Collins

WP 103

AIRBORNE WEATHER RADAR

PILOT'S HANDBOOK


Whither the way? Upward
through clouds and gray.
If man must go where gods abide,
better that he have a guide.

CONTENTS

F O R E W O R D

Collins Radio Company has long been a leader in furnishing aircraft navigation equipment of the most advanced design. Collins was one of the first in the electronic industry to recognize the requirement for navigational equipment which would assist pilots in avoiding turbulence in storm areas. Airborne Weather Radar WP-101 was introduced in 1956 to provide the required aid.

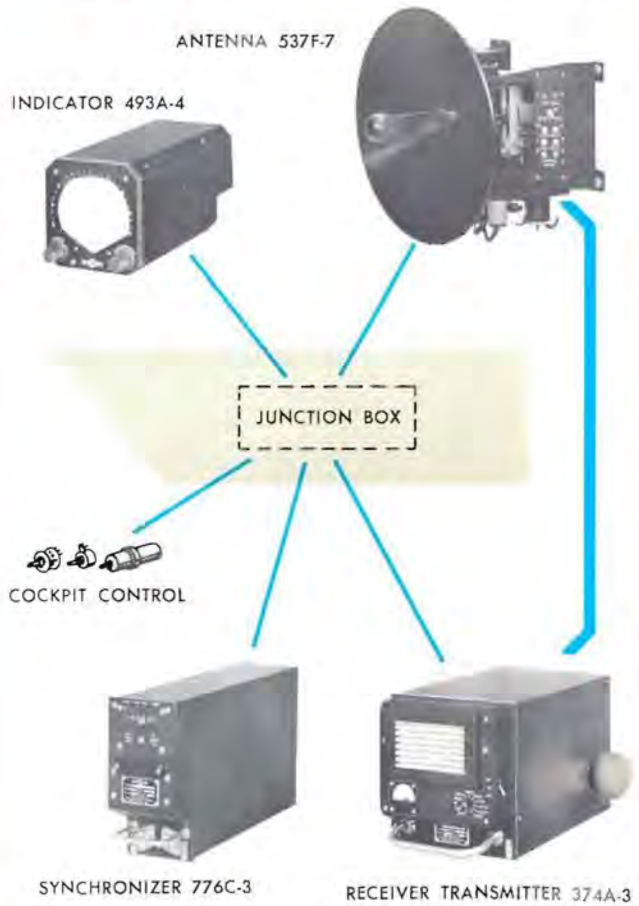
Following the introduction of the WP-101, Collins started on an extensive program to reduce the radar system size and weight, and to incorporate state-of-the-art advances which would be suitable for a radar system.

Incorporating all of the above characteristics, Airborne Weather Radar WP-103 represents a major breakthrough in lightweight airborne radar equipment. Extensively transistorized and with a minimum number of controls, this system provides the pilot with an accurate and continuous picture (weather map) of weather conditions ahead of an aircraft.

The weather map shows the location of weather fronts in terms of range and azimuth bearing relative to the position of the aircraft. It provides identification of areas potentially dangerous to flight, such as thunderheads, hailstorms, and turbulent areas associated with heavy rainfall. With this map as a guide, pilots can navigate aircraft to avoid storms or turbulent areas, usually by detours of five miles or less from the planned flight path.

The system may also be used to provide a ground map which gives a visual display of cities, rivers, lakes, shorelines, mountains, and other terrain conformations. This ground map serves as an invaluable navigational aid by effectively extending the vision of the pilot during all conditions which restrict visibility.

SYSTEM DESCRIPTION



Airborne Weather Radar WP-103 consists of a Receiver-Transmitter Unit, Synchronizer Unit, Indicator Unit, Antenna, and Cockpit Panel. This system is designed to use either Bright Tube Indicator 493A-3 or Standard Indicator 493A-4 as well as either a 12-inch, 18-inch, or 30-inch antenna. All operating controls are mounted on the cockpit panel and the indicator.

