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GCI CONTROLLERS MANUAL

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319th Fighter Control
Squadron
13th Air Force
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G. C. I. Section

Control Division

Army Air Forces School of Applied Tactics

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TEXTBOOK FOR GCI CONTROLLERS

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INTRODUCTION

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INTRODUCTION

GROUND CONTROLLED INTERCEPTION

During the latter part of 1940 the Germans were carrying out large scale day bombing attacks against the British Isles. As a result, the British were using every available fighter aircraft to counteract these blows. The British successfully withstood these attacks and on one memorable day shot down 186 aircraft. Because of the terrific defense the British were putting up against day attacks, the Germans changed their tactics to a great extent and began carrying out night bombing attacks. The British were again faced with the problem of intercepting large enemy raids, only now it had to be done at night. This meant that the control of the fighter aircraft at night would have to be done with an extremely high degree of accuracy.

Control was attempted by plotting both enemy and fighter on an intercept table after the radar information had been passed through a filter room and eventually to the intercept officer. This, of course, produced a time lag on the plots with resultant inaccuracies, and as a result, was unsuccessful. It was then realized that a method of control would have to be devised along with new equipment, that would give the controller the advantage of "seeing" his aircraft and its relative position to a target without time lag. It was realized that it would be desirable to read the positions of both intercepting and intercepted aircraft simultaneously on one instrument.

April 1, 1944

INTRODUCTION

Early experiments at British C.H. (Chain Home) stations showed promise, but readings were not sufficiently accurate for night interceptions. CHL (Chain Home Low) stations gave more accurate control, but only under limited conditions of height and range. Furthermore, "gaps" caused discontinuity of tracking, and the lack of accurate height finding facilities made interception unreliable.

Stations for Ground Controlled Interception (GCI) were, therefore, designed to overcome these defects. These GCI stations are equipped with the necessary gap-filling and satisfactory height-finding facilities, as well as the Plan Position Indicator. (PPI)

The object of night fighter control from a GCI station is to place the fighter in a position behind the target and within the operational limits of the fighter's AI equipment. The fighter, when placed in this position, is able to take over and complete the interception by use of its AI equipment. Combat conditions are entirely determined by the tactics of the enemy, and the fighter has to accept the geographical locality, the weather and light conditions and the conditions of flight itself - speed, height and evasive action - chosen by the enemy.

The RAF have established night fighter forces in Great Britain, the Middle East, Malta, North Africa, Sicily and Italy. These British forces have met with considerable success, and the enemy finds it necessary to go to a lot of trouble to avoid its attentions. American night fighter squadrons are likewise being employed in the Mediterranean theatre. It is to be expected that night fighting will spread to new theatres of war as these are opened up.

GCI does not necessarily refer to Ground Controlled Interception alone, as GCI is a type of siting. Any radar set used for GCI, such as the SCR-588 or SCR-527, may be sited for CHL or COL as well. When sited for GCI the antenna design permits accurate height reading. GCI sets are often placed in conjunction one with the other to provide an overlap in width and depth where the necessity for this type of defense warrants. (See Fig. 1) The normal coverage of the PPI tube is a radius of 50 miles, thereby limiting the area of control to this radius. Although this range can be extended, the accuracy demanded of GCI interceptions will be impaired.

The Plan Position Indicator tube known as the PPI, is one of two cathode ray tubes used in a GCI station. The other cathode ray tube is called the Height Range tube and has a maximum range of approximately 130 miles. This tube is used for early warning.

The function of the GCI Controller is to bring the fighter to a position about a mile and a half to two miles behind the target flying at about the same altitude, on the same heading, and with a slight overtaking speed. (500 ft. lower more feasible) G.T.N.

The AI set in the intercepting aircraft is then used by the radar operator in the plane itself to direct the pilot close enough to the bomber for the pilot to see the target ship and make an attack.

The original use for GCI was to provide a satisfactory method to control night fighters. As this type of control technique has progressed, it has been seen that it can not only be put to use for the control of night fighters, but can also be used for control of day fighters. It is now widely used for directing day fighters in the Mediterranean, Great Britain, and Pacific Theatres. This is proving to be a great advantage because control from the PPI tube affords greater accuracy.

Another use for this type of control is to "home" lost aircraft. As soon as the Controller has identified the lost aircraft on his PPI tube, he is able to direct the aircraft to any place he desires because he has the advantage of being able to "see" the exact location of the aircraft to any desired point he may want to send it.

DESCRIPTION OF EQUIPMENT

Height Range Tube (Fig. 2)

The Height Range tube is on the right of the Controller in close proximity to the PPI tube so that both tubes are within the Controller's field of vision.

The function of this tube is to indicate range, azimuth, and the approximate number of planes. A switching arrangement provides a variable indication of the received energy on this tube, which may be interpreted to give approximate height of aircraft.

For identification purposes the fighters carry IFF (Identification Friend or Foe) equipment. This equipment reinforces the radar echo and affects the echo in such a way on both the Height, Range and the PPI tubes that an aircraft can be identified as one of our own fighters.

PPI (Plan Position Indicator) Tube (Fig.3)

The Controller works from the PPI tube which is to the left of the H/R tube. A transparent perspex cover is fitted on the front of the PPI tube and the PPI operator reads the grid position of the enemy plane as the echoes from them are displayed on the face of the tube. The radar echo of an airplane shows on the PPI tube in the form of a small arc resembling a "sausage". This echo or afterglow is traced on the face of the PPI tube by a bright spot which appears on the time base each time the radar beam makes contact with an aircraft. This beam is directed by the antenna, which is rotated continuously, or made to sweep any sector desired by the Controller. The PPI operator reads the grid position of the enemy and the fighter as often as the Controller desires, and a Plotter-Computer located at an intercept board plots the track of each, computing the speed, heading and track of the enemy for the Controller.

