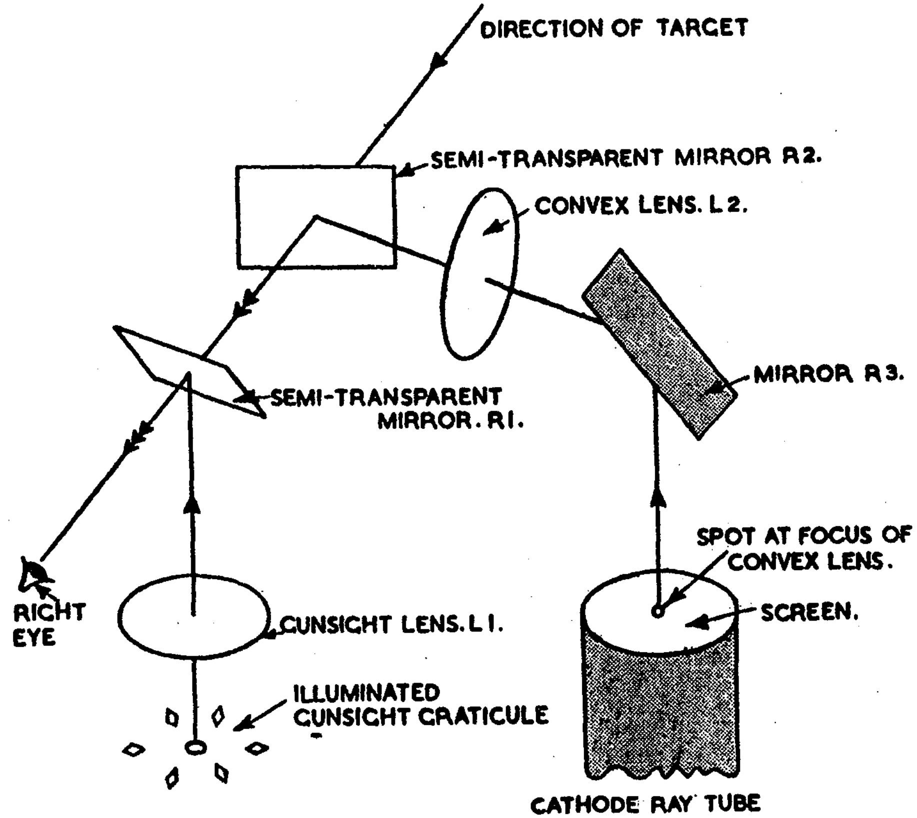
15. If the gunner can see the enemy aircraft he changes over to visual firing. In order to remove the green spot from the cathode ray tube during visual firing, a SPOT CUT OFF switch is fitted between the turret-rate handles.

16. Range is also fed from the radar equipment to a range metre above the wireless operator's position. As an additional aid to the gunner the wireless operator calls the ranges during the interception, and the pilot can judge when to start evasive action.

17. It is apparent that some rapid and sure means must be provided to enable the rear gunner to identify a friendly aircraft picked up on his beam. An IFF equipment called *Liquid Lunch* was being designed to fulfil this function. Another scheme which has been used operationally employs infra-red radiation. Friendly aircraft are fitted with an infra-red lamp in the nose. This is on continuously, but is invisible to the naked eye. A Type Z infra-red receiver, which incorporates an infra-red filter and a fluorescent screen, is mounted on the sight arch to the left of the gunsight. When the gunner wishes to determine the nature of the target picked up on his beam, he looks through the eyepiece of the Type Z telescope, and if he sees a green spot he knows that his target is friendly, but if he sees no such light he knows that he has picked up an enemy target.

The optical system of the gunsight and collimator

18. Fig. 7 is a sketch of the optical system of the gunsight when used with AGLT. The target is observed through a transparent plate R1, which is inclined so that the reflection of the illuminated graticule can be seen. As already mentioned, the central point of the graticule is the gun aiming point, and the turret is operated to make the image of this spot coincide with the target. The illuminated graticule is itself



Optical system of Mark IIC Gyro gunsight and AGLT collimator. (The gunsight fixed graticule which is seen by the left eye is omitted.)

