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MANUAL OF

RADAR METEOROLOGICAL OBSERVATIONS

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MANUAL OF RADAR METEOROLOGICAL OBSERVATIONS

1000. INTRODUCTION

1001. General.--Radar (radio direction and ranging) equipment consists essentially of a radio transmitter that emits pulses of radio energy in a directed beam, a radio receiver, and an oscilloscope. The receiver picks up the pulses of energy that are reflected by "targets" (including meteorological phenomena) in the path of the beam. The received pulses are presented in patterns on the oscilloscope (termed "scope" in these instructions). The search for targets is termed "scanning". The reflected energy as presented on the scope is termed an "echo". For meteorological purposes, echoes from targets of nonmeteorological origin are termed "extraneous echoes". Echoes from meteorological phenomena are evaluated in terms of echo patterns and area coverage, intensity, tendency of intensity, direction and distance from the station, location, width, direction and speed of movement, and altitude. These data are entered upon forms and coded in the abbreviated plain language RAREP code.

1002. Types of Radar.--The types of radar generally used for meteorological search employ wave lengths of from about 3 cm. to 23 cm., corresponding to radio frequencies of about 10,000 mcs. and 1300 mcs., respectively. Limitations of the equipment must be taken into account when evaluating or using radar data. For example, the presence or absence of echoes, and their shape and size are dependent upon the characteristics of the radar equipment used, as well as the prevailing meteorological conditions.

1003. Anomalous Propagation.--When temperature or moisture inversions in the atmosphere prevail, the radar beam may be bent from its normal line of propagation. When the conditions are such as to bend the beam toward the earth's surface (commonly called "ducting" or "trapping"), echoes (especially extraneous echoes) may be received from targets that are below the normal horizon of the equipment. This condition is termed "anomalous propagation". The "duct" may be formed at the surface or aloft, depending upon the prevailing temperature and moisture conditions.

1004. Blocking.--An object near the radar that is high enough to intercept the radar beam constitutes an obstruction to the beam. If the beam is obstructed to a substantial extent, the obstruction is apparent on the radar scope as a "blind" sector in which echoes of objects more distant than the obstruction are usually not seen.

1005. False-Azimuth Echoes.--If the radar is situated close to an obstruction, particularly one presenting a large, flat reflecting surface to the radar antenna, the transmitted and returned energy may be "bounced" from the obstruction to a precipitation area. Such echoes are sometimes termed "back echo reflections". In this case the precipitation echo may also be indicated on the PPI scope at the azimuth of the obstruction at a range that represents the total path length of an outgoing radar pulse. Such precipitation echoes are characterized on the PPI scope by radial alignment of the echoes, compressed in azimuth.

1006. False-Distance Echoes.--If the pulse repetition rate of the radar is such that one radar pulse has not time to make the round trip to the target before the succeeding pulse is emitted, the echo may be displayed on the PPI or A-scope at a false range. Such echoes are sometimes termed "second trip" echoes. In this case the true range is equal to the maximum range at the range setting used, plus the indicated range. False-distance echoes may be distinguished by changing the radar to a lower pulse repetition rate (often interconnected with the control that increases the pulse duration). In this case, the false-distance echoes will disappear.

*1007. Extraneous Echoes.--Extraneous echoes are those returned from permanent obstructions (ground return), such as mountains, hills, buildings, or even smaller local obstructions, or from temporary obstructions, such as waves (i.e., sea return), or ships. Such echoes often increase in number or area under conditions favorable for "trapping". Echoes may be received from chaff (metallic particles which reflect the radar pulse) released from aircraft or rockets (see Fig. 6).

1008. Resolution.--The resolution of a radar set is defined as the ability of the radar to differentiate between targets. The azimuth resolution is a function of the width of the radar beam; the range resolution is a function of the pulse length.