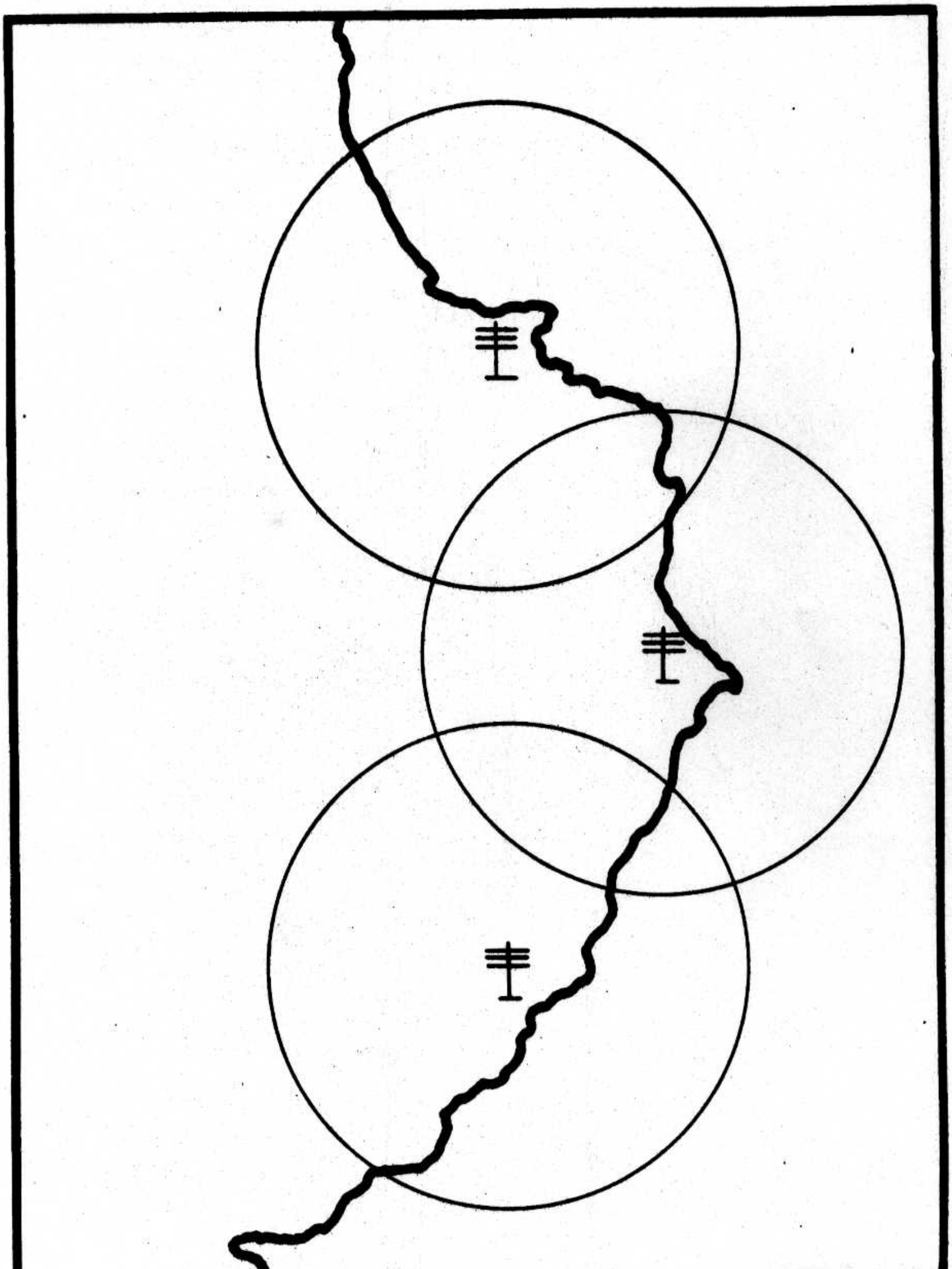

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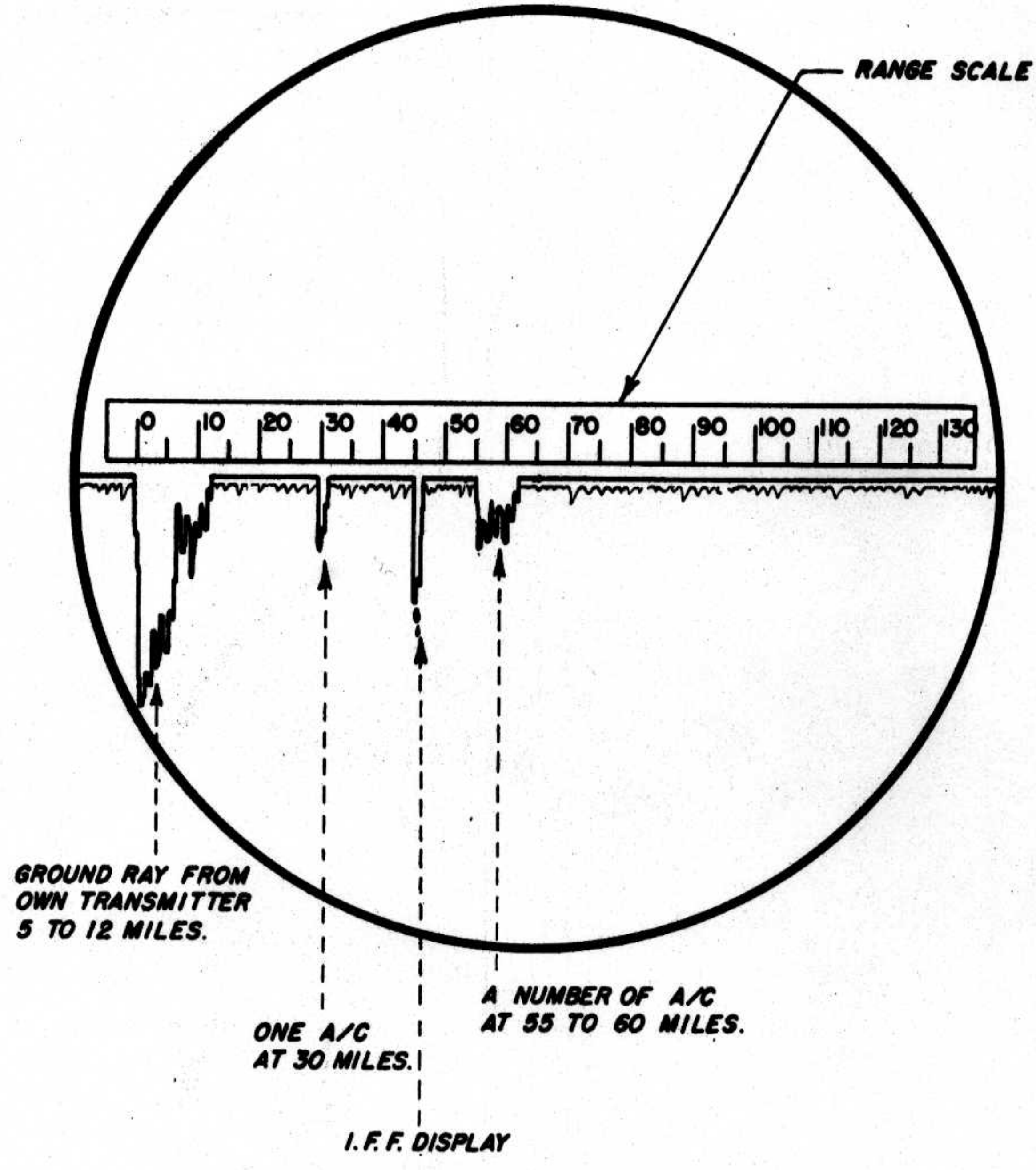
FIG. 1



HEIGHT RANGE CATHODE RAY TUBE

FIG. 2

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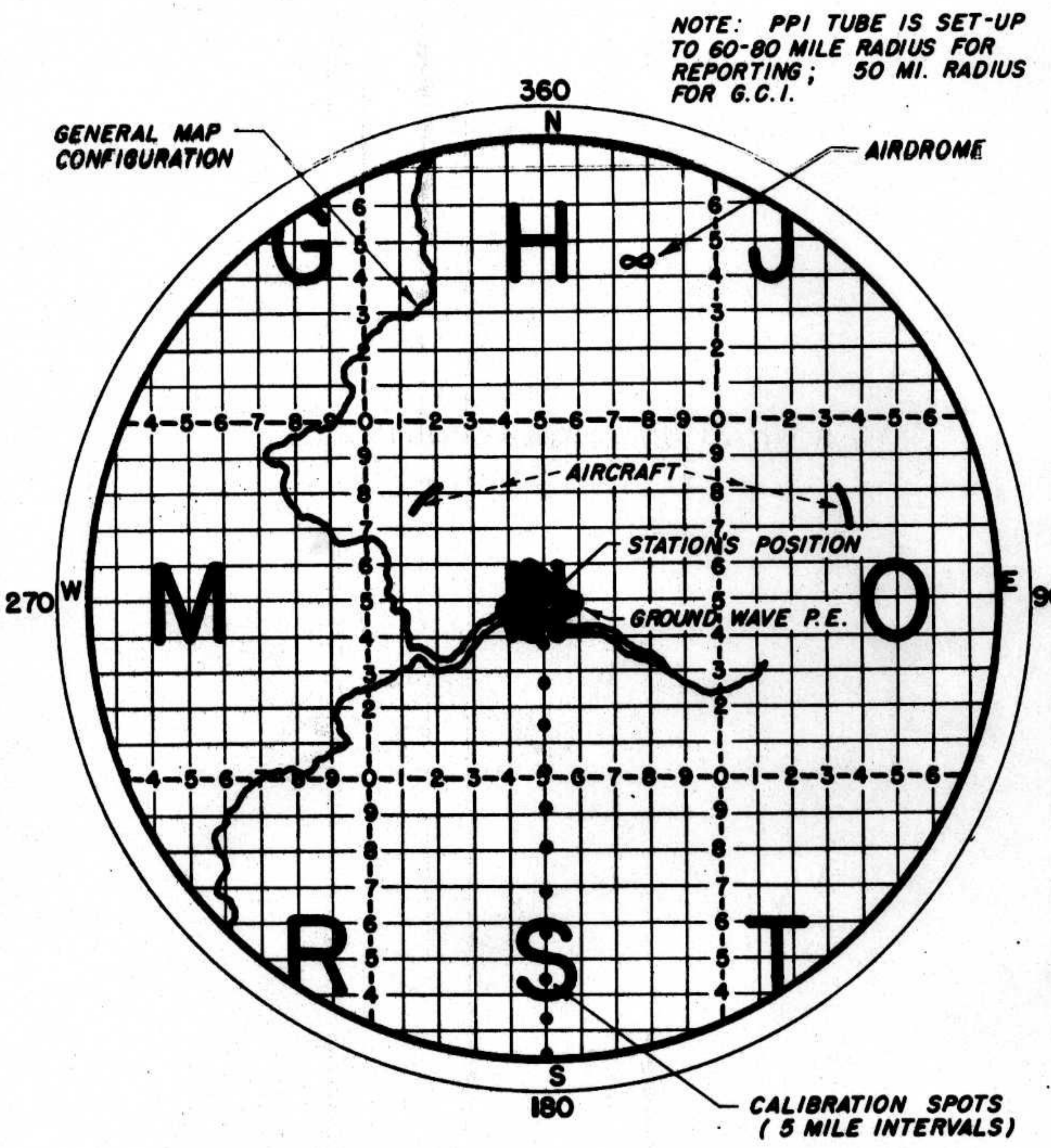

GRIDDED

P. P. I. TUBE

FIG. 3

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SECTION A

PERSONNEL

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Chapter I

DUTIES AND PROCEDURE OF THE G.C.I. CONTROLLER

Duties

1. The G.C.I. Controller will become thoroughly familiar with the performance figures of the aircraft to be controlled. He will also know intimately the pilots and crews who fly these aircraft. Highly improbable.

2. The G.C.I. Controller will know the operational limits of the G.C.I. apparatus, and the peculiarities of his own station.

3. With the above items always in mind, the G.C.I. Controller will direct the fighter so that the latter is not over two miles behind the target, on its heading, and in position for the A.I. to take over.

4. The G.C.I. Controller controls from the PPI Tube. He has a two-way VHF radio-telephone connection with the fighter pilot.

5. When an interception is to be made, the GCI Controller establishes radio contact with the fighter aircraft. Special R/T procedure is used for communicating with the pilot. (See R/T Procedure Chapter)

6. When enemy aircraft approach his effective area, the GCI Controller issues directional, height, and speed instructions to the night fighter.

7. Instructions given by the GCI Controller to the fighter will be corrected to appropriate aircraft instrument readings so that they may be used directly by the pilot. That is, directions will be given as magnetic headings and speed in terms of indicated air speed.

8. The GCI Controller bears the responsibility of training all crew members in proficient GCI operations. Good teamwork and proper training will result in correct, pertinent information being furnished by both the Plotter-Computer, and Height-Estimator.

Procedure

1. The GCI Controller will utilize information received from Area (such as the azimuth at which the target may be expected to appear, altitude of target, possible speed of target; the position, height, call sign, etc. of fighter; latest weather information, etc.). When the target and fighter are both visible on the PPI tube, he correlates this information with that obtained at the GCI station and the interception is begun without delay.

2. Plots on the target and fighter are told to the Area Operations Room in order that Area (including searchlights and AAA) can follow the interception. The Area Controller can thus be prepared to hand over a second fighter to the GCI Controller upon completion of the first interception.

3. Each interception is recorded on a map tracing. The target is plotted in red and the fighter in blue. Time is recorded to the nearest quarter minute, beside each plot. Fighter vectors, speed and height, and the time each order was given pilot is recorded in the lower right hand corner of the overlay.

4. The essential point for precision interception at night is that the controller work off the PPI Tube during the final stage of the interception.

STANDARD GCI CREW OPERATING PROCEDURE

I. INTRODUCTION.

1. A definite operational distinction is made between a Reporting crew and a GCI crew even though in certain circumstances they may be composed of the same personnel, as, for example, when a station is operating for Reporting and GCI. Personnel of a Reporting crew will be trained in all of the operating positions of Reporting, and their positions will be rotated during operations. In contrast, each member of a GCI crew will be trained as a specialist in a specific duty. Thus, as a member of a Reporting crew a man will be trained to fill all of the operating positions, but as a member of a GCI crew he may act as a specialist Height Estimator.

2. Teamwork is essential in GCI technique. All crew members must cooperate to provide the Controller with the necessary information to achieve successful interceptions.

II. OPERATING CREW.

1. The Operating Crew will consist of the following personnel:

a. GCI Controller

b. Height Estimator

c. Plotter-Computer

d. PPI Operator

e. Recorder

f. Crew Chief

g. Radiotelephone Operator

h. Radar Mechanic

i. Power Plant Repairman

j. Switchboard Operator

k. Liaison Operator

l. General Situation Board Plotter

m. Interrogator Operator

2. The duties of the GCI Operating Crew are specialized. Each member will be trained in a specific duty, and crew positions will not be rotated during operations. It is, however, recommended that positions be rotated hourly during periods when station is not on intercept; to avoid fatigue and thereby maintain efficiency. The Controller, Height Estimator, and Plotter-Computer require especially thorough training and considerable experience to properly perform their duties.

3. The duties of crew members are as follows:

a. GCI Controller.

(1) The GCI Controller directs the movements of the Fighter aircraft under his control so as to bring it into the best possible position to accomplish interception of the assigned Target.

(2) He sits directly in front of the PPI tube, using a hand set connected to the VHF radiotelephone for two-way communication with the Fighter pilot.

(3) When an interception is to be made, the Controller calls up the Fighter Aircraft and establishes contact with it,

Never under any circumstances, allow the fighter to continue at high speed into an area where he may cross in front of the target. When approaching target from the side and there is a possibility of overshooting, it is best to vector fighter away from bomber - then back on bomber's course. In making a 180° turn for head-on interceptions, the rate of turn should be determined and adhered to. The turning distance will vary with speed.

