# PART 2

# SECTION 1 — MANAGEMENT OF THE WEAPONS SYSTEM

## CHAPTER 1 — AI23D — NORMAL OPERATION

*(Completely revised at AL5)*

### Contents



### Illustrations

## SWITCHING ON THE RADAR

### Ground Running of the Radar

1. To run the radar on the ground, without aircraft services, electrical power must be provided by an external power supply, and air cooling must be provided by Trolley Air Cooling Mk 2A. The complete starting cycle takes approximately 5 minutes and the ground test switch on the hand controller must be in the up position. To keep the radar in the 'warm-up' condition, the ground test switch is moved down and the run up cycle is halted just before 'heater time'; there is no requirement for external cooling air supplies in this condition. After the engines are started and the aircraft's AC supply becomes available the radar continues its starting cycle irrespective of the position of the ground test switch. It should be noted that cooling supplies from the aircraft's pressurisation system are only available to the radar in the absence of an external cooling source, if the cabin air switch is on, the hood is closed, and the engines are running. If there is a delay between starting up and taking off, it is advisable to taxy with the hood closed to ensure adequate cooling for the AI.

### Sequence of Events

2. After the main radar switch has been turned on, by setting the MAIN ON/OFF switch to the inboard position, the sequence of events should be as given in Table 1.

3. At any time after the main radar switch is on, if AC or DC power is lost the sequence reverts to zero time, and another 5 minutes must elapse before the set becomes operational again. Should the run up be part of a functional test on ground supplies prior to the aircraft going on state, when the test is complete the ground test switch should be moved to the down position whereupon the set reverts to the 'warm-up' condition.

4. The transmitter can be selected on at any time during the run up sequence and the transmitter is automatically energised by EHT at the five minute point. However, the transmitter should normally be left off until just before take-off to avoid causing a ground radiation hazard.

### The Display

5. a. *The Use of Brilliance and Gain Controls.* The brightness of any responses depends on the number of electrons hitting the tube face. These are controlled by the potential difference between the cathode and the grid of the cathode ray tube. The more positive the potential, the brighter the response. The gain control adjusts the amplitude of the signal to be displayed for a given signal strength received. The brilliance control sets the overall background brightness of the tube by adjusting the cathode grid potential; the time base should be barely discernible when no signals are present. With signals present, the cathode grid potential is increased and a bright up on the tube face results. If the grid becomes too positive, however, it attracts all the electrons, none reaches the tube face and the picture goes black. This situation arises:

(1) If the brilliance is set too high, subsequent increase of gain causes the picture to go darker instead of brighter. This gives the impression that the gain control is operating in the reverse sense, ie a 'negative' effect.

(2) If very strong signals are received. This often occurs when receiving noise jamming, and

**Table 1 — Sequence of Events**

| *Time* | *Display Indication and Significance* |
|---|---|
| Zero (Main radar on) | Azimuth and scanner elevation scales illuminated. |
| 3 minutes 45 seconds ('warm-up' condition) | The sequence balts here providing the ground test switch is down and the aircraft's own AC is not on line. |
| 4 minutes (approximate) (heater time) | Selected range scale illuminates. |
| 4·5 minutes (approximate) (HT time) | Display appears on B-scope. This is the GW radar ranging display (less sweeping strobe) as the MAS switch is off. |
| 5 minutes (standby condition) | The transmitter is available 0·25 second after it is switched on. |

a black spoke is seen with white edges. The same effect may come from ground returns. To achieve a normal picture, gain should be reduced.

b. *Appearance of the Picture.* Many other responses appear on the B-scope display besides those of other aircraft.

(1) *Noise.* This is caused by random signals received both externally and produced within the receiver itself. It gives an overall speckled appearance to the display and the gain has to be limited otherwise noise swamps target returns. The AI has a very low noise level.

(2) *Direct Pulse.* A certain amount of the transmitted pulse leaks back into the receiver, and causes a bright line to be painted at zero range.

(3) *Altitude Line.* This is a bright line painted across the tube at a range equivalent to the aircraft's height above the surface. It is caused by energy which 'spills over' from the aerial reflector. It varies in definition and brilliance depending on the type of surface over which the aircraft is flying. The line is sharp and bright from returns from smooth water and faint and diffuse from rough land. It cannot be relied upon as a standard for setting gain.