1008.1. Azimuth Resolution.--A 10 cm. radar set with a 27-inch antenna has a beam width of about 9°; the same type of radar with a 6-foot antenna has a beam width of about 3-1/2 degrees. With the former type of antenna the azimuth resolution is such that at a range of fifty miles the radar can discriminate between two targets only if they are more than about eight miles apart; with the latter antenna the radar can discriminate between them at fifty miles range if they are more than three miles apart. Discrimination of echo details improves with decreasing range. This is especially apparent with decreasing range especially when lines or groups of echoes approach or recede from the station; the echo patterns appear less solid and more detailed as the range becomes shorter.

1008.2. Range Resolution.--With the radar operating on a pulse length of one microsecond, the equipment can discriminate between two targets if they are more than 492 feet apart in range; on a pulse length of two microseconds, discrimination occurs only when the targets are more than 984 feet apart in range.

1009. Distortion of Echo Pattern.--The effect of the finite beam width of the radar is to distort the shape of the echoes (extend them in azimuth). This effect tends to make small precipitation areas appear to be elliptical, and tends to make lines and groups of echoes appear more solid than they really are. (See ¶1008.1.) The effect of the finite pulse length of the radar is to distort the shape of the echoes in range. This effect is usually so small as to pass unnoticed. (See ¶1008.2.)

1010. Echo Evaluation.--Through the proper evaluation of radar scope patterns, certain forms of precipitation and lithometeors may be detected. However, the absence of echoes will not justify the inference that precipitation is not occurring. For example, water on the radar dome from local precipitation may exclude echoes of more distant precipitation areas, especially where 3 cm. radar is used. Also the size, number, and nature of precipitation particles may not be such as to present a satisfactory target.

1020. Scope Photography and Sketches.--Instructions for scope photography and sketches are contained in this section.

* 1020.1. As a general rule, the radar range should be set at 100 nautical miles for thunderstorm photography. An exception to this will be made when there is a tornado reported within range of the radar, in which case the radar range control will be adjusted to the shortest range that will encompass the tornado. The radar range should be set at 180 or 200 nautical miles (depending on the radar or repeater used) for hurricane photography. This range setting will be used for photographing all echoes associated with a hurricane regardless of the

proximity of the eye to the station. The foregoing does not preclude momentary operation of the basic radar set on a shorter range for routine observations, or for height finding, but these interruptions should be kept to a minimum.

* 1020.2. If a VD-2 repeater is used for photography and if circumstances are such that the radar can be operated satisfactorily on short pulse, but not on long, it will be operated on short pulse. If photographs are being taken of hurricane phenomena under this circumstance, the range on the VD-2 repeater should be set at 200 nautical miles, and the sweep length adjusted so as to place the wide echo ring caused by the "second pulse" just off the edge of the scope if possible (or as close to the edge of the scope as possible). This will provide for photography to slightly more than 100 nautical miles.

* 1020.3. If the radar is operated at less than full gain, a note as to the gain setting used should be entered in the "Remarks" column of Form 610-3.

* 1020.4 Whenever a tornado is known to have occurred within the range of the radar while the scope was being photographed, the fact should be reported by letter to the Central Office, attention R-3.41, with a copy to the Radar Analysis and Development Unit (RADU), Kansas City, Mo. Notification of photography of a hurricane should be made by letter to the National Hurricane Research Project at West Palm Beach, Florida, with a copy to the RADU. The exact location and time of occurrence of the tornado or hurricane should be specified, together with the period of camera operation.

* 1021. <u>Time-Lapse Photography.</u>--Where the radar is equipped with a time-lapse movie camera, photographs will be taken at a rate of about two per minute. The switch on the camera control box and the antenna rotation rate will be adjusted so as to yield this rate of picture taking, if possible. If this exact exposure rate is not possible, a rate of antenna rotation and picture taking will be selected to approach it as closely as possible. In any case, pictures should be taken at uniform intervals. A lens aperture of f5.6 will be used initially (see ¶1026.1). The camera will be operated continuously whenever echoes that derive from precipitation are visible on the radar scope, except that the photography will be interrupted as necessary for routine radar observations. The interruptions should be kept to a minimum. Notations will be made in the "Remarks" column of Form 610-3 of the time the camera is turned on and off and of the beginning and end of periods when

the radar was out of operation for maintenance or because of breakdown.