Fig. 7—Optical system

situated at the focus of a convex lens L1, and, therefore, its image appears to be at a very distant point. There is then no error in sighting due to movement of the gunner's eye. The collimator is fitted with two reflectors. The outer one, R2, is a transparent plate mounted obliquely in the line of sight, so that the image of the cathode ray tube spot may be observed. This image also appears at a distant point because the spot itself is at the focus of the collimator lens L2.

19. A selector switch is fitted in the turret and the graticule described above may be seen when the switch is rotated to the GYRO DAY position, (fig. 4(a)). When it is turned to the position marked FIXED, the graticule is no longer visible, but a bright ring with a cross at the centre takes its place, (fig. 4(b)). This is a second aiming point which will be called the fixed graticule to distinguish it from the moving or predictor graticule already described. The ring and cross is illuminated and projected into the sight through another lens placed on the left of L1. Both graticule images are visible if the switch is rotated to the FIXED AND GYRO position (fig. 4(c)). The fixed graticule is in fact seen by the left eye only, and the moving graticule by the right eye, but this is not confusing if the target is some distance away as in actual combat. The fixed graticule indicates the direction in which the guns are pointing, and if it is used in airfiring the gunner must estimate an allowance and place the graticule ahead of the target as shown in fig. 4(d). But when the computer is working and the guns are being laid, the moving graticule is displaced from the fixed one, and automatically gives the correct allowance, so that the gunner simply keeps the six diamonds encircling the target as in fig. 4(a).

20. The computer can deal with allowances up to about 5 degrees, but for greater values errors in prediction are considerably increased, and firing is unlikely to be successful. It is sometimes useful for the gunner to see both graticules as he is then aware of the magnitude of the allowance and can judge when fire is likely to be effective.

THE PROBLEM OF PREDICTION

21. The nature of the allowance which must be made for air firing, and which is worked out automatically by the predictor gunsight, must be considered more fully. Three main factors need to be taken into account.

Relative speed allowance

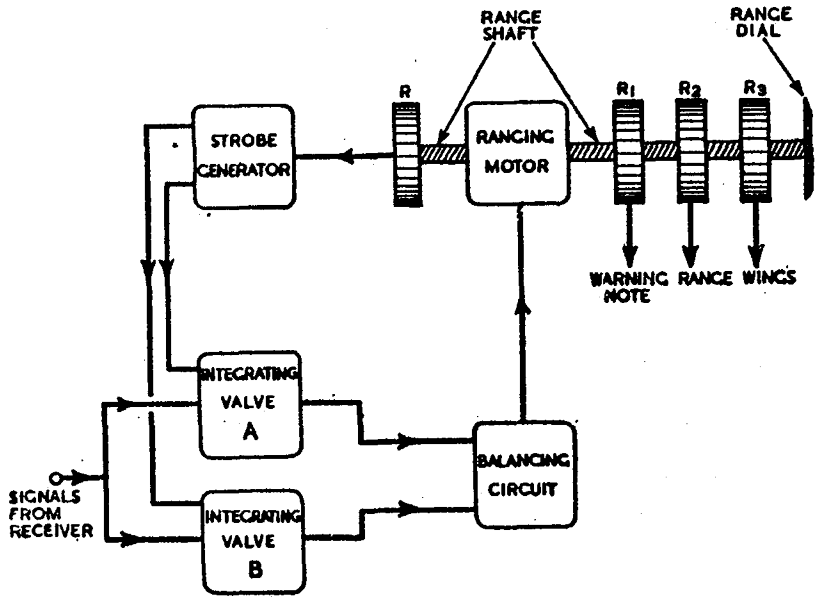
22. Suppose that the gunner's aircraft is flying straight and that the line of sight to the target is rotating at 10 deg. per second. If the image is such that the bullet takes one-half second to reach the target, then the allowance to be made is 5 deg.

23. In the example given, it was assumed that the aircraft was flying straight; it is often necessary, however, for the defended aircraft to take evasive action, and the turning movement of the aircraft must then be taken into account. This is achieved as follows.

24. The sight measures this rotation with respect to a line fixed in space, and not relative to the aircraft axis, by means of a gyroscope. This makes it possible for the sight to calculate the correct allowance even when the gunner's aircraft is taking evasive action. The gunner tracks the target smoothly, keeping the guns correctly aligned, and from the mechanical movement in azimuth and elevation, the relative speed allowance is computed. Target range is supplied continuously by the radar equipment, and time-of-flight is computed therefrom. If AGLT is not fitted, an optical method of rangefinding must be used.