(4) *Ground Returns.* These are direct reflections from the ground. In this case rough ground gives stronger return than smooth water. Coast lines are well defined and can be useful for map reading. Shipping returns can appear similar to aircraft returns but ambiguity can be resolved by observing the movement of the echo. Too high a gain setting produces the 'negative' effect described in para 5 a (1) above.

(5) *Second Time Base Returns.* With 40 NM range selected, each time base covers the range of 0 to 40 NM. There is then a pause equivalent to about 40 NM before the next time base is produced. The time base therefore covers both 0 to 40 NM range on its own transmitted pulse and 80 to 120 NM on the previous pulse when normal PRF is selected. The second trace returns will be between 100 and 180 NM when low PRF is selected. The radar is capable of detecting ground returns at ranges of 80 to 120 NM and these returns are displayed on the 'second' timebase. Second timebase returns appear as fuzzy blips and shaded areas, the edge of which indicate coast lines. A patch of second timebase returns in the area to be searched can greatly hinder target detection. A change of PRF by means of the normal/low PRF switch can sometimes eliminate this.

(6) *Responses from Other I-Band Radars.* These appear as a series of diagonal dotted lines interlaced across the B-scope. This is not normally serious unless there are a large number of radars operating on similar frequencies, in which case a lower gain setting is required to reduce the effect with consequent loss of pick-up range.

## SEARCH AND LOCK-ON TECHNIQUES AT MEDIUM AND HIGH LEVELS

### Search Techniques

6. Outside 15 NM range, search should be in single-bar scan and the scanner moved slowly towards zero from either above or below the target. Inside 15 NM range, the use of 2-bar scan is recommended. Care must be taken in front hemisphere attacks to avoid lagging behind the target elevation at relatively short ranges. Following initial target contact, the return should be optimised by adjusting the scanner elevation so that the target is covered by both sweeps of the scanner. This gives a more accurate assessment of target elevation whilst positioning the scanner at the correct angle prior to selecting acquisition phase.

### Second Time Base and Ground Returns

7. When searching for targets below the fighter, contacts at high level may be affected by second time base returns. Contacts at medium level can be similarly affected by ground returns. Although gain and scanner elevation adjustments may alleviate ground return problems at medium level, the best solution is to descend below the target height if this is tactically feasible.

### Lock-On

8. During the search phase, the acquisition circle should be placed near to the position where lock is anticipated. Accurate placing of the circle during the acquisition phase greatly increases the chance of a successful lock-on. The target should always be centred in the acquisition circle. The aim should be to select the track phase at the precise instant that the target echo is in the centre of the acquisition circle, but it should be remembered that radar faults can result in the acquisition circle not being centred laterally in the acquisition band and/or the gates not being generated in the centre vertically.

