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STUDENT STUDY GUIDE

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RESPONSIBLE AGENCY OF ATC

DESIGNED FOR ATC COURSE USE ONLY

ABOUT STUDENT STUDY GUIDES AND STUDENT WORKBOOKS

Student study guides and student workbooks are designed by the Air Training Command as student training publications for use in training situations peculiar to courses of this command. Each is prepared for the particular learning objective (s) of the plan of instruction.

The **STUDENT STUDY GUIDE** *contains the specific information required in the learning objectives(s) or it will refer to other publications which the student is required to read. It contains the necessary information which is not suitable for student study in other available sources. The material included or referred to is normally studied either outside the classroom or during supervised study periods in the classroom. Also included are thought-provoking questions which permit self-evaluation by the student and which will stimulate classroom discussion.*

The **STUDENT WORKBOOK** *contains the specialized job procedures, important information about the job, questions to be answered, problems to be solved and/or work to be accomplished by the student during the classroom/laboratory, airplane/missile/equipment activity. It serves as a job sheet, operations sheet, mission card, check list or exercise to be performed during classroom or laboratory periods. Also included are questions which will aid the student in summarizing the main points of the learning objective(s).*

The **STUDENT STUDY GUIDE AND WORKBOOK** *is a training publication which contains both student study guide and student workbook material under one cover.*

Since this publication is DESIGNED FOR ATC COURSE USE ONLY and must not conflict with the information and/or procedures currently contained in Technical Orders or other official directives, it is updated frequently to keep abreast of changes in qualitative training requirements. Students who are authorized to retain this publication after graduation are cautioned not to use it in preference to Technical Orders or other authoritative documents.

AIRBORNE WEATHER RADAR SYSTEM AN/APN 158

Since man began flying airplanes, he has learned that weather respects no person. For several decades he has had to contend with this unexpected, unforgiving, life-stealing hazard that has been named WEATHER.

In order for the pilot to travel safely through this hazard called weather, information regarding air turbulence , rain, hail and icing conditions must be obtained. To assist the pilot in obtaining that vital information at a moments notice, the pilot has available at his finger tips the Airborne Weather Radar System AN/APN-158. As pilots of the CV-2 (Caribou) your life may depend on how well you operate this system and on how much you know it can do for you during that IFR flight.

During the next two periods we will cover:

1. Radar Description
2. Operational Features
3. Operational Controls' Functions
4. Radar Weather Observation
5. Procedures for Preflight and Inflight Operations
6. Ground-Mapping Capability
7. Things to Consider

A practical exercise will be conducted during the second period.

The Airborne Weather Radar System AN/APN-158 (MP-103-) ultra lightweight (64.5 lbs.), extensively transistorized, airborne, radar system to present the pilot with an accurate and continuous picture of weather conditions 150 nautical miles ahead of the aircraft in a 120 degree sweep. The avoidance of storms, turbulance, and hail affords the pilot and his

(*) Civilian Nomenclature

aircraft a greater all-weather capability. Ground mapping radar techniques increase the aviator's ability to navigate under tactical conditions and to locate specially marked areas.

Extensive use of transistors, simplified modular card construction and printed circuitry reduce maintenance requirements of this lightweight system.

The radar consists of the following items:

1. Receiver-transmitter, 374A-3
2. Synchronizer type 776C-3
3. Indicator unit (Bright Tube), 493A-3
4. Antenna (18"), 537F-8
5. and Cockpit control kit type 561G-3.

All operating controls are mounted on the cockpit control kit panel and the indicator.

The WP-103 is a pulse-modulated radar system operation in the X-band frequency range of 9375 mc. The narrow beam width of the X-band radar (4.9 degree) provides a sharp definition of targets on the indicator and results in reduced transmitter power requirements.

The short, high-powered pulse of RF energy (20 kw) is radiated by the transmitter portion of the Receiver/Transmitter Unit, 374A-3 through the antenna mounted in the nose of the aircraft. The echoes, or returned signals, of the transmitted pulse are reflected back to the antenna, applied to the receiver portion of the receiver/ transmitter unit where these signals are detected and presented to the pilot as an echo on the screen of the indicator. The receiver/transmitter emplys forced air ventilation and exhausts it through the base of the unit. The 374A-3 weighs 26.6 lbs. Both the synchranizer unit 776C-3 receiver/transmitter feature functionally separable portions of the circuitry constructed on module plug-in cards. Deflection sweep currents and range circle signals for the indicator are generated by circuitry contained in the synchronizer unit. The snychronizer also contains servo amplifier circuitry to stabilize the antenna and prevent disruption of the target display caused by roll and pitch motion of the aircraft. The synchronizer is suitable for attended operation remotely controlled from the aircraft cockpit and is designed for continuous duty.