Bullet trail allowance

25. When a bullet leaves the gun, it is deflected backwards by the slipstream, which may be regarded as having the same effect as a wind blowing at aircraft speed past a stationary gun. This dragging effect is zero when firing straight backwards from the tail of an aircraft, and



R Variable resistor controlling strobe generator

R1 Variable resistor controlling warning note frequency

R2 Variable resistor giving range output to gunsight

R3 Stud switch controlling growth of wings on C.R.T.

Fig. 8—Automatic ranging, schematic

is a maximum when firing at right angles to the line-of-flight. The magnitude of the allowance depends on the direction in which the guns are pointing, relative to the line-of-flight, and also to some extent on the range of the target.

26. The direction in which the guns are pointing, relative to the line-of-flight is electrically transmitted to the computer, and the range is fed in continuously from the radar equipment.

27. The drag is also dependent on the aircraft speed and on the density of the air, which is a function of altitude. The computer is therefore provided with height and airspeed controls which are preset by the gunner. The settings are only altered when an appreciable change has taken place.

Gravity drop allowance

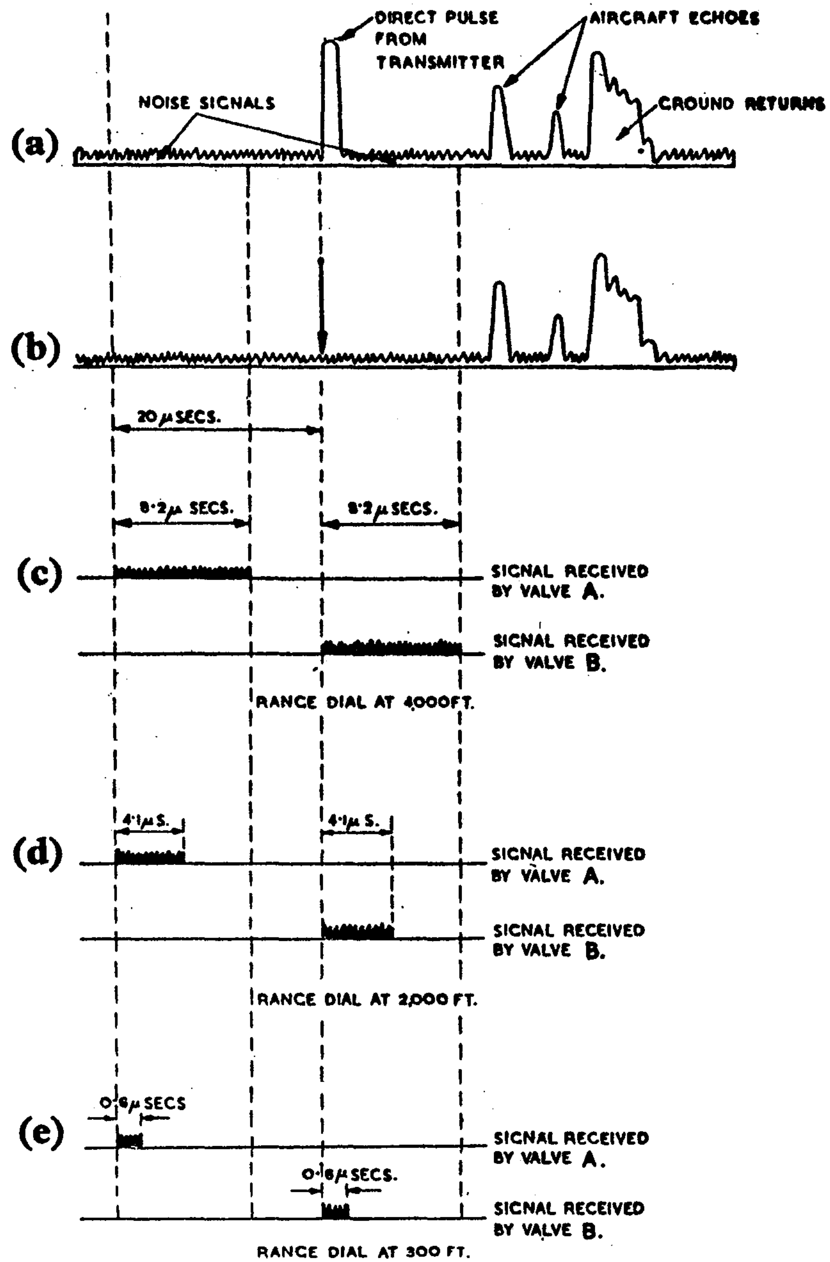
28. The third allowance to be made is for downward deflection of the bullet due to gravity. Here again target range information is required.