The WP-103 is a pulse-modulated radar system operating at 9375 megacycle in the X-band frequency range. The narrow beamwidth of the X-band radar provides sharp definition of targets on the indicator and results in reduced transmitter power requirements.

Short, high-powered pulses of r-f energy are radiated in a narrow beam by the antenna mounted in the nose of the aircraft. When the energy strikes an object within the 150-nautical mile range of the equipment, it is reflected back to the antenna as an echo. The reflected energy is applied to the receiver-transmitter unit where it is detected and presented to the pilot as an echo on the screen of the radar indicator unit.

The synchronizer unit generates and controls the sweep trace and range circles. It also synchronizes the scan of the sweep trace with that of the antenna, ensuring that echos are displayed at the correct range and azimuth bearing.

The sweep trace on the indicator appears as a line of light which sweeps back and forth across the screen in harmony with the scanning antenna. A portion of this beam, representing the received echo, is intensified as an indication of the range and bearing of the weather target. The cathode ray tube used in the indicator retains this weather target echo momentarily after the beam has passed, thereby producing a visual map of the area in front of the aircraft.

The 493A-4 indicator provides a conventional yellowish offset display. The 493A-3 bright tube indicator provides a brighter and longer lasting display, enabling the pilot to view the indicator in direct sunlight without the use of a hood. The 493A-3 features an adjustable Polaroid filter, permitting dimming of the presentation for night operation. The pilot can also vary the presentation from a normal yellow-green color to red for his particular viewing choice. The color change on the indicator, set by the pilot, has no effect on the accuracy or true presentation of the weather target but is incorporated in the indicator for the convenience of the pilot during night operations.

OPERATING CONTROLS

RF GAIN

Controls amplification of received echoes.

ANT TILT

Varies tilt of the antenna between the limits of 15 degrees above to 15 degrees below the horizontal reference plane.

COCKPIT CONTROL

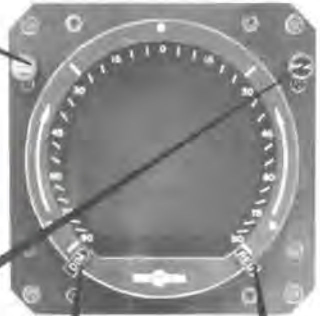
OFF-STBY-OPR-CTR

OFF	Equipment is inoperative.
STBY	Filament voltage is applied; 4-minute time delay is introduced. Holds system in warm-up condition after end of time delay period.
OPR	Equipment is operative after 4-minute time delay. In this position, NORMAL OPERATION, radar echo returns from all targets are displayed as bright spots or areas on the indicator. ISO-ECHO circuit is inoperative.
CTR	In this position, CONTOUR OPERATION, radar echo returns from areas of heavy rainfall are shown as dark areas or black holes within brighter returns which are areas of lighter rainfall. ISO-ECHO circuit is operative.

BACKGROUND

Adjusts the level of background noise (enables very weak signals to be viewed).

INDICATOR UNIT
493A-3



RANGE

30MI-10MRK	Provides a 30-mile sweep trace and three 10-mile range circles.
60MI-15MRK	Provides a 60-mile sweep trace and four 15-mile range circles.
150MI-25MRK	Provides a 150-mile sweep trace and six 25-mile range circles.

DIM TAB

Dims display for night viewing.

RED TAB

Varies display color from a normal yellow-green to deep red for night viewing.

INDICATOR UNIT
493A-4

BACKGROUND

Adjusts the level of background noise (enables very weak signals to be viewed).

OPERATING PROCEDURES

A. INITIAL CONTROL SETTINGS

Set the controls to the position shown in block before energizing equipment.