## SEARCH AND LOCK-ON TECHNIQUES AT LOW LEVEL

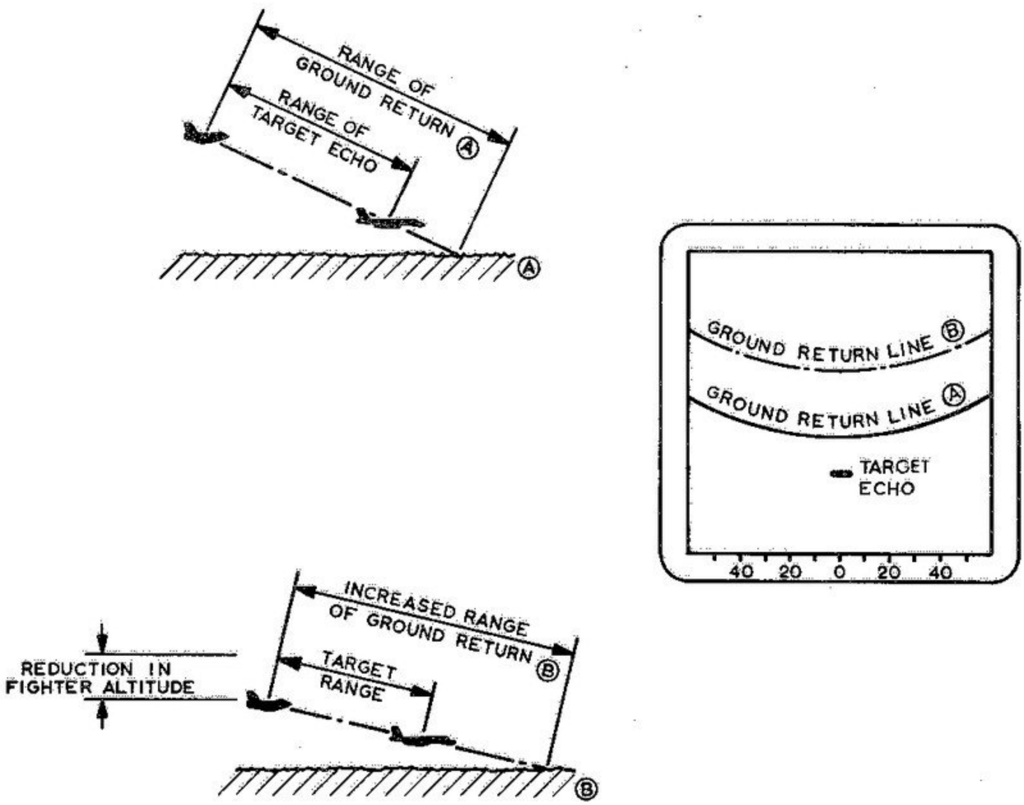
### General

9. The performance of the AI, like other pulse radars, is adversely affected by 'clutter' when operating close to the ground or sea. The amount of clutter varies with altitude and the type of terrain over which the fighter is flying, and is also related to the scanner elevation, gain setting and the position of the acquisition circle. The acquisition circle should be positioned within 10 NM range if the 10 NM scale is in use; if it is positioned at a range greater than 10 NM, ghosting of radar returns can occur in search since the range gates are positioned by the circle voltage.

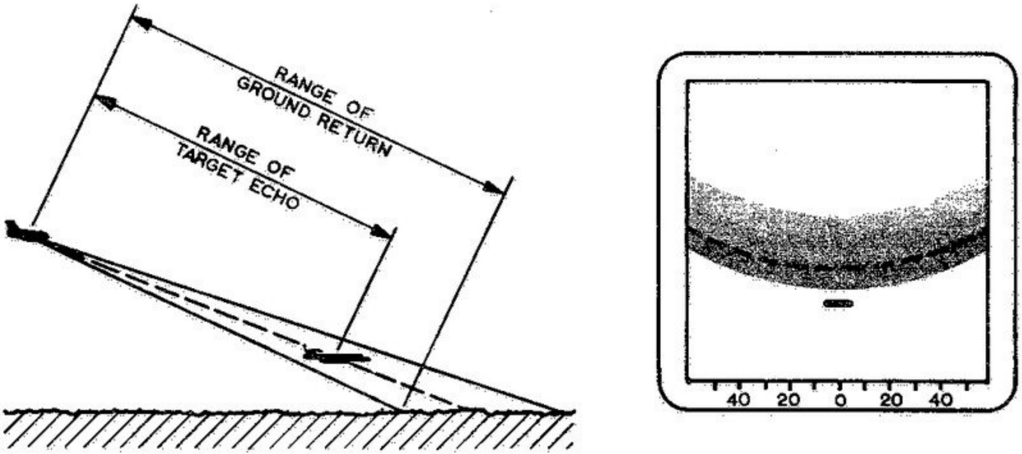
### Set Handling

10. The gain setting to be used at any given altitude varies with scanner elevation; if the scanner angle is positive, there is little or no need to reduce gain, whereas at negative scanner angles it is necessary to lower the gain considerably, with an inevitable reduction in detection range.

11. Since the required gain setting is so sensitive to changes in elevation angle, it is recommended that single bar scan be used. The scanner is normally pointed directly at the target, but in very smooth sea conditions, or when the fighter and target are both well clear of the surface, detection range may sometimes be improved by looking slightly high, with increased gain.