*1021.1. It is extremely important that identification data be kept current on the data plate, and that the clock be kept wound and on time. The following data will be entered on the data plate with 3-H black pencil:

Three-letter Station Identifier
Date (LST)
AM or PM (if clock is not 24-hour)
RBM (range in nautical miles between markers)
Elevation of Antenna
Camera f-stop

* 1021.2. At the time the film is installed in the camera, the name of the station, the year and serial number of the film will be scratched on the shiny side of the film with a sharp instrument (for example, "ACF 56/3" to indicate that this is the third film in calendar year 1956 from Fort Worth). Similar identification as appropriate, will be scratched on the trailing end of the film when it is removed. Entries will be made in the "Remarks" column of Form 610-3 of the serial number of the films when they are installed.

* 1022. Polaroid Oscilloscope Photography.--At stations equipped with a Polaroid oscilloscope camera, photographs should be taken of any important or unusual echo formations and at a frequency that will illustrate any growth or development of severe weather situations. The exposure will be made with the shutter control in the "bulb" position. Some experimentation may be necessary to obtain the correct exposure, but the following is suggested as an initial guide (see ¶1026.1). If the antenna can be adjusted to rotate at 4 RPM, set the lens aperture at f5.6 and hold the shutter open, with the cable release, for one revolution of the antenna. If the antenna can only be rotated at 12 RPM, the aperture opening must be increased and the shutter held open for more than one revolution of the antenna. At this faster rotation speed, two or even three revolutions of the antenna may be necessary to expose the film satisfactorily. The eyepiece must be closed during the exposure. The print shall be coated with the preservative as soon as it is removed from the camera to prevent scratches or finger marks from marring the emulsion. When the preservative has dried, the name of the station, the time and date of the exposure, the f-stop setting, the range in nautical miles between markers, and the number of degrees of antenna tilt shall be written in ink on the back of the photograph.

Notations will be made in the "Remarks" column of Form 610-3 whenever a photograph is taken.

* 1023. Inoperative Camera.--Notations will be made in the "Remarks" column of Form 610-3 of the beginning and end of periods when the camera was defective.

* 1023.1. If the O-15, 35 mm. time-lapse camera becomes inoperative, the Supervising Electronic Technician will be notified immediately.

* 1023.2. If the Polaroid oscilloscope camera becomes inoperative, the Regional Administrative Office will be notified immediately, and that office will arrange for camera replacement or repair.

* 1023.3. If the 16 mm. camera furnished by Texas A&M becomes inoperative and the local station is unable to repair the instrument in accordance with Section IV of the Camera Manual, the Regional Administrative Office will be notified immediately, and that office will arrange for camera replacement.

* 1024. Film Supply.--Each station shall maintain a sufficient supply of film at all times; 8 rolls for stations with time-lapse cameras, a carton for stations with Polaroid oscilloscope cameras. The film should be stored in a cool, dry place (refrigerated if possible). Generally, the films which are stored in an ordinary household refrigerator should last several months beyond the expiration date of the film.

* 1024.1. Film that is stored in a refrigerator should remain sealed in its original wrapper during storage. Before use, the film should be removed from the refrigerator and conditioned at room temperature for several hours prior to removal of the original wrapper. It is very important that during the storage period, the film remain packaged in its original wrapper.

* 1025. Disposition of Film.--As soon as a roll of time-lapse film has been exposed, it will be mailed for processing.

* 1025.1. Thirty-five millimeter film will be mailed to the Naval Photographic Center, Naval Air Station, Anacostia, D. C. An identifying label (supplied by the Regional Administrative Office) will be glued to the paper carton that contains the can of exposed film, and the box of film will then be wrapped and shipped by franked label to the address indicated.

* 1025.2 Sixteen millimeter film will be placed in its box, wrapped and mailed by franked label to the ESO-S Co., 1121 West 47th Street, Kansas City, Missouri.

* 1025.3. Polaroid oscilloscope photographs of tornadoes or other significant weather situations will be mailed to the RADU at the end of each month. Other photographs may be retained at the station and, with copies from RADU, used as training material.