7. The fighter should never be allowed to get more than two miles behind the target.

8. The advisability of intercepting the target from above or below depends upon a number of factors, chief of which are light and cloud conditions, speed of the fighter relative to the target, and the operational characteristics of the A.I. equipment.

During the initial part of an interception, as many height readings as possible should be taken on the target. In all cases a number of height readings must be averaged to give reliable results.

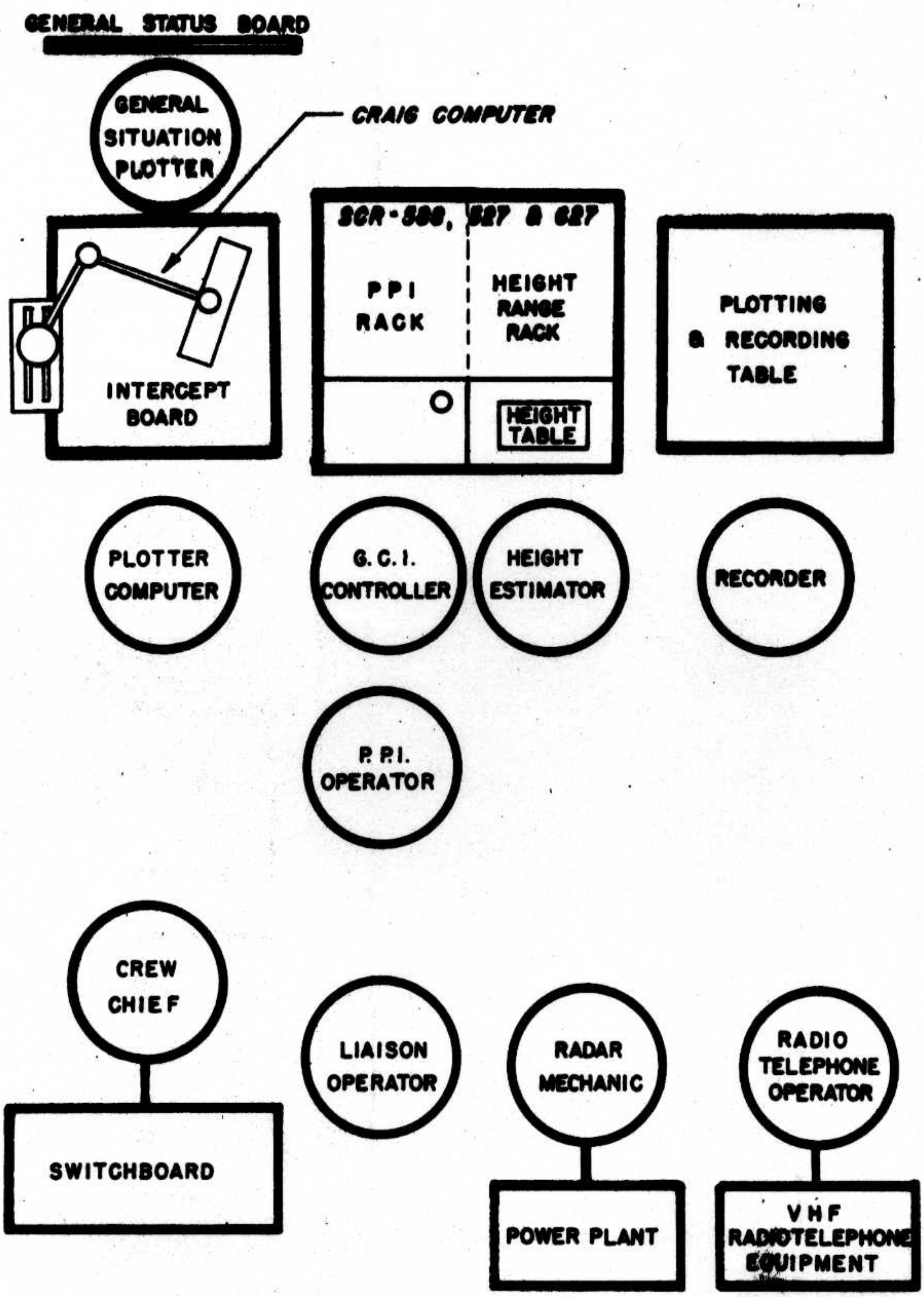
As in all interceptions, it is essential to give:

(1) A cutting off vector to bring the two aircraft together

(2) Final vectors to turn the fighter into a position behind the target on the same course.

5. It is necessary to know the target position at all times in order that the proper vectors and changes of vector may be given to the fighter at the appropriate time. This means keeping a constant eye on the target as well as the fighters and receiving aid from the computer if the blips fade temporarily. The eye should be constantly focused on the tube else a momentary glance away will often result in losing the relative positions of the two aircraft. It is essential that the controller know where the fighter is when on patrol. This will aid in identifying the fighter when the blips fade or when several planes appear in close proximity. The controller should also know the vector the fighter is flying while on patrol. This knowledge will be particularly helpful when giving the initial cut-off vector. If the fighter is patrolling in the opposite direction of the initial vector, obviously an appreciable amount of time will be consumed by making a 180° turn.

6. When fighter is turned onto course of target, it must be borne in mind that the change of vector must be given in ample time so as to allow for the turn of the fighter.



OPERATIONS SET-UP

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(4) The Controller then gives the following directions to the Fighter:

(a) Corrected headings to fly.

(b) When necessary, corrected speeds at which to fly.

(c) Corrected altitudes at which to fly.

(d) Any other pertinent information necessary for completing the interception.

(5) All instructions given by the Controller must be corrected to appropriate aircraft instrument readings so that they may be used directly by the pilot.

(a) Heading must be corrected for wind drift and magnetic declination of compass.

(b) Speed must be corrected for wind drift and height of aircraft above sea level and converted into an indicated airspeed reading.

(c) Height must be corrected for altitude of the GCI station above sea level, barometric pressure, and temperature at the altitude of the Fighter, so as to appear as a direct reading on the Fighter's altimeter.

(d) Computation of corrected readings will be done by the Plotter-Computer and reported immediately to the Controller.

(6) When Fighter and Target close the Controller must give the Fighter the following additional information:

(a) Difference in height between the two, indicating whether the Fighter is above or below the Target.

(b) Speed of the Target, so that the Fighter may avoid overshooting.

(c) A final heading to fly.

(7) When the Fighter has made contact with the Target,

either visually or by means of airborne Radar, control passes to the aircrew of the Fighter and the GCI Controller's duties terminate with respect to that interception.

(8) The Controller must make full use of all available sources of information pertaining to the interception. The Intercept Board will be so placed and illuminated as to be readily visible by the Controller. A General Status Board maintained by the Crew Chief will display necessary operational data. A hand set will be provided for the Controller for communication with the Area Controller and such other liaison organizations as are necessary.

(9) He must be thoroughly familiar with the performance and capabilities of the aircraft and air crews under his control. He must also know the operational abilities of his GCI station and crew.

(10) The receiver should be equipped with a PPI safety mask if possible, so that the Controller may control directly from the PPI tube, plotting vectors and courses on the mask.

(11) The Controller may use either sector or continuous rotation at high speed in the operation of the antenna sweep control. The antenna control may be operated by the Controller himself, or by the PPI

Operator or Height Estimator as is most convenient.

(12) The Controller, with the Crew Chief, bears the responsibility of training his crew to thorough proficiency in GCI operations. Close teamwork and careful workmanship must exist if successful interceptions are to result.

b. Height Estimator.

(1) The Height Estimator sits in front of the Height-Range tube and makes height estimations on Target and Fighter aircraft as required.

(a) During initial stages of the interception height readings will be taken on the Target only. When Fighter and Target close, alternate heights will be taken on each, and the difference in height be-tween the two passed to the Controller; indicating whether the Fighter is above or below the Target.

(2) If the station is equipped with a height-finding antenna, height estimations will be made from the height chart with height ruler in the following manner:

(a) Split control will be switched to "Height".

(b) Antenna Selector and "Phase-Antiphase" Switches will be switched so as to give best response, or as necessary to resolve ambiguities in height determination.

(c) The Height Estimator must note which echo is larger, echo ratio, phase of transmission for best response, and range of response, in order to determine height.

(3) If the station is not equipped with a height-finding antenna but has been accurately calibrated and fitted with

a working vertical polar diagram type height chart, the Height Estimator will estimate heights from pick-up, maxima, and fade points.

(a) With this method all possible auxiliary sources of height must be used. Filtered heights may come from Area Operations or Filter Room. Judgment will also be affected by a knowledge of the coverage of the station (high or low angle) and the habits of the raiders.

(4) Heights of Target and Fighter Aircraft will be plotted on the illuminated height desk and connected to indicate the vertical progress of the tracks.

(5) The Height Estimator will filter his heights in order to obtain an accurate reading on the Target before the Fighter is ready to make contact.

(6) Accuracy of heights will be checked by requesting height of fighter aircraft from the pilot.

(7) The Height Estimator must operate the antenna and phase switches so as to give continuous coverage on Target and Fighter.

(8) He must watch for appearances of IFF on either Fighter or Target and report this information immediately to the Controller. When, during the interception the target and fighter are at approximately the same azimuth from the station, he will, at the request of the Controller, state the correct distance between the two aircraft.

This he can do by referring to the range scale.

c. Plotter-Computer.

(1) The Plotter-Computer sits at the intercept board and wears a head set connected to the PPI operator.

(2) He plots the positions and tracks of the hostile Target and the Fighter aircraft with chinagraph pencils on a gridded plotting table. Plots are joined to form tracks.

(a) Target will be plotted in red.

(b) Fighter will be plotted in blue.

(3) He will appropriate computing instruments to accertain indicated air speed, track and heading of target. He will pass this information to the Controller.

(4) He will track the Target and Fighter by dead reckoning if that becomes necessary because of fading.

(5) At the direction of the Controller he will compute wind direction and velocity by comparing track and ground speed with known heading and true air speed of the Fighter.

(6) At the direction of the Controller he will fix the position of any aircraft by the D/F bearing method.

(7) At the direction of the Controller he will verify any homing or emergency landing steer given.

(8) At those stations provided with a Craig Interception Calculator he will compute for the Controller the proper vector to intercept.

d. PPI Operator.

(1) The PPI Operator sits behind the Controller on a special stool, wearing a head and chest set connected to the Plotter-Computer and Recorder at the station, and to Area Operations and Filter Room if liaison lines are provided.

(a) A supplementary PPI rack paralleled with that of the Controller may be provided for the exclusive use of the PPI Operator in reporting. In such case, modifications may be made in the Operations Room set-up so that reporting may go on simultaneously with interception if desired.

(2) The PPI Operator tells plots on the Target and the Fighter to the Plotter-Computer and Recorder, and to Area Operations and Filter Room if possible.