**2—1—1 Fig 1 Look Down Technique — Effect of Negative Scanner Angles**




**2—1—1 Fig 2 Look Down Technique — Effect of Beam Width**

**Look-Down Technique**

12. In night/IMC conditions it is necessary for the fighter to fly at a safe altitude to enable the pilot to devote his attention to the radar. It follows that the target is often below the fighter, thus committing the pilot to looking down. The relationship between a target echo and the ground return associated with a negative scanner angle is illustrated in Fig 1.

13. It can be seen that the target echo appears at a closer range than the ground return by an amount that is a function of scanner depression angle and the target's height above the surface. To increase the 'gap' the fighter must lose altitude, raising the scanner to keep the target in view. For simplicity, Fig 1 has assumed an infinitely narrow radar beam. The effect of having a beam of finite width is shown in Fig 2.

14. The dotted line on the B-scope indicates the range of the centre of the radar beam. Note that the ground return from the lower half of the beam covers a narrower band than the upper half, and that it forms more intense clutter. If the width of the beam is sufficient, the target disappears into the bottom of the band of clutter. (It is important to remember that gain adjustment has no effect on the lobe pattern or *actual* beam width of the AI, but only on the width of the beam which is displayed.)

**Lock-On**

15. Although targets can sometimes be detected amongst clutter by suitable adjustment of the gain control, lock-on may prove difficult. If the gain can be adjusted to make the target echo prominent in the clutter lock-on should be possible. When the acquisition circle is placed about the target and the trigger held depressed as track phase is selected, the receiver will remain in manual gain until the trigger is released. By this means lock-on to the target echo can be achieved without interference from clutter echoes. If lock-on is not successful it is necessary to return to search phase and repeat the procedure. This procedure is also useful for lock-on under adverse weather conditions. Experience has shown that a successful lock can be achieved under these conditions placing the acquisition circle in the clear area about 1 circle diameter below the target. The reason for this is that the range gate jumps out 2500 feet before searching in.

16.

**Table 2 — Lock-On Indications**

| | *Discrete Target* | *Spoke* |
|---|---|---|
| *Timebase* | Thin, dim with target brightup | Standard brightness over whole length |
| *Acquisition circle* | Range locked-on<br>Steady circle | Steady line: KR accurate<br>Sweeping: KR inaccurate |
| *Time Circle*<br>*Modes* 1, 2 & 3 | $\dot{R}$ | 150 knots indicated KR accurate |
| *Small gap*<br>*Modes* 4, 5 & 6 | ABC KR accurate | 2400 knots KR inaccurate<br>ABC KR accurate |
| *Large gap* | No gap KR accurate | No gap KR inaccurate |

Note: Loss of range lock is indicated by a sweeping acquisition circle.

**Re-attempts at Lock-On**

17. If the target is not visible on the time base, search should be re-selected and the lock-on procedure repeated. If the target is visible on the time base, the reject in/out facility should be used.

**Use of 40 to 80 Nautical Mile Scale**

18. If lock has been attained when using the 40 to 80 NM range scale, lock will be lost when selecting the 0 to 40 NM range scale. Before changing range the position of the target in bearing and elevation should be noted in order that the hand controller can be suitably adjusted when the lock sequence is re-commenced.