UNIT	CONTROL	POSITION
COCKPIT CONTROL	OFF-STBY-OPR-CTR	OFF
	ANT TILT	0 DEGREES
	RF GAIN	*CCW
INDICATOR UNIT	BACKGROUND	*CCW
	RANGE	150MI-25MRK

*Maximum counterclockwise position

B. STARTING THE EQUIPMENT. Turn OFF-STBY-OPR-CTR switch to OPR. There is a 4-minute delay (warmup period) before the equipment will become operative.

C. OPERATION OF INDICATOR UNIT. To obtain weather or ground-map presentations.

(1) Start equipment.
(2) Set RANGE switch in 30MI-10MRK position.
(3) Turn RF GAIN control on cockpit panel fully counterclockwise (lowest gain).
(4) Turn BACKGROUND control fully counterclockwise, then turn BACKGROUND control clockwise until sweep line is barely visible. (The sweep line is the line from the bottom center to the edge of the indicator face.)
(5) Turn RF GAIN to the maximum clockwise position.
(6) Reset BACKGROUND control until desirable background level is obtained. (A marked contrast between echo returns and the radar indicator background is desirable. Excess background will produce excess brightness on the indicator screen.)
(7) Operate RANGE switch to another position; this switching action should not affect settings.
(8) Rotate ANT TILT control to direct antenna up and down for observation of targets above and below aircraft.

D. TARGET OBSERVATIONS. To observe a particular target in detail:

(1) Vary ANT TILT control to obtain maximum target returns.
(2) Turn OFF-STBY-OPR-CTR switch to the CTR position (CONTOUR).
If the target contains heavy precipitation, which usually is accompanied by intense turbulence, a hole or "black core" will appear in the target.
(3) Compare desired target with others.
(4) Reduce the RF GAIN control until the black holes begin to disappear, and compare the desired target with other targets. The less intense targets will disappear first; targets containing violent turbulence will remain. Thus, a comparison of a particular target with others is obtainable.

RANGE AND AZIMUTH DETERMINATION

A. GENERAL. For both range and azimuth determination, bottom center of the screen represents the position of the aircraft. The 0-degree calibration on the indicator face represents the heading of the aircraft. Therefore, all echo returns displayed to the left or right of the 0-degree reference denote objects which are located to the left or right, respectively, of the aircraft.

B. RANGE DETERMINATION. To determine the distance between aircraft and targets:

(1) Note the position of echo returns which are displayed on the screen.

(2) Determine the distance between the bottom center of the screen and echo returns using the known range marks (circles). If targets are between range marks, use simple interpolation to obtain distance.

C. AZIMUTH DETERMINATION. The periphery of the indicator screen is graduated in 5-degree increments which extend 60 degrees to the left and right of the 0-degree reference mark. Determine the azimuth bearing of targets with respect to the heading of aircraft as follows:

(1) Note the position of echo return which is displayed on the screen.

(2) Note the angle between the 0-degree reference and the sweep trace as the trace passes the echo return.

(3) Determine the azimuth bearing of targets using the calibrated azimuth scale.

RADAR WEATHER OBSERVATION

A. GENERAL. The principal function of the WP-103 Airborne Weather Radar System is the detection and the presentation of weather hazards as a weather map on a radar indicator. This weather map, particularly helpful during severe weather conditions, enables a pilot to select a path which will assure a smooth, safe flight around scattered storms or even through solid lines of storms.

In order for the pilot to travel safely through thunderstorms, information regarding air turbulence, rain, hail, and icing conditions must be obtained. Such information is based upon rainfall gradients (varying rainfall densities with respect to distance) which can be displayed on a radar indicator.

Conversion of rain densities to video presentations on a radar indicator utilizes the principle that radio-energy pulses transmitted by a radar are reflected by precipitation; i. e., rain drops, hail (when covered by a thin layer of water), and wet snow (when greater than 1 mm). As the density of precipitation grows heavier, the reflection grows larger. Detection of variations in rainfall gradient is made possible by the utilization of an ISO-ECHO circuit which is controlled in the WP-103 with the OFF-STBY-OPR-CTR switch. When this switch is in the CTR (CONTOUR) position, the ISO-ECHO circuit is operative and areas of heavy rainfall are presented as dark areas or black holes within the brighter returns. The bright returns are areas of lighter precipitation.