(3) Reference is made to reporting procedure for further discussion of the duties of the PPI Operator, these being modified as necessary to fit GCI requirements.

e. Recorder.

(1) The Recorder sits at the Plotting and Recording Table and wears a head set connected to the PPI Operator.

(2) He plots on an overlay map a complete record of the tracks of Target and Fighter Aircraft. A separate overlay will be used for each interception.

(a) Times of plots will be recorded at the beginning and end of each track and with each plot if possible.

(3) He will record on the overlay in abbreviated form all orders and instructions issued by the Controller to the Fighter.

(a) A complete record will be made from the time the station is ordered "On Intercept" to the time the interception is completed.

(b) Time of orders will be recorded whenever possible. Time will be recorded to the nearest fifteen seconds in the twenty-four hour clock system.

f. Crew Chief.

(1) The Crew Chief is responsible for the efficient functioning of the enlisted members of his crew during its tour of duty. He enforces standard operating procedure to meet the requirements of the Controller and supervises operations so as to secure accuracy, speed, and continuity of tracking of Target and Fighter.

(2) He exercises such control over the enlisted members of his crew as will insure that the station is ready to go into active interception operations immediately when required by the Area Controller.

(3) He sees that tuning and calibration of the receiver are checked when the station is ordered to "Alert".

(4) During interception operations he will operate the switchboard unless a trained operator is available for duty.

(5) He will display necessary flying operations data on

the General Status Board. Such information may include:

(a) Operational status of local airdromes.

(b) Weather Reports.

1. Wind direction and speed at various altitudes.

2. Visibility.

3. Cloud height and density.

(c) Fighter Situation.

1. Time airborne.

2. Number in air.

3. Type.

4. Call signs.

5. Approximate positions.

6. Flying time left.

(d) Trend of enemy activity.

(e) Phase of moon and position each hour (for night interception.)

(6) He records in the station log all necessary information relating to the station's operational activities, indicating times of occurrence. This information will include:

(a) Orders issued by Area Controller

(b) Operational status of station (Standby, Alert, on Intercept, Maintenance etc.)

(c) Pertinent data relating to each interception attempted.

(d) Operating positions of crew.

(e) Breakdowns, "Off the Air," "On the Air", etc.

(f) Maintenance periods.

(g) Interference.

(7) The Crew Chief bears the responsibility of training his crew members during slack periods. He must be proficient in all GCI duties and be able to substitute at any position if necessary.

g. Radiotelephone Operator.

(1) The Radiotelephone operator is responsible for keeping the rediotelephone equipment in such condition that the Controller will be able to maint ain contact with the Fighter at all times during interception.

(2) He will monitor the radiotelephone communications as required by the Controller.

(3) He will keep a log of all messages received and transmitted.

h. Radar Mechanic.

(1) The duties of the Radar Mechanic are:

(a) The Radar Mechanic is responsible for the efficient operation of the Radar equipment during his watch.

(b) He must see that both transmitter and receiver are tuned properly and that the receiver is adjusted so that the operators may calibrate accurately.

(c) He must be thoroughly familiar with the circuit layouts of the equipment, to be able to trouble-shoot quickly, and make emergency repairs.

(d) The Radar Mechanic performs routine daily maintenance which is planned to uncover troubles before they occur.

(e) He keeps operating logs of the equipment and takes meter readings hourly, entering them on the prescribed forms.

i. Power Plant Repairman

(1) The duties of the Power Plant Repairman are:

(a) The Power Plant Repairman is responsible for the operation and care of the diesel power units.

(b) He makes routine service checks at regular intervals and keeps the operating logs.

(c) He must be able to make field repairs.

(d) If commercial power is being used the Power Plant Repairman must see that the standby power supplies are ready to go into operation quickly whenever required.

j. Switchboard Operator.

(1) The Switchboard Operator will operate the telephone switchboard.

k. Liaison Operator.

(1) The Liaison Operator will maintain liaison with the Area Operations Room, Filter Room, Local Airports, adjacent Radar Stations and such other sources of information as may be desireable.

(2) He will obtain from the proper sources whatever

operational information the Controller may require.

l. General Situation Board Plotter.

(1) The Situation Board Plotter will plot on the General Situation Board, all hostile and unidentified flights which are beyond the range of the PPI tube and within 100 miles of the station.

m. Interrogator Operator

(1) The Interrogator Operator will operate the RC-188 as directed by the Controller.

4. The crew for a Mobile GCI Station shall be the same as outlined above except: The duties of the switchboard operator may be assumed by the Liaison Operator: plotting on the General Situation Board need not be beyond 80 miles from the station. A Plotter Converter will be required to convert plots to false coordinates in order that they may be passed by radio with security.

DUTIES AND PROCEDURE OF GCI LIAISON OFFICER

1. Experience has shown that the efficient use of GCI Stations demands the closest liaison with Area. It is therefore essential that the GCI Liaison Officer in the Area Operations Room and the Area Liaison Operator at the GCI Station, are people with a high degree of intelligence and who are not saddled with responsibilities other than their work.

2. Before operations commence, and at other periods when more recent information becomes available, the GCI Liaison Officer should give to the GCI Station all relevant information. This will include pertinent weather information, movements of friendly aircraft, call signs of fighters, a/c number of fighters, types of aircraft available, airdromes from which they are operating, etc.

3. As soon as area receives warning of impending hostile activity, the Area Controller instructs the GCI Liaison Officer to warn the GCI station. If the GCI Liaison Officer has the information available he will inform the GCI Controller of the grid coordinates, of the line of approach, the speed and the altitude of the hostile raid. He will also give the approximate azimuth reading at which the controller can expect to see the raid appear on his PPI tube.

4. As soon as the fighter aircraft are airborne, the first fighter should be taken over immediately by the GCI Controller, whether the targets are visible on the PPI tube or not. This is valuable for checking height calibration, VHF, wind speeds, etc. Aided by the information he has received from the GCI Liaison Officer, the GCI Controller

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will vector his fighter to a position suitable for commencing an interception.

5. However good the Controller and crew at the GCI may be, the number of interceptions he is able to make is conditioned upon the quality of the liaison between the GCI Station and the Area Operations Room. During periods of continuous enemy activity opportunities for the GCI to make interceptions have been lost because the Area Liaison Officer was unaware of the position of the new fighters and hence unable to hand them over to the GCI Stations. In general, a single GCI requires approximately three a/c to keep it continuously occupied. One will be actually under control, while the proceding one will be on an AI chase, and the third will be waiting for the next interception.

6. The GCI Liaison Officer should be constantly upon the alert watching for the approach of the fighters toward any danger areas such as AAA, balloon barrages, etc. In such case he should advise the GCI Controller and take such measures as ordered by the Controller.

7. The duties of the GCI Liaison Officer can not be laid down rigidly. In general, it may be said that at all times he will keep himself completely in the picture and be able to keep close track on the progress of operations in which the GCI station is concerned. He should have a lively appreciation of the tactical situation at any moment.

SECTION B

PRESENT EQUIPMENT

CHAPTER I

EQUIPMENT USED IN GCI

The primary task of the GCI Controller is to bring the fighter into such a position that the target is within three dimensional range of the fighter's AI equipment. The job requires considerably more information than the Controller can read from the PPI tube. It requires the organizational use of many specialized instruments by trained members of his crew. The Controller can get invaluable assistance from his crew if he sees that they are properly trained in the use of their particular instruments and equipment.

Equipment Needed at SCR-588 Installation

1 General Situation Board
2 Moulded Perspex screens for each PPI position
1 Craig Computer for each intercept board
(Craig Computers can be obtained from the Air Service Command, Patterson Field, Dayton, Ohio)
1 Intercept board, slanted, with plexiglass cover for each PPI position
(If Craig Navigation Table is provided as standard equipment, it replaces Intercept Board Above)
1 Intercept Officer's kit. Type I - Model V. Order No. (1V585) 43-4301
1 Recorder's table for each PPI position
1 Protractor, simple type, for each PPI position
1 Status board
2 Clocks with sweep second hand, 8-day, key-wound, 10-inch face (Signal Corps Supply)
2 Stop watches, type A-8, Part #1778, Sup. #6200-478950
1 Doz. blue chinagraph pencils, supply #8600-548200
1 Doz. red chinagraph pencils, supply #8700-549200
1 Doz. blue crayon pencils
1 Doz. red crayon pencils
2 Rolls paper, tracing
4 Doz. black (medium) pencils
1 Sponge for Craig Navigation Table

Moulded Perspex Covers

These plastic glass screens (See fig. 1) mounted over the face of each PPI tube, enables the Controller to mark by a dot in chinagraph pencil the position of an aircraft as seen from the echo or blip. The successive dots are joined to form a track.

Craig Computer

It should be remembered that the direction of the track of an aircraft as drawn on the PPI screen will differ from its heading in proportion to the wind's direction and velocity. To make precision interception, the fighter must be given the same heading the target is flying and must be placed directly behind the target and given a slight overtaking speed. The Craig Computer determines the target's heading and true air speed if track, ground speed, wind direction and velocity are known.

Attached to the intercept board and operated by the Plotter-Computer the Craig Computer (see fig. 2) enables the operator to quickly obtain the above information for the Controller.

Intercept Board

This board, (See fig.2) is located on the Controller's left so as to be readily seen by the Controller. A gridded map covered with plexiglass is drawn on the board on which the Plotter-Computer plots the position and tracks of the hostile and fighter aircraft. By means of the Craig Computer and a stop watch he determines the true air speed and heading for the target aircraft. Knowing the true airspeed, alti-