29. The three allowances previously mentioned are compounded, and the moving graticule is automatically offset from the fixed aiming point by an amount corresponding to the total. Angles up tc 5 deg. are quite common in the daytime, but at night they are not likely to exceed 3 deg., owing to the limitation imposed by darkness on fighter tactics.

Optical rangefinding

30. As previously mentioned, the calculation of relative speed and gravity allowances by the predictor demands the feeding-in of target range information. When the sight is used without radar, an optical system of rangefinding is employed as follows. Suppose that the target is flying directly towards the gunner. The diameter of the moving graticule can be varied by means of pedals. If attacking aircraft all had the same wing-span, the gunner could move the graticule until it just encircled the aircraft, and the movement could be calibrated to give range.

31. It is necessary, however, to take into account the diffierent wing-spans of attacking aircraft. This is done by means of a " span setting " knob situated on the front of the gunsight which varies the diameter of the graticule independent of the pedals (fig. 3). The gunner sets this control to the wing-span of the attacking aircraft. The pedals are then moved until the graticule is encircling the aircraft. Range is then automatically fed into the computer. The wing-span scale is marked in feet and the names of the commoner types of enemy aircraft are engraved on it at points corresponding to their wing-spans.



(Diagram not actual waveforms, strobe times slightly altered for simplicity)

Fig. 9—Automatic ranging (1)

32. The optical method of rangefinding has many disadvantages. The gunner may be unable to recognise the enemy aircraft so he must guess the wing-span by noting the number of engines. The span is usually set at 35 ft. for a single engined aircraft and at 60 ft. for a twin-engined one. Again, the aircraft may present a side view of the gunner, or even some intermediate aspect, so that an estimate must be made of the correct graticule diameter. Radar range, on the other hand, is transmitted automatically to the computer leaving the gunner free to concentrate on smooth laying on the target.

33. A further disadvantage of the optical method is that at long ranges the enemy aircraft appears small, and ranging tends to be inaccurate, but it is more important that long ranges should be accurate than short ones. At short ranges allowance is small—perhaps one or two degrees—and range errors may well be negligible, but at long ranges, when allowances may be of the order of 5 degrees or more, range accuracy is important if firing is to be effective. The radar method of rangefinding has the advantage that it is equally accurate at all ranges. With AGLT Mk. I, ranges are measured to within 30 yds., an accuracy which is more than adequate for present predictor design. Ranges up to 4,000 ft. can be read off from the dial on the equipment but ranges greater than 2,400 ft. are not electrically transmitted since this is the maximum range at which the computer can operate.

Automatic ranging

34. A detailed description of the AGLT ranging system is given in A.P.2917A or B, and the following account merely deals with the main principles involved in the design.

35 The signal output from a radar receiver installed in an aircraft usually consists of noise, a direct pulse from the transmitter, and echoes from other aircraft and from the ground (fig. 9). In the AGLT receiver the direct transmitter pulse is eliminated and the output might be displayed on an oscilloscope as in fig. 9(b). The arrow marks the time at which the transmitter triggers off. It is important to notice that no echoes are received in the short time before the transmitter fires, and only random noise would be visible on the 'scope during that time. The waveforms of figs. 9 and 10 are not seen by an AGLT operator as no oscilloscope with range timebase is provided in the equipment.