Studies of thunderstorms indicate that violent turbulence is associated with steep rainfall gradients (where the change from no rain to heavy rain occurs in the shortest distance).

NORMAL

CONTOUR

Steep gradients are displayed on the radar indicator as relatively large cores surrounded by a narrow ring of bright returns. Conversely, if cores are not displayed or if they appear as small centers surrounded by a wide ring of returns, relatively little turbulence exists. The inner and outer edges of the bright returns surrounding the black areas are two contours approximating rainfall rate.

When entering a storm area, the pilot should enter and pass through areas where no cores are displayed or where core separation is greatest. It is more important to avoid regions which display narrow contour separation than to avoid areas of heavy rainfall which, in themselves, may not be dangerous to flights. In most instances, a thunderstorm may look to a pilot like a single storm cell; however, a large thunderstorm cloud may contain a collection of many individual storm cells in varying intensities; i.e., from the initial stage through the most violent stage and to the dissipating stage. Thus, the pilot should rely on the radar presentation to determine the storm conditions of a storm mass.

Studies have indicated that the average life of a storm cell in a thunderstorm cloud is approximately 1½ hours. Since a thunderstorm will usually have more than one storm cell, characteristics of the storm are changing constantly. Therefore, the pilot when approaching a storm should make his own decision. A flight 30 minutes ahead would have encountered completely different conditions than the pilot will encounter when he is entering the thunderstorm area.

Hail in a thunderstorm is associated with either strong updrafts and downdrafts, or is pushed upward and outward from the cell of the thunderstorm. Damaging hail and turbulence are usually indicated on the radar as fingers, hooked fingers, scalloped edges, or U-shaped projections extending from areas of intense echoes. Experience has shown that these presentations are due to hail fallout. Avoid these projections; they are dangerous. Also, avoid flights beneath the overhang of a thunderstorm. The overhang of a thunderstorm may be a hail-shaft formation.

In summary, when entering a thunderstorm area, the pilot should fly the aircraft around these storms by avoiding areas which produce intense, bright returns. If penetration of a storm area is necessary, the pilot should enter and pass through areas where no cores are displayed or where separation between cores is the greatest. If, for example, the radar indicator has a display of two large black holes separated by a narrow strip of bright returns, the narrow bright strip usually denotes an extremely turbulent area which

must be avoided. If a wide area of light or fuzzy returns separates the black holes, turbulence in this area is generally mild. The aircraft can be flown through these light or fuzzy returns, midway between the black holes, with relatively little difficulty, providing sufficient separation is indicated.

B. OPERATING PROCEDURES. The operating procedures for weather interpretation are as follows:

(1) Start equipment and obtain the initial screen presentation as described previously.

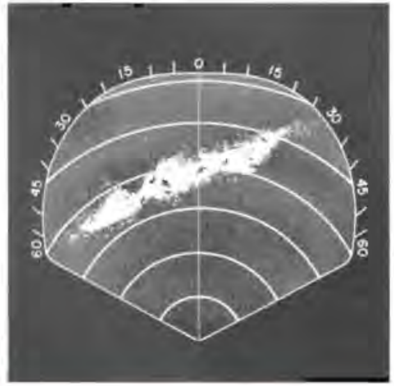
(2) Adjust ANT TILT control up or down as necessary to obtain the desired radar indicator presentation.
NOTE: Adjust antenna tilt position in small increments; allow sufficient time between adjustments for presentation to develop. Use the storm areas above and below the rainfall areas.

(3) Turn OFF-STBY-OPR-CTR switch to CTR position. Check whether heavy rainfall areas (dark holes within bright returns) are apparent.