## FOLLOWING THE STEERING DOT

**General**

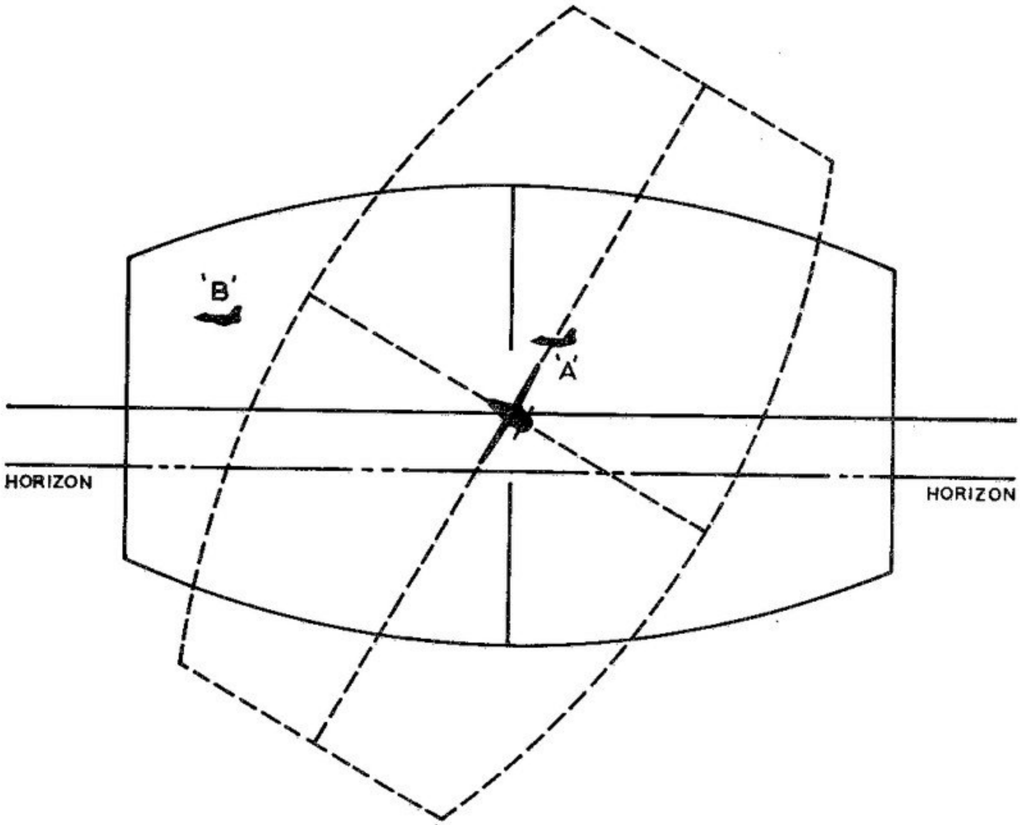
19. After lock-on, the pilot is required to follow the steering programme of the radar by centring the steering dot. The steering dot indication may not be reliable immediately after lock-on. If the positioning of the acquisition band was not exact prior to locking on, there may be spurious steering demands for two to three seconds.

**High Level**

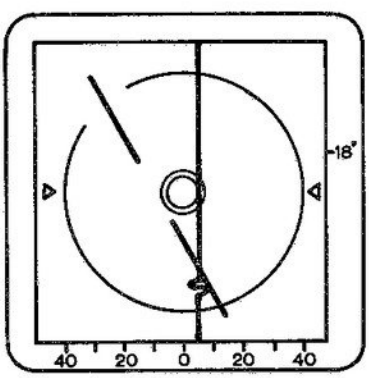
20. The demands of the steering dot should normally be satisfied by natural roll and pitch responses. In front hemisphere attacks with the target below the fighter and displaced in azimuth, responses should be made by first over-banking and then meeting the pitch demands. If this steering priority is not followed, there may be conditions where it is difficult to centre the steering dot in azimuth while bunting. It is always important to track accurately, particularly in front hemisphere attacks where the steering dot must always be centred before Launch Warning is displayed. This often requires aggressive tracking, particularly during the elevation law changes, but care should be taken to avoid over-controlling. Flight orientation during the tracking phase should be maintained by reference to the roll datum triangles and the horizon bar.

**Low Level**

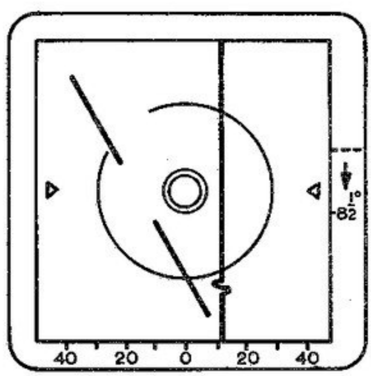
21. Low level targets are always attacked from rear hemisphere interceptions. When the fighter starts from above, or level with the target, the steering dot programmes a pure pursuit descent. As this can place the fighter as much as 4° below the target, tracking the steering dot at low level can therefore be dangerous. The solution is to maintain a safe altitude, normally not below 1000 feet, and initially accept any steering dot error at 6 o'clock. A bunt