36. Fig. 8 is a diagram of the ranging system. The receiver output is passed into two integrating valves A and B. Valve A switches on 20 microseconds before the transmitter fires, and accepts the receiver output for a short interval of time as shown diagramatically in fig. 9 (c) Valve B switches on just at the instant when the transmitter fires and accepts the receiver output for an equal interval of time (fig. 9(c)). No echoes are received during the first period because it precedes the transmitter pulse. The time intervals during which A and B are active are always equal, but they vary from a maximum of 8·2 microseconds to zero. (The timing figures have been slightly altered for ease of explanation; the "strobes" do not in fact run to zero). The duration of the intervals is determined by a strobe generator valve which is itself controlled by a variable resistance R mounted on the same shaft as the range dial. The latter is graduated in 20 yard intervals from 0 to 1,400 yards, and the shaft is driven through gearing by an electric motor (fig. 8). Suppose that the motor is switched on so that the variable resistance is driven fully clockwise. At this point the dial will indicate maximum range,—4,000 ft. (fig. 9(c)). If the motor is run so that the range shaft rotates counter-clockwise both intervals shorten. For example when the dial reads 2,000 ft. they are both 4·1 microseconds (fig. 9(d)), and when the dial is at minimum range of 300 ft. both are reduced to 0·6 microseconds (fig. 9(e)). Finally when the variable resistance is fully counterclockwise the intervals are zero.

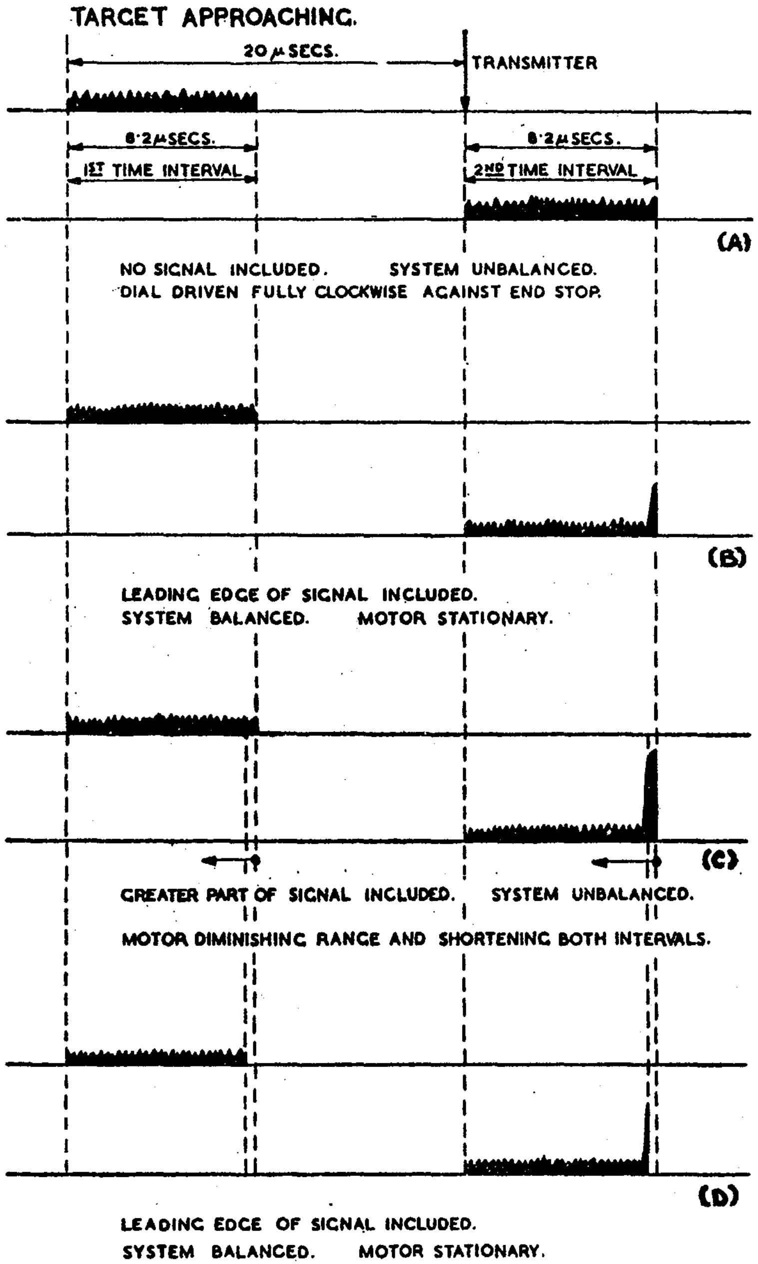
37. Valve A adds up all noise signals received in the interval before the transmitter fires. No echoes are present before the transmitter fires so the output consists of the total noise signal received during the first interval. Similarly valve B integrates the receiver output for the equal interval of time after the transmitter fires, and the output of B consists of the total noise plus any echo signal received during the second interval. The total or integrated outputs of the A and B valves are represented by the shaded areas in figs. 9 and 10. The outputs of A and B are fed into a balancing circuit which really subtracts them. The balancing circuit is set up as follows :—