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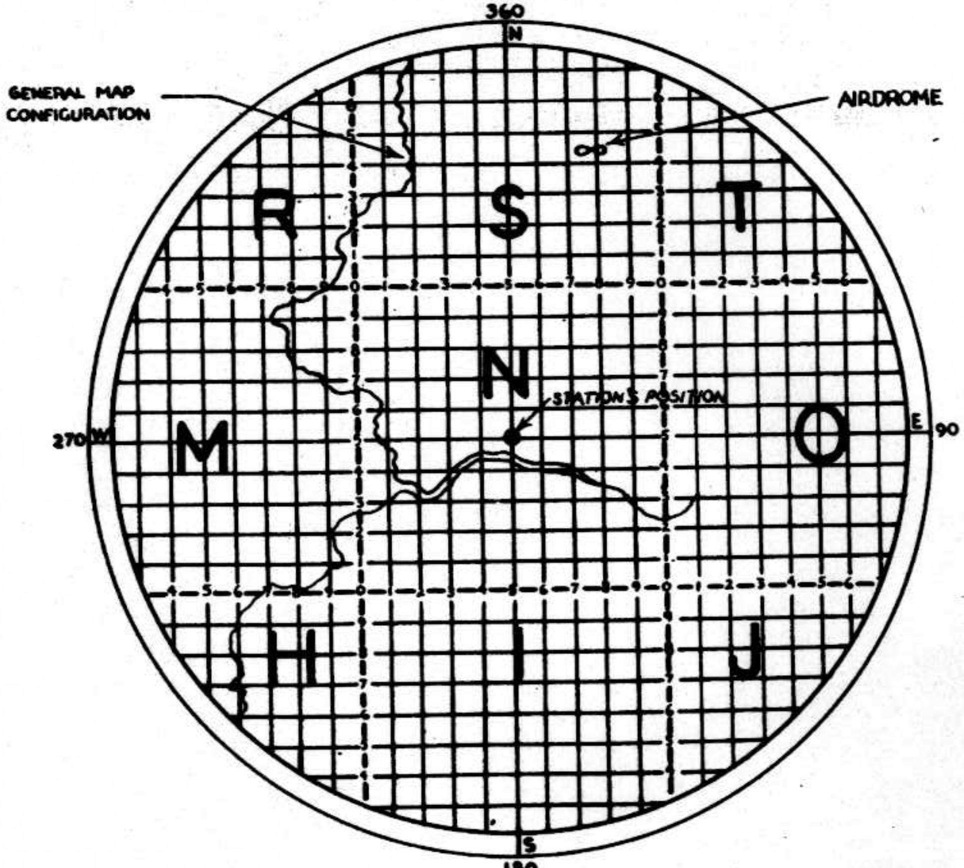
PERSPEX COVER FOR P.P.I. TUBE



PRESENT P. P. I. TUBE HOLDER

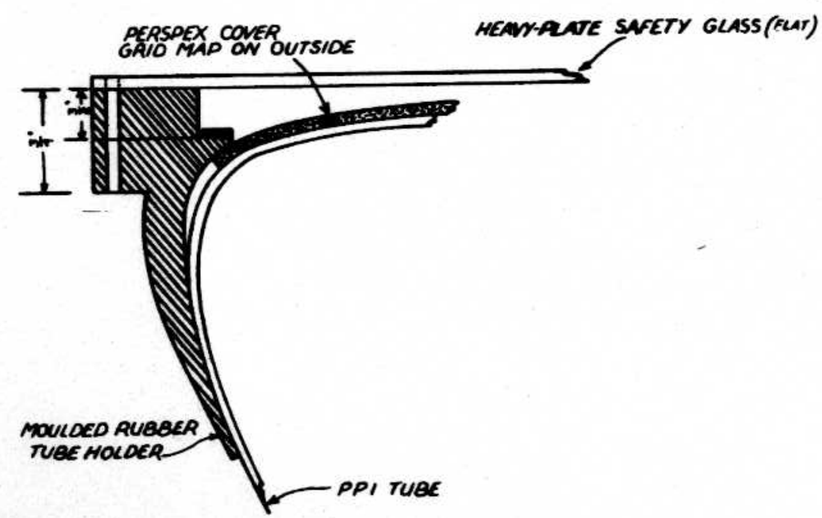


Fig. 1

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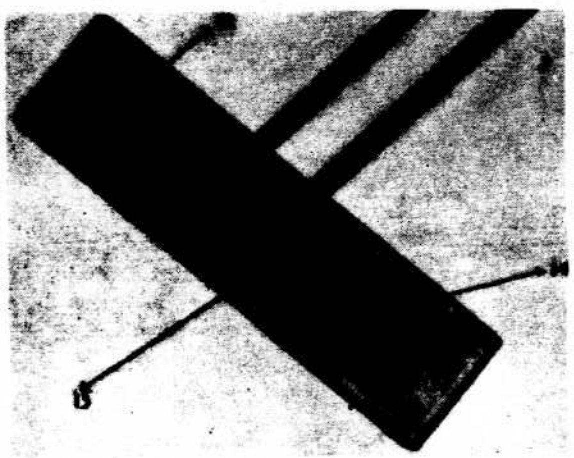

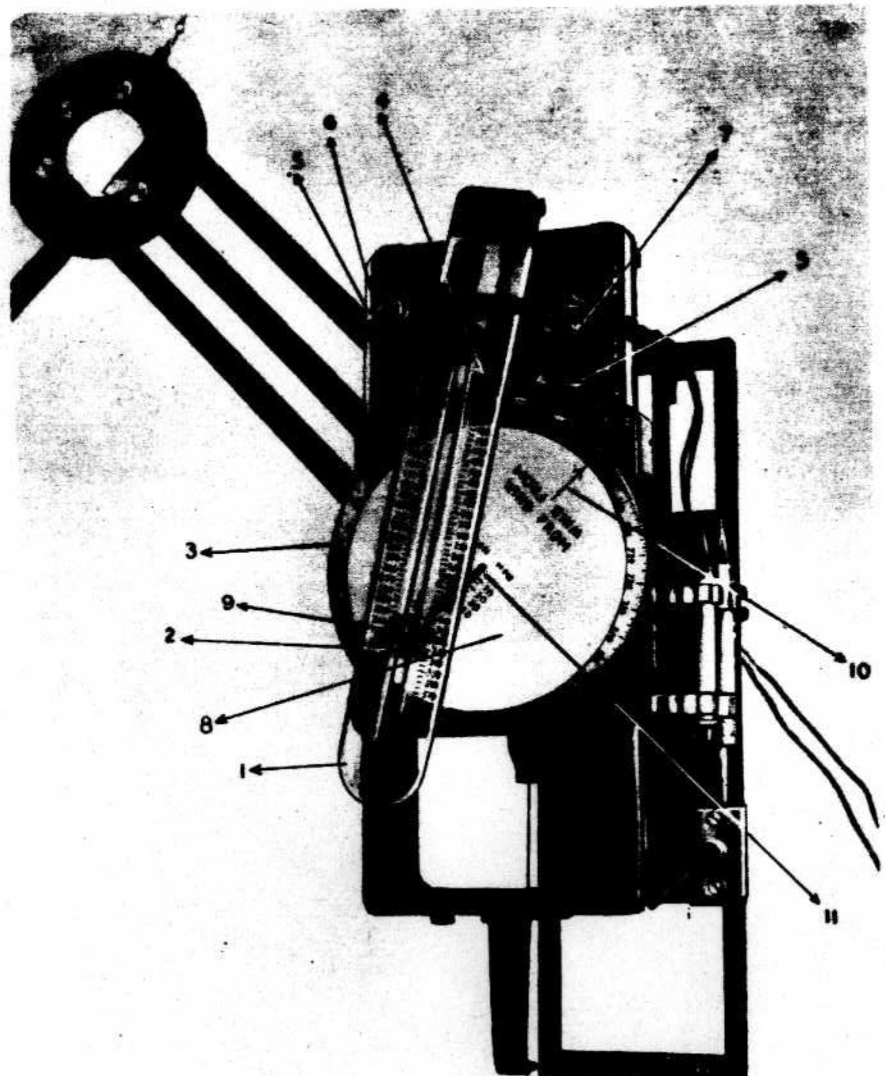

1. AIR SPEED BAR
2. AIR SPEED MARKER
3. BEARING PLATE
4. TRACK MARKER
5. GROUND SPEED INDICATOR
6. GROUND SPEED PLATE
7. HEADING COURSE INDICATOR
8. WIND PLATE
9. WINDPOINT PIN
10. WIND ARROW MARKER
11. WIND VELOCITY SCALE
12. TRANSPARENT RULER
13. MAGNETIC VARIATION SCALE
14. GROUND SPEED COMPUTER

CRAIG COMPUTER

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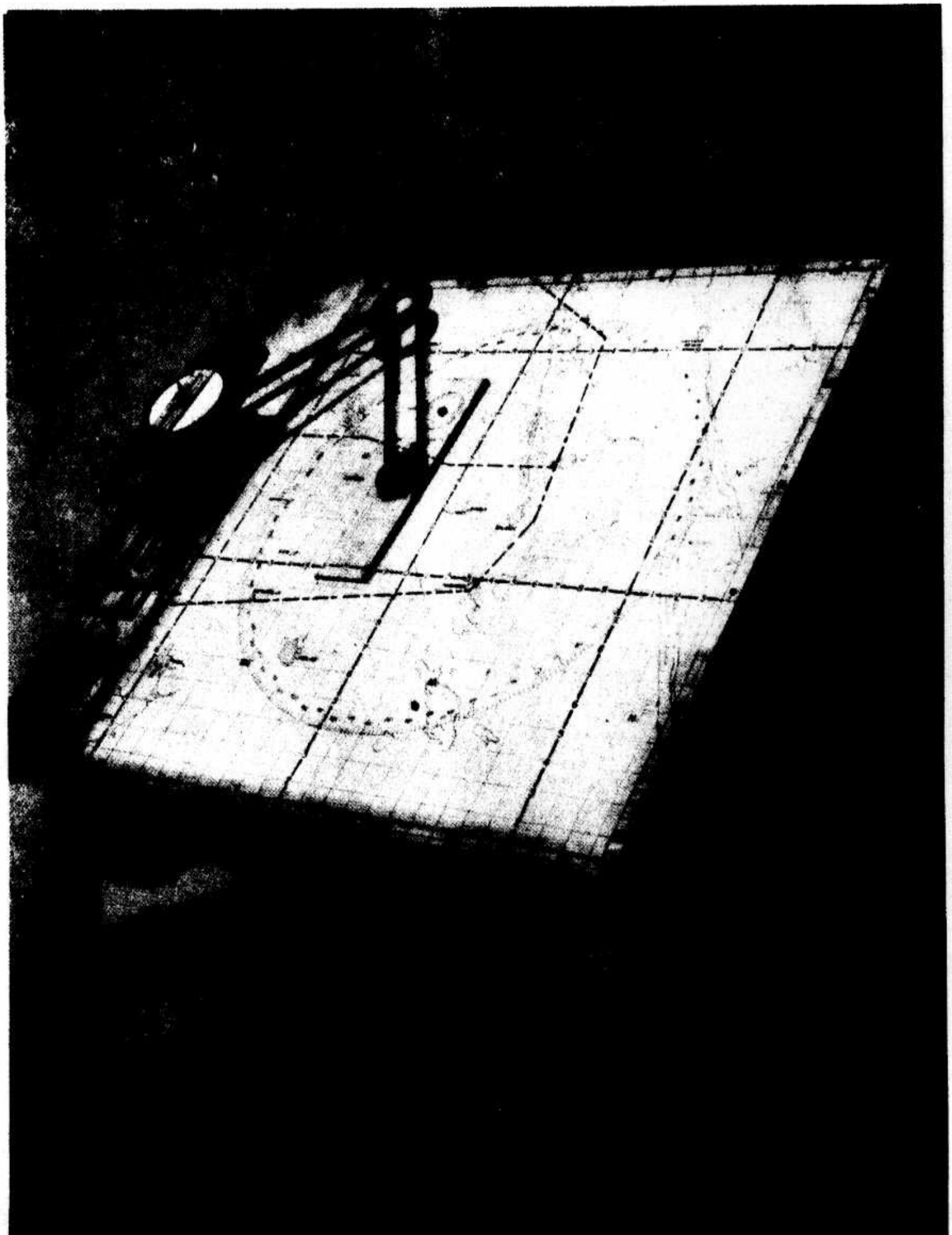

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Fig. 2

INTERCEPT [illegible]
WITH
[illegible] COMPUTER

tude, barometric pressure and temperature, the target's indicated air speed can be ascertained by means of a suitable computer, or by appropriate tables designed for this purpose. Dead reckoning of both the fighter and target planes is done by the Plotter-Computer on the intercept board. All information is passed on to the Controller.