(4) Reduce the RF GAIN control until dark holes begin to disappear. The less intense targets will disappear first; targets containing greater turbulence will remain.

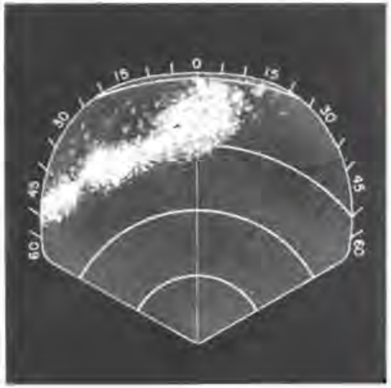
(5) Operate RANGE switch to position which provides most current navigational information.

C. RADAR WEATHER INTERPRETATION. *The following illustrations are photographs of radar indicator displays showing the buildup of a weather front.*



Initial detection of the weather front is made with the RANGE switch in the 150MI-25MRK position and the OFF-STBY-OPR-CTR switch (master switch) in the CTR position.

The front extends in azimuth from 30 degrees right to 60 degrees left of the 0-degree reference. Dark areas within the bright returns denote the presence of rainfall in the weather front. The echoes are very intense and sharp-edged, indicating turbulent areas.

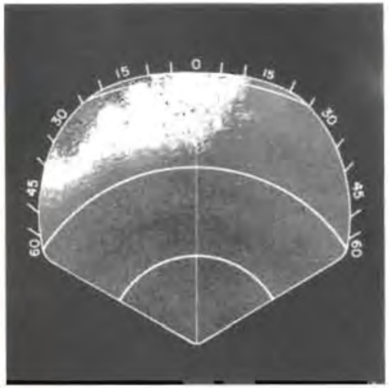


The range switch is now in the 60MI-15MRK position; the master switch is in the OPR position. The closest portion of the front is displayed approximately 30 degrees left of the 0-degree reference at the distance of approximately 40 nautical miles.

The extent in azimuth of an active, turbulent storm is shown in this display; however, no information relative to areas of heavy turbulence or rainfall gradients is obtainable. An aircraft may be flown around this front by avoiding areas of intense echoes.

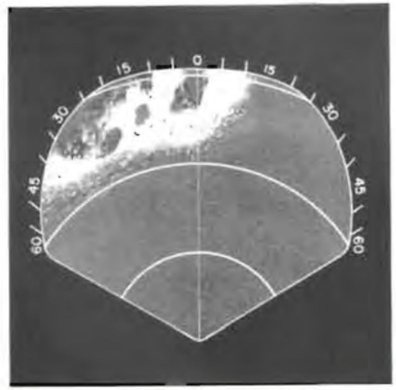
The range switch is still in the 60MI-15MRK position; however, the master switch is now in the CTR position. This display shows areas of heavy turbulence. An area of heavy rainfall is displayed at 0 degrees/35 nautical miles. Smaller areas of light rainfall are shown at 15 degrees left of the 0-degree reference and 35 degrees left of the 0-degree reference at a range of approximately 30 nautical miles.

The rapid change from bright to dark at the 0-degree reference position indicates extreme turbulence in the area around the contour of the black hole. The rain gradients at 15 degrees left of center are not steep; turbulence may exist at this position, but it is not as extreme as at the 0-degree position.



The RANGE switch is now in the 30MI-10MRK position and the master switch in the OPR position. The bright, intense echoes indicate active turbulent areas. No information is presented, however, relative to areas of rainfall and degree of turbulence.

The closest portion of the front has advanced to approximately 5 degrees left of the 0-degree reference and is approximately 23 nautical miles from the aircraft. Switching to the 30MI-10MRK position expands the immediate information over a larger portion of the radar indicator, allowing detailed analysis.