(1) If output B *is equal to* output A the motor is switched on so that the shaft is driven clockwise and the range readings increase.

(2) If output B *is slightly greater than* output A the motor is switched off, and the range dial remains stationary.

(3) If output B *is much greater than* output A the motor is reversed so that the range readings diminish.

38. Consider what happens when the equipment is switched on in flight. Suppose no aircraft is within 4,000 ft. Only noise and, perhaps, interference will be present and these random signals will be received during each time interval. Output B, on the average, will equal A and the motor is switched on so that the shaft is driven clockwise and the



(Diagram not actual waveforms, strobe time slightly altered for simplicity)

Fig. 10—Automatic ranging (2).

range readings increase. Finally when the dial has reached maximum range it strikes an end stop and the motor is cut off. Nothing further happens as long as there is no aircraft within the beam at range less than 4,000 ft., *see* fig. 10(A). When an aircraft comes within 4,000 ft., the echo appears within the second time interval. At first only the leading edge of the signal is included and nothing happens (fig. 10(B)), but soon a larger part of the return signal is included and the output of B becomes much greater than that of A. According to condition 2 the motor then operates in the reverse direction and the range reading is diminished (fig. 10(C)). As the motor drives the range shaft, both time interval. are reduced and part of the echo is excluded from the second one. Output B is then only slightly greater than A and so the motor stops (fig. 10(D)). The process is repeated as the range diminishes, the motor driving the range shaft in steps of about 15 yds. The aircraft range may therefore be read from the dial. If at any time the target range increases the echo disappears, and output B becomes equal to A, so that the range dial is driven clockwise again until equilibrium is restored. The ranging system therefore follows a receding target as well as an approaching one.

39. There is only one condition of balance—when the output of B is slightly greater than that of A. In absence of echo the dial is driven to maximum range and comes to rest on the end stop. When a signal is present the time intervals are automatically set so that the leading edge of the signal just comes within the second one, and the dial indicates the range of the aircraft.

40. The system measures the range of the nearest aircraft within the beam because only the leading edge of the nearest echo is included in the second interval, and all other echoes are excluded. This limits the number of casual contacts and eliminates the ground returns. The accuracy of the ranging system depends largely on the care with which the balancing circuits are set up, but the time should be measured to within 0·12 microseconds which gives a range accuracy of about 20 yds., and therefore, allowing for slight errors in setting up, an accuracy of 30 yds. should be obtained. The minimum range which can be measured is about 150 yds.

41. Referring again to fig. 8 it will be seen that the range shaft drives three variable resistors in addition to the one already mentioned for controlling the strobe generator. The first of these additional resistors, R1, controls the frequency of the warning note pips. The second resistor, R2, feeds out range to the gunsight computer, and the third, R3, determines the rate of growth of wings on the cathode ray tube.

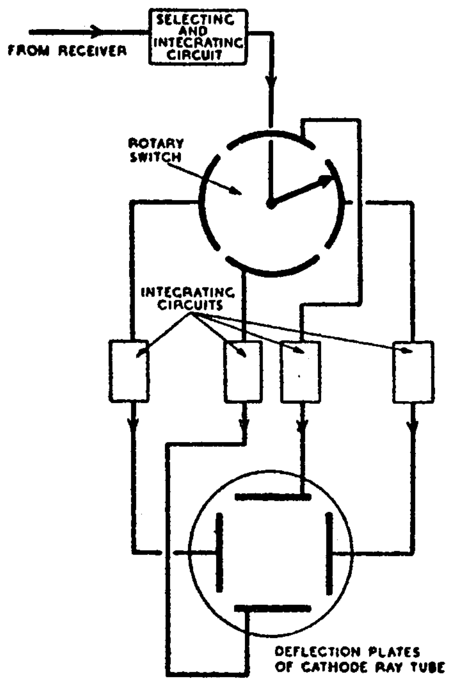


Fig. 11.—Direction finding schematic

Direction finding

42. The AGLT aerial is mounted eccentrically so that the beam is deflected $5\frac{1}{2}$ deg. from the main axis of the mirror, and the aerial is spun at 33 revolutions per second. The beam therefore scans out a cone of vertical angle 11 deg. This conical movement is not required for ranging but is necessary for direction finding.