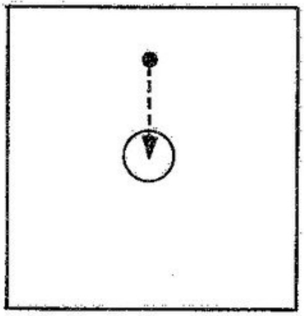

2—1—1 Fig 3 Look Angle Boundaries in Track Phase



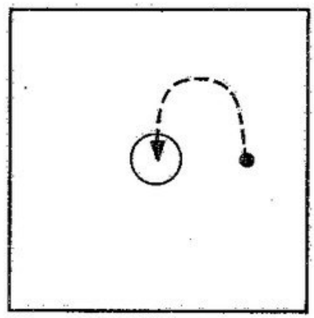

2—1—1 Fig 4 B-scope — Roll Stabilised



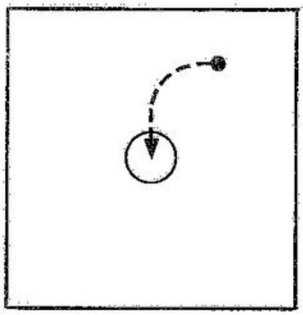

2—1—1 Fig 5 B-scope — Roll Axis Locked



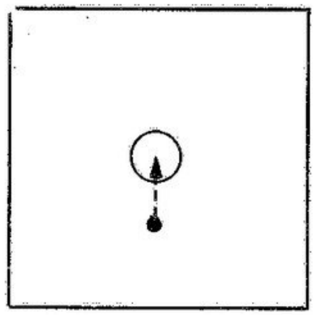
Demand for an increase in rate of pitch, and therefore a pull on the stick, irrespective of bank angle.



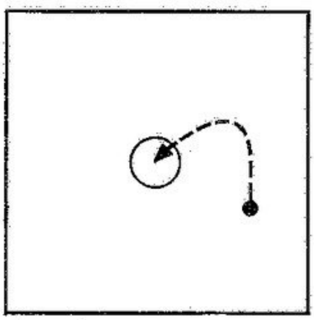
Demands a bank to the right. The action of banking to the right moves the dot upwards, demanding a pull.



Demands a combined roll to the right and pull.



Demands a forward movement of the stick.



Demands a roll to the right and a push. However, experience has shown that the majority of pilots prefer to overbank until the demand becomes a positive pull.

**2—1—1 Fig 6 Interpretation of the Steering Dot**

should be made just prior to firing to reduce the tracking error to within 4°.

**Roll Axis Lock**

22. *Effect on the B-scope Picture.* The AI computer provides slaving signals for the missiles, which are derived from azimuth and elevation information from the scanner. As the AI is roll stabilised, it is necessary to resolve these signals to the pitch and yaw axes of the aircraft, ie through the aircraft's bank angle. No system of roll resolution is absolutely accurate, and so there is normally a small slaving error, the size of which depends on bank angle and the amount of lead. As far as Firestreak is concerned, with a maximum head slaving angle of $\pm 5°$, such errors are insignificant. The same proportion of error applied to a Red Top, however, the head of which can be slaved $\pm 30°$ (limited to 25° by the radar steering equations) could be sufficient to make the missile miss the target, or even fail to acquire. By reducing the 'bank angle' between scanner and aircraft axes to zero at Launch Warning, in Red Top modes, the problem is eliminated.

23. The look angle boundaries in the track phase, together with the aircraft and scanner axes are represented diagrammatically in Fig 3. In this diagram the solid outline represents the field of view of the scanner when roll stabilised. The fighter is in a gentle climb of 6°, banked 60° to the left. Measurements of azimuth and elevation of target 'A' with respect to the stabilised axes are:

Azimuth angle = 5°; Elevation angle = 10°

Fig 4 shows how this looks on the B-scope. The timebase is at 5° azimuth.