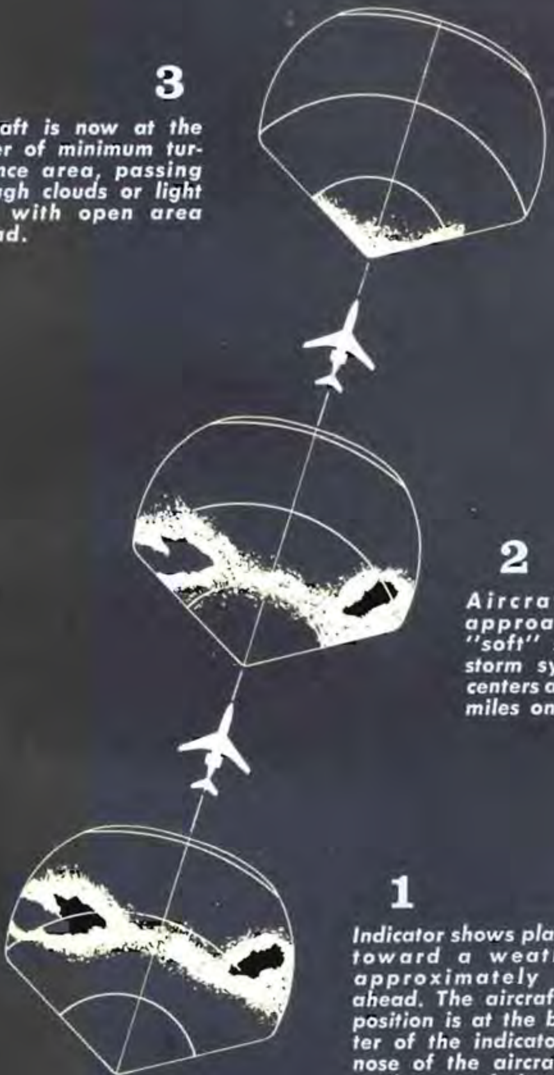


The RANGE switch is still in the 30MI-10MRK position; however, the master switch is now in the CTR position.

Heavy rainfall is denoted by the black areas within the bright returns at 0-degree reference at a distance of 25 miles, 15 degrees left at 22 miles, and 25 degrees left at 22 miles.

Extreme turbulence exists in the areas surrounding the contour of the black holes at 0 degrees, 15 degrees, and 25 degrees. These areas should be avoided.

Aircraft should try to go around this portion of the storm.



3

Aircraft is now at the center of minimum turbulence area, passing through clouds or light rain with open area ahead.

2

Aircraft is now approaching the "soft" spot of the storm system. Rain centers are 12 and 13 miles on each side.

1

Indicator shows plane is fly[ing] toward a weather front approximately 13 miles ahead. The aircraft's relative position is at the bottom center of the indicator with the nose of the aircraft pointing to the top of the instrument.

The accompanying illustrations show the path of an aircraft through a storm front. The portion of the front extends in azimuth from 35 degrees right to 50 degrees left of the 0-degree reference.

A light, fuzzy (or wispy) return is indicated on the radar between 15 degrees right to 10 degrees left of the 0-degree reference. Since rainfall gradient changes are very gradual in this area, little turbulence exists. This area may be penetrated safely. The pilot may also elect to fly the aircraft around the storm. The illustrated course of the aircraft will permit avoidance of the two areas of heavy rainfall and associated turbulence located at 25 degrees right and left of the 0-degree reference.

D. SUMMARY. *The following assumptions generally hold true:*

(1) Areas of extreme turbulence exist where rainfall gradients are highest.

(2) Turbulence is highest where a narrow ring of bright returns surrounds the contour of the black holes.

(3) Aircraft should enter weather front preferably where no dark holes are displayed.

(4) Aircraft should enter weather front where the widest separation of dark holes is displayed.

(5) Aircraft should be navigated to avoid the areas of contour "squeeze"; i.e., where the contour is squeezed to only a narrow, bright ring surrounding the center of rainfall. Areas of heavy rainfall need not be avoided where a wide contour ring of light, wispy return surrounds the area of maximum precipitation.