Intercept Officer's Equipment. (Kit)

This is the new Cox-Stevens cased computer. In the lid space is provided for:

2 Sadowsky Timers, (1:250,000 Scale and 1:500,000 Scale)

2 Speed rulers (1:250,000 Scale and 1:500,000 Scale)

2 Transparent rulers 11" long, graduated in inches, in eights.

Two items on the list, the true air speed vs indicated air speed computer and the speed scales will be used to a greater extent than the other items. The entire list, however, is included as GCI equipment for emergency use in the event a Craig Computer is not available.

Recording Table

This table is designed for use by the recorder to plot on an overlay map a complete record of the tracks of target and fighter aircraft. A separate overlay is used for each interception. All orders given by the Controller to the fighter are recorded in abbreviated form on the ov erlay together with the time to the nearest 15 seconds the orders were issued. This is invaluable for showing why various instructions were given and for reconstructing the entire int erception so that it can be later analyzed. It is felt less emphasis should be put on recording, inasmuch as it can be accomplished anywhere in the station layout. The large, indirectly lighted board may very likely be replaced by a printed, gridded form of sufficient size to make plotting easy and legible.

Transparent Protractor

A simple type transparent protractor, as shown in figure 1, Chap. IIB, on which is engraved a compass rose, is a valuable aid to controllers in estimating accurate vectors. The protractor, if held properly oriented against the PPI tube with the center of the rose over the fighter's arc, will assist the controller in giving the proper vector to intercept enemy aircraft. This is a waste of valuable time.

Clock With Sweep Second Hand

Two clocks are needed, one each for the intercept board and recorder table. Accurate time is extremely essential to the plotter-computer for dead reckoning and for synchronizing his stop watch. Another clock enables the recorder to determine and record times of plots and operational orders to the nearest 15 seconds in the 24 hour clock system.

Stop Watch

A stop watch is used by the plotter-computer to determine ground speeds of aircraft. The time interval between two plots of known distance is measured. By setting time and distance on the time vs distance computer, ground speeds can be read directly. The two plots used for computing ground speed should be taken at least $1\frac{1}{2}$ minutes apart and preferably over two minutes apart.

Pencils - Chinagraph and Colored Pencils

Chinagraph pencils are needed by the controller and plotter-computer for marking on the perspex cover and plexiglass covered intercept board. Blue designates the friendly fighter and red the enemy bomber. Ordinarily red and blue pencils or crayons are used by the Recorder.

Paper - Tracing

Records of each interception are recorded on sheets of transparent overlay paper.

Status Boards

GCI Controllers and crews will have posted on easily seen status boards the information shown in Fig. 3. Aircraft, Airdrome, Weather, Moon phase, and Station Status, with a section for additional bulletins, should be included.

Dependent upon arrangements at each GCI station, the above information may be consilidated on one general status board or the various sections posted in the best available positions in the station.

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INSTRUCTION IN THE USE OF THE CRAIG COMPUTER

In connection with the following instructions, course and track are used in the British sense. The British definitions of these two terms follow:

Track is the direction of the path of an aircraft over the ground. The "Required Track" is the direction which an aircraft is intended to follow. The "track made good" is the direction of the path actually traced over the ground. In the American sense, British Track is the same as our Course.

Course is the direction in which an aircraft is heading. Since the direction in which an aircraft is heading may be measured from the True, Magnetic, or Compass meridian, the course must be named according, T., M., or C. In American sense again, British Course is the same as our Heading.

1. To Find Windspeed and Direction Given Course and Air Speed, Track and Ground Speed.

a. Place the windpoint pin (Part No. 9) in the center of the wind-plate (Part No. 8)

b. Fix the true airspeed on the airspeed bar (Part No. 1) by means of the airspeed marker (Part No. 2)

c. Revolve the ruler (Part No. 12) until the track made good is shown on the bearing plate (Part No. 3) against "T" (Part No.4)

d. Place the ground speed indicator (Part No. 5) against the correct ground speed on the plate (Part No. 6)

e. Place the course indicator (Part No. 7) against the course steered on the bearing plate (Part No. 3)

f. Through the center hole of the airspeed marker (Part No. 2) place the pencil which will make a dot on the windplate (Part No. 8)

g. Place the airspeed marker (Part No. 2) over the windpoint pin (Part No. 9)

h. Rotate the bearing plate (Part No. 3) until the pencil mark lies in the slot in the lower part of the airspeed bar (Part No. 1)

i. Read the windspeed against the graduations on the airspeed bar. This is done by subtracting the speed reading opposite the pencil dot from the true airspeed as indicated by the airspeed marker.

j. The direction of the wind can now be read off against the mark "T" (Part No. 4)

2. <u>To Find Course and Airspeed Given Track, Ground Speed and Wind Speed, and Direction.</u>

a. To set the windspeed and direction slide the windpoint pin (Part No. 2) to the outside of the windplate by depressing the windpoint pin. Rotate the windplate until the arrow marker (Part No. 10) lies against the bearing from which the wind is coming. Slide the windpoint pin and place against the speed graduation of the wind scale.

b. Place the ruler (Part No. 12) along the track or rotate the ruler until the track is indicated on the bearing plate against the track pointed "T".

c. Unscrew the airspeed marker (Part No. 2) and slide the ground speed plate until the pointers indicate the given ground speed.

d. Place airspeed marker over the windpoint pin and screw up. The course of the aircraft may now be read on the bearing plate against the course indicator "C". The airspeed in indicated by the marker on the slide of the airspeed bar.

3. <u>To Find the Course and Groundspeed Given Track, Airspeed, Windspeed and Direction.</u>

a. Set windspeed and direction as in 2a above.

b. Unscrew the airspeed marker.

c. Replace the ruler (Part No. 12) as in 2b above.

d. Place the airspeed marker over the windpoint pin.

e. Slide the ground speed plate until the true airspeed is shown against the airspeed marker. Tighten up the airspeed marker. The course to steer may now be read off against the course indicator "C". The groundspeed may be read off against the groundspeed indicator.

4. <u>In Setting Up the Craig Computer,</u> care should be taken that the transparent rule is aligned along the true north meridian with the windpoint pin at zero. This may be checked against the fixed track index Mark I which should read zero plus a westerly variation of 360 minus easterly variation according to what setting variation is made on the rule.

5. Method of Performing Speed Calculations.

It is important that the plotter-computer should always be prepared to give the controller accurate speeds on both the target and the fighter. Reasons for this are as follows:

First: The blips often fade on your PPI tube and the plotter-computer should always be prepared to dead reckon either aircraft or both at once if necessary.

Second: The target and fighter may go through the ground ray requiring dead reckoning.

Third: Assuming the target follows a steady course and the fighter has been given a cut-off vector to intercept, the plotter-computer should be able to tell the controller how many minutes it will take for the fighter to reach the target's line of flight and whether he will get there ahead of the target or too far behind.

The following is the general procedure used in making accurate speed calculations:

1. Set up the wind direction and velocity on the Craig.

2. Assuming the target is being plotted, when the PPI operator calls "target", start your stop watch and mark this plot with a "T" for later reference. Do not wait until the grid coordinate is read to start the watch, since this lapse in time will throw off your final accuracy.

3. Continue to record your target plots for 2½ to 3 minutes. When this period of time elapses and the PPI operator calls "target", stop your watch and mark this plot with a "T". (Calculations of less

than $2\frac{1}{2}$ to 3 minutes cannot be considered accurate).

4. Measure the distance between the two designated plots with your parallel rule - read the elapsed time from the stop watch - then set the distance covered over the ground against the elapsed time on the ground-speed computer on the parellel rule. Read your groundspeed from the arrow marked "60". (The groundspeed computer on the parallel rule allows for figuring fractions of miles and fractions of minutes; therefore, do not try to get your readings on even minutes or even miles).

5. Set your ground speed on the Craig Computer making sure your parallel rule is held along the track of the target with the arrow on the rule pointing in the direction of flight when setting the groundspeed.

6. Read the true airspeed from the airspeed marker on the airspeed bar.

7. Use the Cox & Stevens computer on which the indicated altitude and barometric pressure is set and read backwards from True Airspeed to Indicated Airspeed.

When figuring speeds on the fighter, use the same procedure as above, the exception being that you know the Indicated Airspeed and can easily read the True Airspeed of the fighter by using the Cox & Stevens.

The parallel rule being marked off on both sides in miles, it is a simple matter to mark off the minutes on the intended track for dead-reckoning knowing the ground speed of the aircraft.

Calculating speeds of targets or fighters that are continually weaving, diving, climbing or orbiting is very difficult. In such cases, plots may have to be used that only cover a period of one minute of straight and level flight. Although in this case, inaccurate readings will probably be arrived at, but they are better than no readings at all. Two or three of these types of readings may prove fairly accurate if they are averaged.

PROTRACTORS USED

by

G.C.I. CONTROLLERS

The most successful results in GCI controlling have been obtained by the use of the "cutting off vector" method of interception.

In using this method, the controller will project the bomber's line of flight and estimate where, along that line, the fighter could intercept it by flying a straight course from its indicated position.

The controller may wish to combine the "cutting off vector" method with the "curve of pursuit" method. The "cutting off vector" method is used first, and the "curve of pursuit" in the final stages of the interception.