43. To explain how the direction of an enemy is found, suppose that a bomber aircraft is in flight with the guns pointing straight backwards from the rear turret. Consider a fighter is approaching from directly behind the bomber, but slightly above, so that it subtends an angle of 5 deg. in the gunsight. For convenience this target position from the gunner's point of view is designated as 12 o'clock at an angle of 5 deg. off centre. The beam then sweeps across the fighter 33 times per second, and each time it passes through the 12 o'clock position maximum signals are received. On the other hand when the beam is at 6 o'clock, signals of minimum amplitude are received (fig. 12). Of course, echoes are returned from the ground and from other aircraft, but the receiver output is passed into a selecting circuit which passes out only the signal from the nearest aircraft as in the case of the ranging system. A waveform represented in fig. 12 is thus obtained.

44. It should be noted that the receiver output is being considered over a much longer period of time than when describing the ranging system. The waveforms drawn for the ranging system had a time-scale of about 40 microseconds and included one transmitter pulse only. For direction finding one must deal with one complete scanning cycle which takes place in one-thirtythird part of a second (approximately 30,000 microseconds). During this comparatively long time about 45 pulses are transmitted.

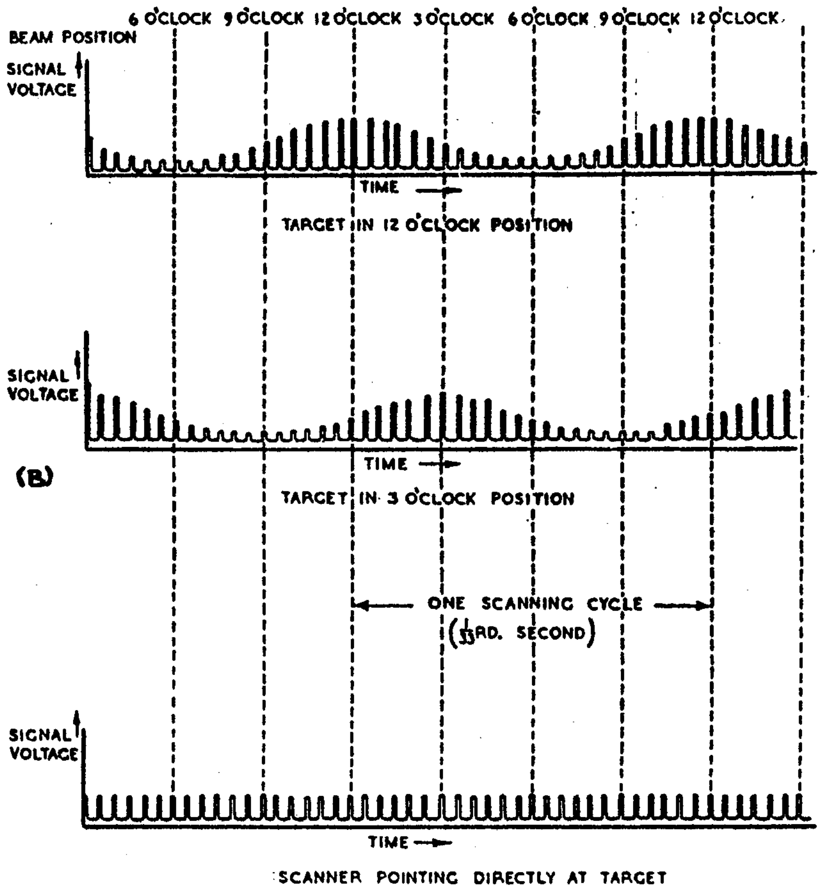


Fig. 12.—Direction finding (not to scale)