(6) The aircraft should be navigated to avoid areas of contour "squeeze" when leaving the weather front.

GROUND MAPPING

A. GENERAL. A secondary function of the WP-103 is the presentation on the radar indicator of a ground map which shows the location of cities, lakes, rivers, mountains, and shorelines. When the OFF-STBY-OPR-CTR switch is in the OPR position and the antenna is tilted below the horizontal reference (0 degrees), a circular segment of the terrain in front of the aircraft is scanned with each sweep of the antenna. This area of scan is similar to that which would be illuminated by a narrow beam of light from a flashlight which is elevated, tilted downward, and rotated about a vertical axis. As the aircraft flies over the terrain, succeeding circular segments are scanned and displayed as a ground map on the indicator screen.

The width of the segments varies with altitude and the tilt of the antenna. A wider segment is scanned as the altitude of the aircraft increases or as the antenna tilt decreases. For instance, at an altitude of 20,000 feet and an antenna tilt of 10 degrees down, a circular segment approximately 15 nautical miles wide is scanned with a 12-inch antenna. A segment of approximately 10 nautical miles is scanned when the aircraft has an 18-inch antenna. If the altitude increases to 30,000 feet, a segment 22 miles wide is scanned with a 12-inch antenna or 15 miles wide with an 18-inch antenna. The ground-map display is similar to an ordinary pilotage chart and can be interpreted easily. Cities are characterized by the intense echoes, ground by lighter echoes, and lakes and rivers by echoes of the least intensity. Ground-mapping is especially valuable during darkness and other conditions which restrict visibility. It should be noted that the scanned areas are displayed in range with respect to the position of the aircraft and in azimuth relative to the aircraft heading.

B. OPERATING PROCEDURES. Procedures for obtaining a ground-map presentation are as follows:

(1) Operate OFF-STBY-OPR-CTR switch to OPR position.

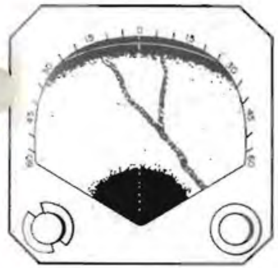
(2) Adjust ANT TILT control to obtain desired area scan.

(3) Operate RANGE switch to desired range.

(4) Turn RF GAIN control fully clockwise.

(5) Turn RF GAIN control slowly counterclockwise until cities can be differentiated from surrounding terrain.

(6) To obtain the correct contrast to permit mapping of terrain and rivers or bodies of water, the RF GAIN control should be turned farther counterclockwise. Bodies of water will be presented as shaded strips.



C

C. GROUND-MAP INTERPRETATION. An aircraft flying over terrain which includes a river is shown in the accompanying illustration diagrams A, B, and C. These diagrams show the terrain as scanned by the radar beam. The aircraft is flying at an altitude of approximately 10,000 feet with an antenna tilt of 6 degrees below the horizontal plane. A segment of terrain approximately 19 miles wide is scanned by the radar system.

B

Each diagram includes a ground-map presentation which displays the areas scanned at each position of the aircraft. Successive, instantaneous aircraft positions are designated by P1, P2, and P3.

One section of the river is scanned and displayed in diagrams A and B. The fork of the river is scanned and displayed in diagram C. The river fork in the map display of diagram C, in conjunction with a pilotage chart, clearly fixes the position of the aircraft.

A

In all diagrams, the scanned river areas are displayed as shaded strips within the brighter return from the surrounding terrain.

DEFINITIONS

Rainfall Gradient
Variation of rate of rainfall with distance.

Target
Weather front or terrain from which radar energy is reflected.

Echo (or echo return)
Reflected energy (from targets) which appears as a bright spot or area on the screen of the indicator unit.

Sweep Trace
A bright radial line which extends from bottom center to the outer periphery of the indicator screen.

Range Circles
Calibrated concentric circles on the indicator screen from which distances between aircraft and targets can be determined.

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