The Bright Tube Indicator 493A-3 eliminates the need for a cumbersome radar scope hood in the cockpit and presents a weather map of the general sky area. The weather map, displayed as a visual presentation on the screen of the radar indicator unit, shows the location of rain formations in terms of distance and azimuth with respect to the aircraft and provides identification of potentially dangerous areas, thunderheads and hailstorms. With the indicator mounted in the aircraft's instrument panel the presentation can be read during the instrument cross check by either the pilot or the co-pilot.

A modified Plan Position Indicator (PPI) with an off-center sweep display shows both range and azimuth information. The pattern on the indicator appears as a line oflight which sweeps back andforth across the screen in harmony with the scanning antenna in the nose. 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 indicator is panel mounted and requires no shockmountings. Range marks are calibrated in nautical miles and presented in 30 mile range with marks 10 miles apart; 60 mile range with marks 15 miles apart, and 150 mile range with marks 25 miles apart. Full range sweep deflection is 3". All indicator controls are located on the front panel face.

The Stabilized WP-103 system uses an 18" parabolic dish type, Antenna 537F-8, which is mounted on the forward bulkhead of the aircraft and can be accommodated with negligible nose configuration changes on the majority of aircraft. The antenna, which weighs a total of 7.8 lbs., transmits pulses of RF energy and receives the return target signals. A servo motor (Antenna stabilization system) utilizes the output of the aircraft's vertical gyro and automatically tilts the antenna to within its maximum limits to maintain its assigned elevation by compensating for the pitch and roll of the aircraft. This presents an accurate and steady picture of the weather ahead. The antenna scans 60 degrees off-center for a total presentation of 120 degrees on the indicator at the rate of 60 scans per minute. The manual tilt control permits a 15 degree downward tilt with a controllable accuracy of plus or minus 1 degree.

The Cockpit Control Kit 561G-3 mounts directly into the sliding control console. The three controls provided in the kit include: power control switch (OFF-STBY-OPR-CTR), Antenna Tilt (plus to minus 15 degrees), and RF GAIN. The radar inverter supplies 115 volt 3 phase 400 cps power.

OPERATIONAL FEATURES

BRIGHT TUBE INDICATOR -Permits daylight operation without the use of a scope hood. Weather formations may be more easily distinguished in high background light levels. The indicator offered as an optional item features a polaroid filter permitting dimming for night operation.

LIGHTWEIGHT - Composed of five basic units, the system weighs only 64.5 lbs.

LOW POWER REQUIREMENTS - Extensively transistorized, the WP-103 requires 320 watts ac.

EASE OF MAINTENANCE - Modular card circuitry, accessible test points and improved design provide maximum serviceability and convenience.

X-BAND - Greater target resolution and better definition ofstorm cells at lower transmitter output result.

STABILIZED ANTENNA - The 537F Series antenna is line-of-sight stabilized to compensate for pitch and roll of the aircraft permitting the pilot to make a more accurate study of the weather target.

ISO-ECHO CONTOUR - Switched to the contour position, the system reveals areas of heavy precipitation as dark areas on the indicator pointing out to the pilot severe storm cells which should be avoided.

RELIABLE - Minimum heat dissipation and effective thermal engineering provide maximum reliability. Use of fixed deflection yoke means no moving parts in the standard or bright tube indicators.

COMPACT - Weight saving units combined into smaller packages require less room in the aircraft. The 12" or 18" antenna can be accommodated with negligible nose configuration changes on the majority of aircraft.

OPERATING CONTROLS

COCKPIT CONTROL

1. RF Gain - controls amplification of received echoes.
2. ANT TILT - varies tilt of the antenna between the limits of 15 degrees above to 15 degrees below the horizontal reference plane.

3. POWER CONTROL SWITCH

a. OFF - equipment is inoperative

b. STBY - filament voltage is applied; 4-minute time delay is introduced. Hold system in warm-up condition after end of time delay period.

c. 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.

d. 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. This is due to the ISO-ECHO circuit being operative.

RADAR INVERTER ON-OFF SWITCH - primary switch to supply necessary power for for the operation of radar equipment.

INDICATOR UNIT

1. BACKGROUND - adjusts controls between the echo return and screen background. Adjusts the level of background noise (enables very weak signals to be viewed).