The elevation marker shows:

$E = \text{Elevation Angle} + \text{MRG Angle} + 2° = 10 + 6 + 2 = 18°$

At Launch Warning with Red Top, the roll axis lock signal comes through, and motors the scanner round to the position indicated by the pecked outline. Azimuth and elevation with respect to the locked axes are now:

Azimuth angle = 11°; Elevation angle = 0·5°

$E = 0{\cdot}5° + 6 + 2 = 8{\cdot}5°$

The B-scope display is now changed to that in Fig 5. The elevation marker is not reliable after Launch Warning and should be ignored. It is possible, for instance, in a lead situation, for a negative 'E' to be indicated even with the target above.

24. *Loss of Lock at Launch Warning.* Target 'B' in Fig 3 indicates clearly the dangers of having too much lag at Launch Warning. Although well within the scan limits while the AI is stabilised, the target is out of scan when roll axis lock takes effect. This applies particularly to tight attacks, where Launch Warning occurs early in the turn, the lag angle is high and height difference has yet to be taken out. If the steering dot is being obeyed, azimuth lead angle is limited to 25° and no problem arises.

25. *Effect on the Steering Dot.* Like the missile slaving signals, the steering dot demands are resolved into pitch and yaw signals for presentation on the B-scope. Consequently, roll axis lock has no effect on the steering dot, which can always be centred using the normal polar control principle of roll towards the steering demand and then pull. It is possible that the AI, missile slaving, and steering dot may behave erratically when roll axis lock occurs. There are two main explanations for this:

a. Inaccurate response to tracking demands by the aerial servo systems as the roll axis motors round to the locked position. This can be seen as instability of the elevation marker and azimuth timebase, or as 'excursions' of the steering dot. These should settle down almost immediately, but a poor set may, as a result, lose AI lock. It is important to be able to differentiate between this sort of break-lock at Launch Warning, and the 'out-of-scan' break-lock described earlier.

b. False range brackets generated while still outside normal 'time-to-go' switching. This could lead to wild movement of the steering dot due to changing directly from the initial approach programme to the final attack programme.

**Breakaway After Missile Attack**

26. *General Information.* At the end of a radar attack in the GW mode, breakaway should be effected as follows:

a. *AI Computer Setting* 1 *or* 2, *Target Visual.* Breakaway normally.

b. *AI Computer Setting* 3 *to* 6 *or Target Not Visual.* Breakaway must always be made on instruments using the appropriate method at para 27 or 28 of this Chapter immediately the X on the CRT is displayed, to ensure adequate fighter/target separation. Do not pull beyond the stage of slight buffet if this occurs at less than 3g.

27. *Manoeuvre Below* 10,000 *feet.* Reverse the bank and then pull up, at about 3g, to a climbing attitude of 30°.

28. *Manoeuvre Above* 10,000 *feet.*

a. *Target Below Fighter.* Level the wings and then pull up, at about 3g, to a climbing attitude of 30°.

b. *Target Above or Level with Fighter.* Roll in the direction of any existing bank until inverted and then pull about 3g to establish a descending attitude of 30°; thereafter resume normal flight.

29. *Considerations.*

a. *Rolling.* The normal rolling limitations must be observed and consideration should be given to the poor rate of roll which may be experienced at about 1·3M, particularly in the single missile configuration (firing only one of two). Correcting sideslip with rudder will improve the rate of roll and reduce fin loads.

b. *Target/Fighter Separation.* Below 10,000 feet, the use of settings 3 to 6 is not recommended because of reduced separation.

c. *Front Hemisphere Attack.* Unless operationally necessary, blind attacks from the front hemisphere should be avoided on targets which are less than 2500 feet below the fighter.

d. *Attitude Indicator.* As a guide to rapid interpretation of the attitude indicator, the tail of the zenith (or nadir) star just touches the outer reference circle at an aircraft attitude of 30°.

## EVENT SIGNALS

### Firing Brackets

30. The display of firing brackets is inhibited when the range is greater than 50,000 feet, therefore when the closing rate is in excess of 3300 feet/second, less than 2 seconds of Launch Warning will be displayed, due to the solution of the equation for the onset of Launch Warning being greater than 50,000 feet. It is unlikely that false firing brackets will be displayed during a computed attack but may be indicated when KR inaccurate is displayed or shortly after lock-on until the range servo has settled.