Whatever his choice of methods may be, the GCI Controller has access to two mechanical aids in determining what vectors to give to his fighter. They are (1) the simple protractor and (2) the interception protractor. (British Mark IX) (See fig. 2)

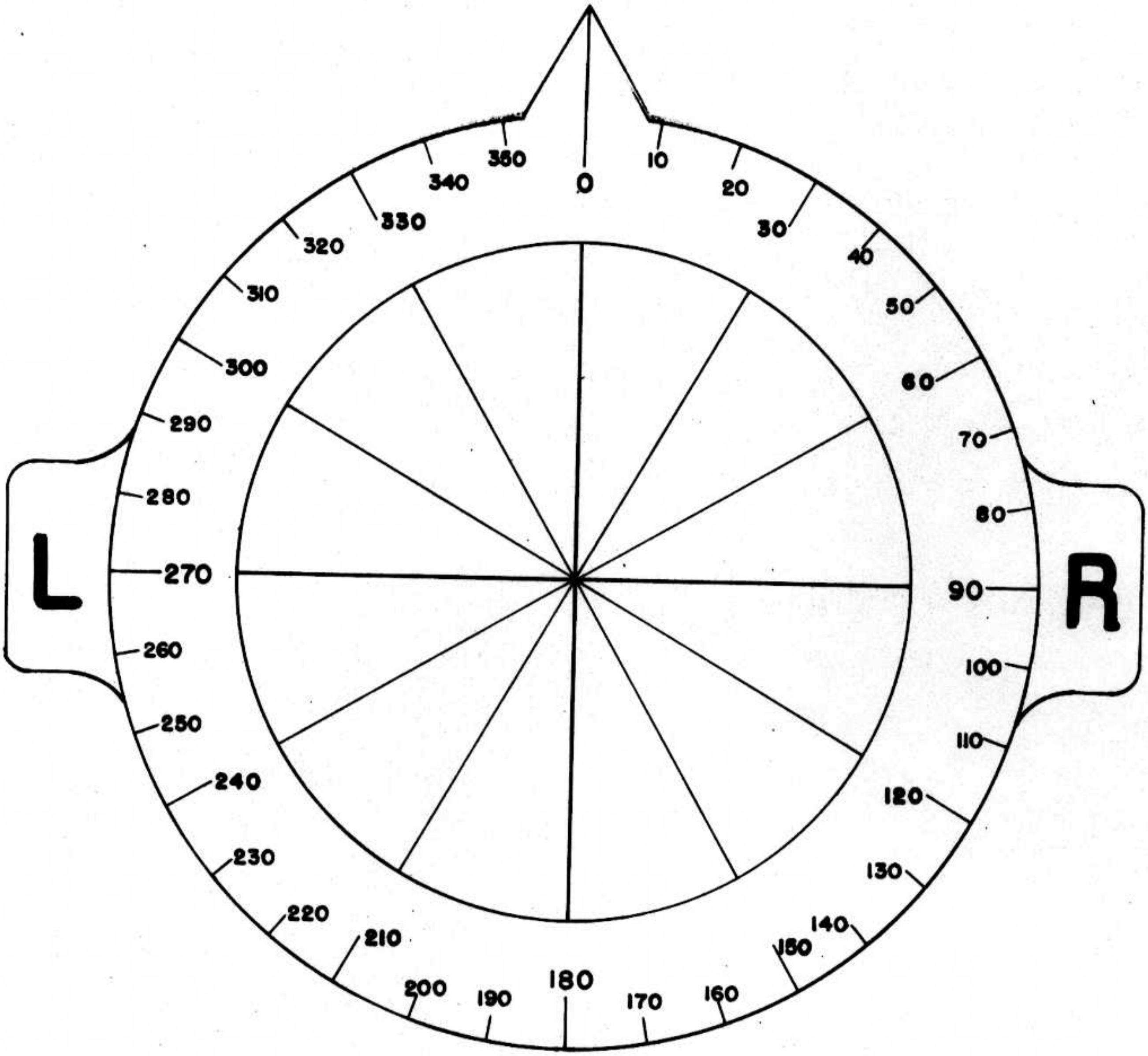
a. The simple protractor is nothing more than a compass rose printed on a transparent disk (Fig. 1.) When the controller wishes to know the vector from the fighter's indicated position to the bomber or to any point on the area of the PPI tube, he places the protractor on the face of the tube with the center of the compass rose over the indicated position of the fighter and orients the protractor with relation to compass directions. He can read the azimuth which most nearly coincides with the desired line of flight. This is the vector he passes on to the fighter.

b. The cut-off interception protractor has been designed to assist GCI Controllers in estimating the correct cut-off vector direct from the PPI tube. (See Fig. 2)

The protractor shows the vector which must be given to the fighter to intercept the target. It also shows the point at which the fighter should be told to turn on to the target's course so that, after the turn, the fighter is at the desired position relative to the target.

The protractor consists of a square frame, on which a compass rose is engraved and a rotatable inset on which there are various markings. The straight lines radiating from points approximately around the center of the protractor are "approach lines", and each line is marked by a letter. These letters are on the inner semi-circle of letters on the inset. Another set of letters form an outer circle on the inset. These letters are adjacent to the compass rose, and a particular letter indicates the vector which corresponds to the line of approach marked by the same letter on the inner semi-circle. The inner points at which the lines of approach terminate are called "turning points". There are two scales, graduated in miles, on the bomber direction line of the rotatable inset.

To use the protractor, the center line of the circular inset is set to point along the bomber's course. The protractor is held against the PPI tube with the sides of the square frame parallel to the grid lines and the arrow pointing north. Having decided the distance behind the bomber at which it is desired to place the fighter on the same course; the controller holds the protractor on the PPI tube so



SIZE: 3 INCHES IN DIAMETER.
BLACK FIGURES ON
TRANSPARENT BASE.

SIMPLE TYPE PROTRACTOR

FIG. 1

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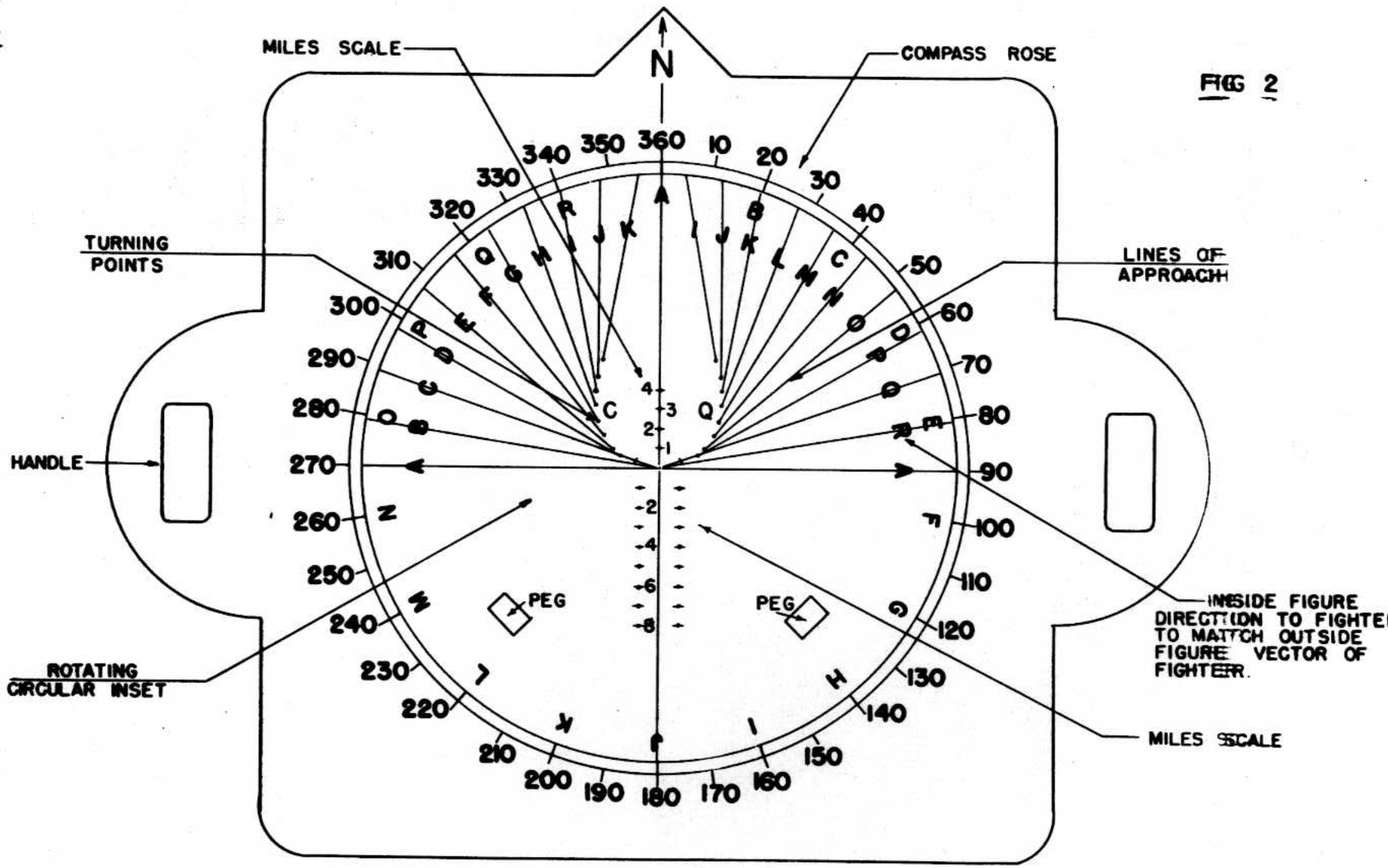
INTERCEPTION PROTRACTOR - MARK IX

FIG 2



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that the required point on the distance scale, referred to above,is over the center of the bomber blip. As the bomber moves across the PPI tube, the protractor is moved along with it so that the point on the distance scale always is on the center of the bomber blip.

With the protractor set up and held against the bomber blip as described above, the letter on the line of approach, or extention of the line, on which the fighter blip lies is noted, and the correct vector to give the fighter is that which corresponds to the same letter on the outer scale.

As the protractor is moved forward with the bomber blip, and the fighter settles down on the course it has been given, the fighter arc will slide along the line of approach and finally reach the turning point. At this point, the fighter is turned onto the appropriate safety vector, corresponding to C or Q as the case may be.

When the fighter reaches the turning point at the inner end of the approach line C or Q, it is turned on to the bomber's course, and by the time the fighter has finished his turn, he will be at the required distance behind the bomber and on the same course.

The protractor has been designed on the assumption that speeds of bomber and fighter are equal. In practice this is rarely the case; and this is indicated when the fighter does not slide along one line. of approach, but slowly changes from one to the other. The more rapid the change, the greater the difference in speeds. These differences should be immediately compensated for by changes of vectors and speeds.

Only half of the circular inset is covered by lines of approach. This means that all fighters in the blank space should be put on the bomber's course at increased speed until they are in an area from which they may get on to a direct line of approach. Normal procedure may then be followed.

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Chapter III

CAPABILITIES AND USE of THE SCR-588

1. General - The SCR-588 is manufactured by Research Enterprises Limited at Leaside, (Toronto) Canada for use by the U.S. Army Air Forces. It is similar to the British GCI Transportable Set and closely resembles that equipment in appearance and operation. The SCR-588 is comprised of three principal units: (1) transmitter, (2) receiver, and (3) antenna. Transmitter and receiver units are usually housed in permanent installations such as shown in figure 1. The antenna array is mounted on a fixed base, usually concrete, and is mechanically rotated. Figure 4 shows the antenna array for a 588 station sited for GCI.

The other units, the diesel-driven generator and the thyratron, or antenna control unit, are, for reasons of brevity, not described here. Whenever possible, commercial power of good regulation should be used in order to save the diesel-generator for emergency operations.