* 1026. Monitoring.--There will be furnished (through the Regional Administrative Offices concerned) to all stations equipped with cameras a supply of pre-addressed post cards to be completed by the various stations whenever an unusual storm such as a hurricane or tornado is observed or reported within the range of the radar. The card will serve to inform the recipient to watch for important echo developments shown on the film or photographs. A space will also be provided for the station to indicate that a copy of the film or photograph is desired for local use. Arrangements will then be made for such copy to be supplied.

1026.1. A form letter, or card, will be used to apprise the stations of changes in camera operation or photography techniques that should be made to improve the program.

1027. Sketches.--If the station is not equipped with a camera, or if the camera is inoperative, drawings or sketches should be made of unusual echoes, especially those of precipitation areas associated with hurricanes and tornadoes.

1100. OPERATIONAL USE

1110. Use of Equipment.--Use the radar equipment as an observational facility to the greatest practicable extent whenever echoes are observed, and especially whenever disturbances of unusual severity are forecast or reported to be within radar range.

* 1111. Time of Observations.--Observations will be taken:

1. At 0100 GCT and every three hours thereafter, except that

   a. Observations will not be taken when the antenna mechanism is so cold that the drive motor operation is sluggish.

b. If a large area surrounding the station is under the influence of fair weather, as evidenced by clear skies or a small amount of high clouds, an observation will be taken once daily at 1231 GCT to assure that the equipment is in proper operating condition.

2. On the hour, in addition to (1) above, whenever precipitation echoes are observed or were observed on the preceding observation, whenever precipitation is observed, reported or expected within the area of surveillance, and as deemed necessary for the early detection of precipitation in areas where rapid storm development may be expected, either on the basis of forecasts or local experience under similar synoptic situations.

3. At 30 minutes after each hour, whenever necessary to define a rapidly changing echo pattern, or to track a severe storm. Rapidly changing echo patterns are defined as follows:

a. Echoes noted on a previously clear scope.

b. Speed of echo movement equals or exceeds thirty knots.

c. Direction of echo movement changes by 45° or more since the previous observation.

d. Scattered echoes become a solid line or a solid line changes to scattered echoes.

e. The scope becomes clear.

4. Whenever requested by an aircraft in distress.

5. For flight planning purposes as time permits.

1111.1. During hurricanes and during periods when the area about the station is alerted for severe local storms, the radar scope will be watched as continuously as possible for evidence of significant developments and rapid changes.

1112. Tuning Procedure.--Direct the antenna by manual control to a known ground obstruction that will return an echo. Adjust the antenna in azimuth and elevation for maximum return, and reduce the gain of the receiver until the echo is just discernible on the scope. This point is termed the "threshold level". Proceed thereafter in accordance with tuning instructions prescribed in maintenance and operation manuals.

1112.1. After tuning adjustments have been made, increase the gain of the receiver to as high a point as is consistent with prevailing interference. Tilt the antenna to the angle that yields the best results for the station at the range being used. This will usually be the lowest angle at which the radar beam will clear most obstructions. This angle may vary with azimuth. It is preferable to keep the antenna at a low angle even though a few minor sectors are blocked out.

1113. Scanning.--Scan all ranges, starting with the longest, through several angles of antenna tilt during each observation. To obtain the most accurate and the best defined presentation of an echo, use the shortest range that will include it.

1114. Observing the PPI Scope.--At the time of each observation, observe the scope for a minimum of three minutes. After echoes have been initially detected, the equipment will be maintained in operating or stand-by status until echoes are no longer observed.

* 1114.1. Observing the RHI Scope (Where Available).--When echoes are observed, the antenna will be stopped in azimuth on an observed echo and scanned in the RHI position.

1115. Identification of Extraneous Echoes.--Prepare a map of the extraneous echoes normally observed on the scope through 360°, for use as an aid in distinguishing them from echoes of meteorological origin. The known or expected pattern of extraneous echoes during conditions of anomalous propagation may also be indicated on the map or on a separate map; i. e., as an extension of the normal pattern that includes echoes from prominent distant hills and mountains.