### False Breakaway

31. A false breakaway signal can occur, and it is more often seen during front hemisphere attacks than rear attacks, and usually occurs between 1 and 2 seconds before the real breakaway signal is given. As there is no difference in presentation between the false and real signal, there is no option but to react to the first signal seen. However, during the breakaway if the Fire Signal reappears and, if missiles have not already been launched, they may acquire and be fired, provided the trigger remains pressed.

## VISUAL IDENTIFICATION

### Introduction

32. Although the design minimum range of the AI is about 500 yards, it is usually possible to operate down to about 300 yards, but it is not possible to accurately determine target ranges below 2000 yards on the normal B-scope display. The radar therefore enables an expanded range display to be selected in the final stages of a vis-ident interception. Vis-ident does not alter the minimum range performance of the radar, but merely provides the pilot with more accurate range and range rate displays down to the specified minimum range.

### Vis-Ident Display

33. The vis-ident display is selected by the vis-ident switch on the hand controller. The display appears in one of two forms as the target range decreases:

a. *Thermometer Range Scale.* The thermometer range scale is displayed at the right hand side of the B-scope adjacent to the 0 to 10 NM range scale. It indicates ranges from 5000 yards down to zero, the 10 NM mark of the B-scope corresponding to 5000 yards, the 8 NM mark to 4000 yards and so on.

b. *Range Circle.* The range circle display is the normal time circle with no gap, but the radius is made proportional to range. The maximum radius is equivalent to 900 yards range. A vertical scale on the centre of the B-scope marks ranges of 900, 600 and 300 yards; the mark between 300 and 600 yards being the calibration point of 500 yards (minimum guaranteed lock range).

34. Either the thermometer scale or the range circle is displayed according to the particular target range. For example, if the aircraft is at 5000 yards range from the target and closing, the thermometer scale is displayed initially at full height and then decreases as range closes to 900 yards. At that range, the thermometer scale disappears and is replaced by the range circle, which then contracts as range further decreases. As range closes, particularly with large targets, the action of the automatic gain control causes the timebase on the B-scope to become dimmer. If the timebase is used to position the fighter during the vis-ident, it may be necessary to increase the brilliance.

35. *Loss of Lock Indication.* Loss of lock is indicated by either the thermometer scale or the range circle blinking, depending on which is being currently displayed, and also by a flashing red light behind the scales on the right hand side of the B-scope. These indications of loss of lock are immediate and there is no five second memory time delay. When near to the minimum range, it is possible for the set to transfer lock to internal noise without any indications of loss of lock. When GW is selected and range lock is lost inside Launch Warning range the computer red switches to range memory, therefore the vis-ident indication will be dependent on the memory circuit and not on the position of the range gate. This is a dangerous characteristic, due to collision risk, which must be guarded against. When guns are vis-ident the range circle (below 900 yards) will present a range rate gap. If range lock is lost the computer red will not switch to range memory but will drift into zero range.

36. *Breakaway.* A breakaway signal in this mode is only initiated by missile obscuration and is displayed as one diagonal of the normal breakaway cross.

## SWITCHING OFF THE RADAR

37. Selecting the main radar switch to off removes all power from the radar, including the supply to the scanner gyro stabilisation circuits. Eventual damage to these circuits and the drive motors will result if manoeuvres, including landing, are made without scanner stabilisation.

## AEROBATIC MANOEUVRES

38. The scanner roll stabilisation is limited to $\pm 110°$. It is necessary, therefore, to have the main radar switch on, and to have either LFS selected on the LFS/CRT switch or the MAS selected to OFF, in order to prevent damage to the scanner drive circuits during aerobatic rolling manoeuvres.

## FORMATION FLYING

39. Following any lock-on approach to another aircraft, ie close formation, air to air refuelling after a vis-ident, etc, it is necessary to remove scanner drive inputs to prevent damage to the scanner drive motors; this can be done by selecting search, LFS, or the MAS to OFF. It is also essential to have the AI transmitter off before manoeuvring close to any object.


XA699