2. Description - a. Receiver.

The receiver (see figure 2) houses two main racks, one containing the PPI, or Plan Position Indicator tube, and the other the H/R, or Height-Range tube. The PPI tube indicates the plan position of the target in grid coordinates. The H/R tube indicates range, number, and height of aircraft. Both tubes display IFF and serve to identify fighter planes.

These tubes are designed to work in conjunction with transmitter either as a reporting or as a GCI operating unit depending on the type of antenna installation used. For reporting a single antenna (CHL) is sited high, usually on a cliff overlooking the sea. This installation provides low angle coverage for long-range warning and low-flying aircraft, but does not enable accurate heights to be obtained. For GCI operations two pairs of antennas sited on very flat ground are used. This installation (CHB) enables accurate heights to be obtained for GCI control. (The code initials CHL and CHB are technical distinctions used to indicate how the antennas are constructed and sited.)

When operating as a reporting installation, the SCR-588 functions as an early warning detector for approaching aircraft. In this case the H/R tube is used to indicate the accurate range of any aircraft, whenever this is required, for estimating the number of aircraft producing any particular multiple signal, and for identifying aircraft by means of IFF. By means of direct phone connections, this data is phoned directly in to the area filter room.

When operating as a GCI installation, the SCR-588 is used in conjunction with a VHF system, which provides two-way voice communication between plane and ground, and functions as a control base for interceptor aircraft. For GCI use, the PPI tube determines the plan position of aircraft and identifies the fighter aircraft by manifesting IFF. The H/R tube serves the same purpose for GCI as in reporting, but in addition, it displays the ratio of signals received from two antennas at different heights and enables accurate altitudes of aircraft to be determined.

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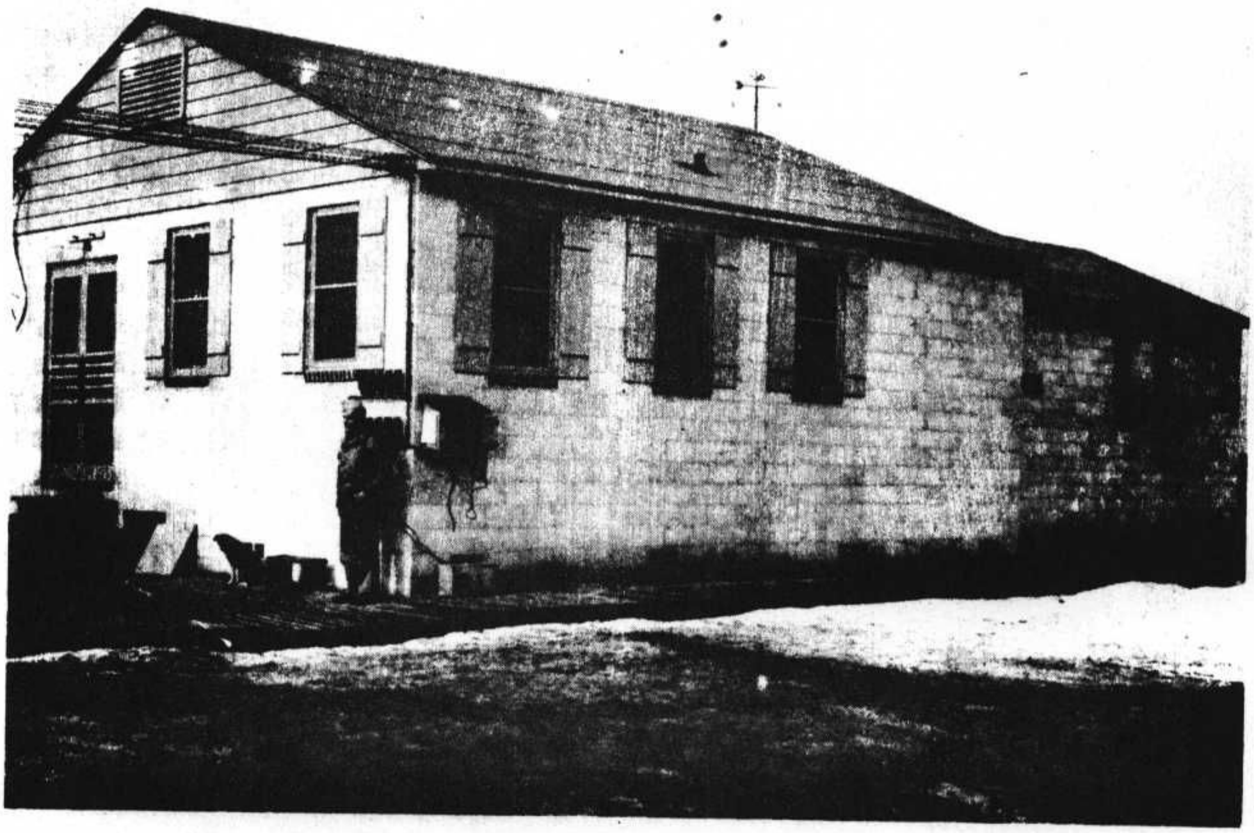

TRANSMITTER AND CONTROL ROOM
FIG. I

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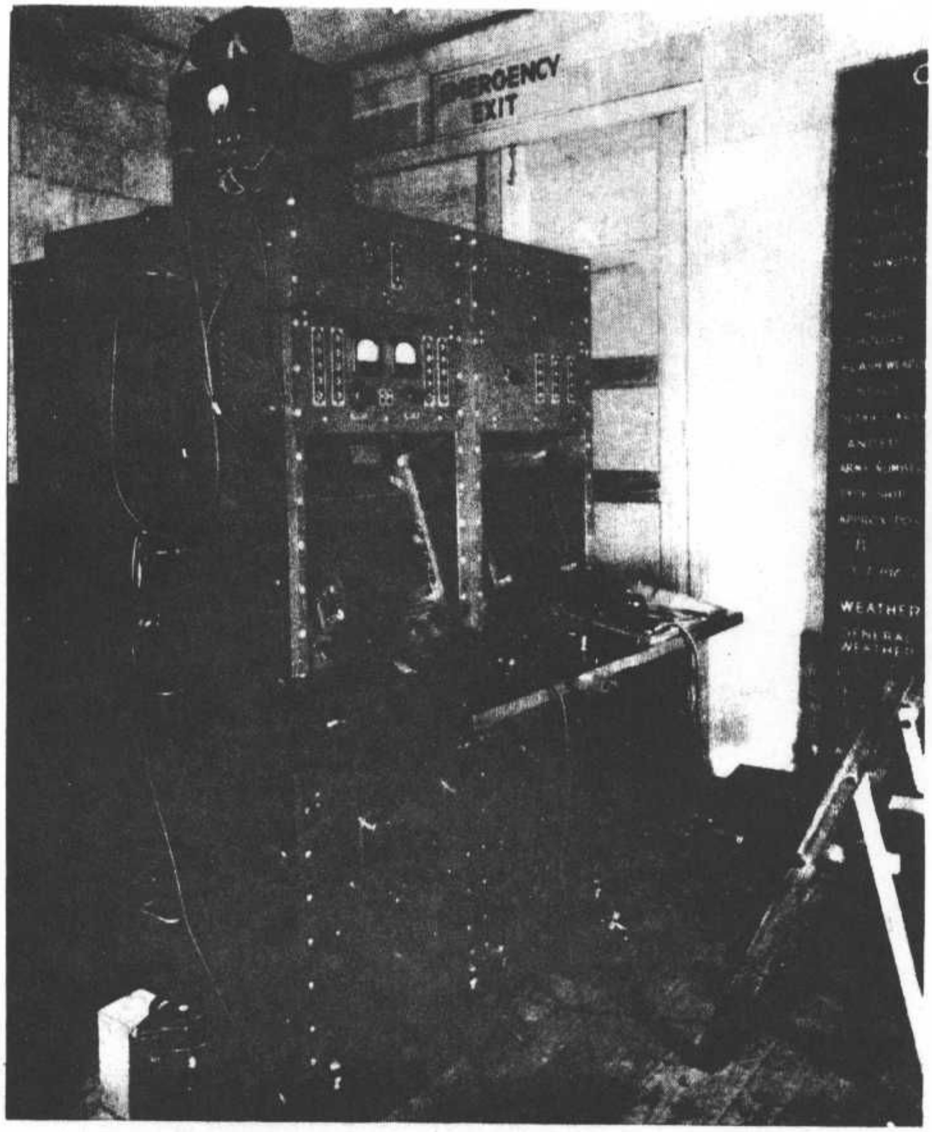

SCR — 588 RECEIVER
FIG. 2

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These signals or echoes are displayed side by side on the H/R tube so that a quick visual estimation of their ratio can be made. The ratio is always estimated in tenths, that is 10 to 7, and read from left to right. Having read the range of the echo, height calculation is possible by reference to a calibrated Height-Range chart on the desk in front of the H/R tube.

b. Transmitter.

The transmitter (see fig. 3) transmits an energy pulse for an interval of two to five microseconds, to the antenna array at a frequency of about 200 megacycles per second on a wave length of 1.5 meters (approximately 56 inches). As soon as the energy pulse transferred to the antenna array by the transmitter has been sent into space, a switching arrangement connects the receiver to the antenna and isolates the transmitter from it. The pulse, which is thrown out into space about 600 times a second in a distinct pattern of lobes, travels with the speed of light (186,000 miles per second) in the direction determined by the orientation of the array. If it should meet an object, such as an aircraft, part of the energy is reflected and part of the reflected energy is picked up by the antennas and transferred to the receiver. The time taken for the wave of energy to travel from the antenna to an object one mile distant and return is an exact interv'al of time (10:73 microseconds). Since receiver measures the elapsed time between the transmission of the pulse and reception of the echo, the distance to the object can be determined, and the direction of the object is the direction from which the antenna array picked up the maximum echo.

c. Antenna

Two antenna arrays (see fig. 4) are used for GCI operations. In addition to the 12.5-7.5 (split ten) antenna used in the British mobile set, a 25-foot antenna is provided. Because of the increased height of this antenna above the ground, the angle of displacement of the lobes above the ground is less. This permits lower angle coverage by the station and enables the detection of aircraft flying at lower altitueds.

The two antennas are placed one vertically above the other but identically oriented in azimuth. All pulses are transmitted from both antennas but two alternate echoes are received, one on the top antenna and one on the bottom. By comparison of the ratio of the two signals observed on the H/R tube, the height of the aircraft above the gound may be determined by reference to a calibrated height chart.

The upper GCI antenna array is centered on a line 25 feet above the ground. The lower array is in two sections which are centered on lines 12.5 and 7.5 feet above the ground. The center line of the entire lower array is 10 feet above the ground. A switch mounted on the H/R desk allows the choice of receiving alternately on the 25 and 10 feet arrays, or receiving alternately on the 12.5 and 7.5 feet arrays. This arrangement is useful in resolving misleading readings in height findings as will be explained in detail later on in this chapter.