1120. Recording Observations on Form 610-3.--Enter observations in chronological order on Form 610-3, Radar Weather Observations. A new form will be started with the first observation following 0000 LST on the first day of each month.

1121. Omitted Data.--Omit entries for data that are missing or unknown, and omit all entries during periods of inoperative equipment, except reports of cessation and resumption of operation (see ¶1211.4).

1122. Entries.--In the heading of each form, enter:

1. Name of the station.

2. Type of radar; e.g., WSR-3 (10 cm.).

3. Antenna diameter in inches or feet.

4. Month and year; e.g., June 1957

1122.1. Additional instructions, pertaining to the evaluation of echoes and entry of evaluated data on Form 610-3, will be found in Section 1200.

1123. Disposition.--Original forms will be mailed to the Radar Analysis and Development Unit (RADU), Weather Bureau Forecast Center, Kansas City, Mo., at the end of each month.

1200. OBSERVATIONS

1201. Evaluation and Recording of Echo Data.--Echo data will be evaluated and entered in appropriate columns on Form 610-3 in accordance with the following instructions. Entries on each line will be used to describe single echoes or related groups, use additional lines to describe concurrent echoes or groups not adequately described by preceding entries.

* 1202. Anomalous Propagation Echoes.--Enter in "Remarks" the date, time, direction and distance of echoes considered to be the result of anomalous propagation (see ¶1003, 1007, and 1205). When anomalous propagation echoes are observed on the scope at the same time as precipitation echoes, both the echoes from precipitation and anomalous propagation will be entered on Form 610-3, but only those from the precipitation will be transmitted in a RAREP message.

1203. Date.--Enter the date corresponding to the standard time zone entry at the top of the Time column.

1204. Time.--Enter the 24-hour clock time to the nearest minute, corresponding to the time of the last entry for the observation, and the standard time zone entry at the top of the column.

* 1205. RAREP Number.--Number the observations consecutively,

beginning with the first observation following 0000 LST, and excluding the 1300Z status report entry and entries pertaining to anomalous propagation echoes.

* 1206. Character.--Classify the echoes in accordance with the following list and enter the corresponding contraction:

Character	Definition	Contraction
Isolated echo	Isolated solid mass of echo	CELL
Widely scattered area	An area less than 1/10 covered with echoes	AREA WDLY ⦶
Scattered area	An area 1/10 to 5/10 covered with echoes	AREA ⦶
Broken area	An area 6/10 to 9/10 covered with echoes	AREA ⦷
Solid area	An area solidly covered with echoes	AREA ⊕
Line of widely scattered echoes	(See widely scattered area)	LN WDLY ⦶
Line of scattered echoes	(See scattered area)	LN ⦶
Line of broken echoes	(See broken area)	LN ⦷
Solid line of echoes	(See solid area)	LN ⊕
Spiral band	Curved lines of echo which occur in connection with a hurricane	SPRL BND

Note that the echo pattern will be classified as a "line" only if the echoes are arrayed in a recognizable and organized line such as might be reflected from a squall line or front. This pattern should normally have a length to width ratio of at least 5 to 1 and will normally be at least 20 miles long.

Note also that the echo coverage is determined by a comparison of the relative amount of echo as compared to the total area as outlined by the position groups. In case of an "area" of echoes this total area is that enclosed by a line connecting the reported points. In case of a line this total area is a rectangular area described by the reported width along a line drawn through the reported points.

* 1207. Intensity.--The intensity of an echo will be determined as "weak", "moderate", "strong", or "very strong" on the basis of the returned signal strength and the range of the echo. The term "very strong" should only be used when, in the best judgment of the observer, some form of severe weather is probably occurring in connection with the echo.

1207.1. With 10 cm. radar and where an A-scope is available, use Figure 1 to relate the appearance of the A-scope to the intensity.

1207.2. Where an A-scope is not available or where 3 cm. radar is used, estimate the intensity from the PPI scope, on the basis of experience with the relative intensity of the patterns for existing operating condition of the equipment and the factors governing attenuation of the beam.