2. DIM TAB - dims display for night viewing.

3. RED TAB - varies display color from a normal yellow-green to deep red for night viewing.

4. RANGE - selects range of operation and correspondence range marks.

a. 30 MI/10MRK — Provides a 30-mile sweep trace and three 10-mile range circles.

b. 60MI/15MRK -- Provides a 60-mile sweep trace and four 15-mile range circles.

c. 150MI/25MRK -- Provides a 150-mile sweep trace and six 25-mile range circles.

RANGE AND AZIMUTH DETERMINATION

RANGE - 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 (represents aircraft) and echo returns using the known range marks (circles). If targets are between range marks, use simple interpolation to obtain distance.

Azimuth - The periphery of the indicator screen is graduated in 5-degree increments which extend 60 degrees to theleft and right of the 0-degree reference mark (represents aircraft heading). Determine the azimuth bearing of targets with respect to the heading of aircrafts 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

The principal function of the 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 pa th 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. When switch is in the CTR (Contour) position, areas of heavy rainfall are presented as dark areas or black holes within the brighter returns. The bright returns areareas 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 ahortest distance).

Steep gradients are displayed on the radar indicator as relatively large cores surrounded by a narrow righ 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 1 1/2 hours. Since a thunderstorm will usually have more than one storm cell, the characteristics of the storm are changing constantly. Therefore, thepilot when approaching a storm should make his own ecision. 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 overhand of a thunderstorm. The overhang of a thunderstorm may be a hail-shaft formation.

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.

ABBREVIATED PREFLIGHT CHECKOUT OF AN/APN-158

1. Turn the system control switch to STBY (Standby) for 4-minute warmup.
2. While awaiting the end of the four-minute time delay, check the following:
   a. RF GAIN control fully counter-clockwise.
   b. ANT TILT control at zero degrees.
   c. RANGE switch on 30-mile range/10MARK.
   d. BACKGROUND control set fully counter-clockwise.
3. At the conclusion of the four-minute time delay, the radar should operate.

Check to see no person, aircraft, or metal object is within 50 inches in front of the radar. Turn control switch to OPR and adjust the background control until a marked contrast is noted between echo returns and the radar indicator background. Excess background will produce excess brightness on the indicator screen. Some nearby ground targets should be visible on the screen, and three range marks should be displayed.

4. Check the operation of the receiver gain control by slowly turning the control clockwise. The targets on the screen should gradually increase in brightness until targets appear well defined.
5. Check the operation of the manual elevation control by rotating the control up and down from the zero setting. Ground targets should disappear as the control is varied from zero. Reset the control for maximum targets on the indicator, generally 1-2 degrees above zero.
6. Adjust Red and Dim control level as desired for daylight and night operations.
7. Check operation on the 60- and 150-mile ranges by switching to those ranges and observing that operation is normal with four range marks on the 60-mile range and six range marks on the 150-mile range.
8. Switch the system control switch to STBY, if flight will be conducted under VFR, OPR, if flight will be conducted under IFR.
9. During landing roll turn control switch to STBY or OFF position.

INFLIGHT PROCEDURES

1. If control switch is in STBY position, move switch to OPR POSITION.

2. Adjust ANT TILT control up or down as necessary to ob tain 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. Adjust RF GAIN and BACKGROUND control as desired.
4. Turn power control switch to CTR position. Check whether heavy rainfall areas (dark holes within bright returns) are apparend.
5. Reduce the RF GAIN control until dark holes begin to disappear. The less intense targets will disappear first; targets containing greater turbulence will remain.
6. Operate RANGE switch to position which provides most current navigational information.

GROUND MAPPING

A secondary function of the WP-103 is the presentation of the radar indicator of a ground map which shows the location of cities, lakes, rivers, mountains, and shorelines. When the power control switch is in the OPR position and the atenna 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 (topographical) 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. 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.

P rocedures for obtaining a ground-map presentation are as follows:

1. Operated control switch to CPR position.
2. Adjust ANT TILT control to obtain desired area scan.
3. Operated 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.

THINGS TO CONSIDER

1. Radio frequency energy having a high power density can have harmful effects on the human body. Personnel should never stand directly in front of the antenna or radome when the transmitter is operating. For the AN/APN-158 the recommended safe distance is 18 feet for the 18-inch antenna. Infrequent accidental exposure at somewhat closer distances should not be harmful.

2. Operation of the AN/APN-158 near combustible materials should present no problem if they are kept at least 18 feet away for the 18-inch antenna when they are directly in front of the antenna.

3. DO NOT OPERATE in hanger or within 50 feet radius of any metal object — damage will result to receiver crystals due to 20 kilowatt peak power output.

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