45. Returning to the waveform obtained by selecting signals from the nearest aircraft for a complete scanning cycle, it is noted that the signals vary in amplitude as the beam rotates, and are at maximum when the beam is at 12 o'clock and crossing the target. This amplitude variation can be used to control the deflection of the cathode ray tube spot in the following manner. The output waveform is first integrated in order to smooth out the rapid variations of each individual echo signal. The output of the integrating circuit is distributed to the four deflection plates of the cathode ray tube by means of a four-position switch rotating in synchronism with the aerial (fig. 11). Each quadrant of the switch is connected to the appropriate deflection plate of the cathode ray tube. When the beam is pointing upwards (12 o'clock position) the upper quadrant of the switch is being traversed, and the signals are then being applied to the upper deflection plate of the tube. When the beam is to starboard they are applied to the right-hand plate of the tube and so on for the other quadrants. The spot moves towards the deflection plate receiving the maximum signal strength. In the example given it will move towards the upper plate, but, should the fighter be below the bomber, the lower plate will receive maximum signal strength and the spot will be deflected downwards. Provided that the switch is correctly synchronised with the scanner the spot moves from the centre of the tube giving the correct clock reference of the target aircraft. It is arranged also that the magnitude of the deflection is proportional to the target angle "off-centre," so that if the equipment is used in daylight the spot and the target are coincident. The latter relationship, however, only holds for angles "off-centre" less than 4 degrees.

46. As shown in fig. 11 there are integrating circuits between the switch quadrants and the cathode ray tube deflecting plates. These are included to average the signals applied to the deflection plates over a period of about one-quarter of a second, so that the spot does not flicker as the switch rotates, and a steady deflection is obtained corresponding to the target bearing and elevation. When the system is in use the directional accuracy obtainable is of the order of half a degree.

LIMITATIONS OF THE DISPLAY

47. AGLT Mk. I display suffers from four defects, three of which limit the blind firing accuracy attainable. The first of these may be called *spot wander* or *jitter*. This is caused by the rapid fading of an echo due to propeller modulation. As a result of this, the cathode ray tube image does not coincide exactly with the target, but wanders over a small circle which has a maximum radius of about half a degree.

48. The second defect is that correspondence between the cathode ray tube and target position does not hold for angles greater than 4 deg. off-centre. Suppose that a target aircraft is at the same height as the bomber, but 6 deg. to the gunner's right, and that the guns are pointing straight backwards. The spot moves to indicate the correct clock reference (3 o'clock), but the deflection from the centre of the tube does not correspond exactly to 6 deg. Hence, when flying during the day, target and spot are not quite coincident for angles greater than 4 deg. This happens because the spot deflection from the centre of the tube depends on the beam width and the 11-deg. scanning cone, as well as on the angle subtended by the fighter.

49. The third defect of the display is that there is a time lag in the movement of the spot which does not take up its final position instantaneously. The lag for the AGLT equipment is about one-quarter of a second and is due to the integrating circuits between the rotary switch and the tube deflection plates. The gyro gunsight computer also introduces a lag of about 1½ seconds. The total effect is not very serious, but can be seen if the equipment is flown in the daytime. If the guns are jerked or moved rapidly the spot leaves the target and does not return for an appreciable fraction of a second.

50. A fourth limitation of the display is that it cannot present more than one aircraft at a time on the cathode ray tube. Confused results will be obtained if there are two aircraft within 100 yds. of one another in range and within about 30 deg. of one another in direction. Under these conditions the spot will tend to wander in an indeterminate way between the two aircraft.

AGLT Mk. III

51. When using AGLT Mk. I the gunner must keep moving the turret to be sure of obtaining early warning of attack. The process of manual searching is tedious and an equipment known as Mark III is now (December, 1944) under development to overcome the difficulty. A project known as AGLT Mk. II has been discontinued. The scanner is mounted on the airframe below the rear turret and does not move with the turret. For searching, a wide coverage is got by an automatic scanning movement of the mirror. When a target is detected the scanning ceases and the mirror "locks" on to the target. The axis of the mirror then indicates the azimuth and elevation of the fighter aircraft, and the information is displayed on a collimator. The gunner operates the turret until the green cathode ray tube spot is coincident with the predictor graticule as in the case of AGLT Mk. I.