* 1207.03. Enter the appropriate contraction under the caption Intensity, as selected from the following list:

Intensity	Contraction
Weak	WK
Moderate	MDT
Strong	STG
Very Strong	VRY STG

* 1208. Tendency.--The tendency will be based upon consecutive observations of intensity. Under the caption Tendency, enter the appropriate contraction from the following list:

Tendency	Contraction
Increasing	+
Unchanging	NO CHG
Decreasing	-
Slowly	SLOLY
Rapidly	RPDLY

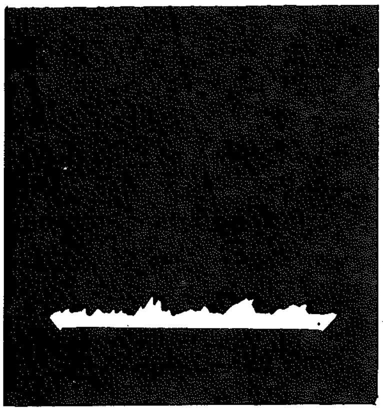
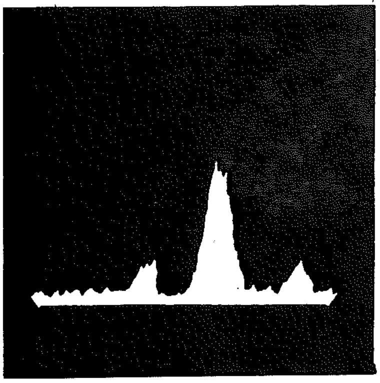
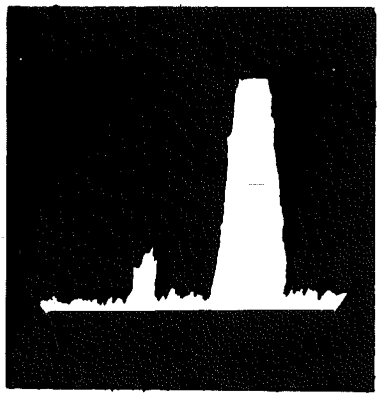
Appearance of A-scope	Intensity
 Echo can be detected at or near the noise level.	Weak if range is less than 100 miles. Moderate if range is more than 100 miles.
 Echo easily distinguished above noise level but fails to reach or exceed saturation.	Moderate if range is less than 100 miles. Strong if range is more than 100 miles.
 Echo completely saturates scope.	Strong if range is more than 50 miles. Moderate or strong if range is less than 50 miles.

Fig. 1. Relation of the appearance of A-scope to intensity.

1209. Description of Echoes.--Describe the shape and location of echoes on the following basis, except as specified for special cases in subsequent subparagraphs. Read and record azimuth and range to as many points on the periphery of individual echoes or groups of related echoes as is necessary to outline generally the contour of the envelope surrounding the clear-cut echo areas (see Fig. 3).

* 1209.01. Determine and record echo measurements as follows:

1. Direction from station in whole degrees. True north will be entered as 360 degrees.

2. Distance from station to the nearest nautical mile.

3. (Optional) In addition to (1) and (2) above, and if necessary for local briefing or broadcast purposes, the direction to sixteen points of the compass and distance in nautical miles from a reference point other than the local station (city or town, geographical feature, aeronautical fix, or landmark) to the echo.

4. Width (W) of a line or diameter (D) of cells or areas to the nearest nautical mile, if necessary, to define the echo shape. These distances may be obtained in terms of equivalent lengths measured along a radius, normal to the range circles.

* 1209.1. Spiral Bands.--Spiral bands of the type associated with hurricanes or typhoons (see Figs. 4 and 5) will be evaluated independently, regardless of the distance separating them. Give the direction and distance to as many points on the longitudinal center of the bands as are necessary to establish the general shape and extent of the bands. Record these data in progressive order preceding from one end of each band to the other end, preferably from the ends of spiral bands nearest their common center (see Figs. 2, 4, and 5).

* 1209.2. Cells or Circular Area Echoes.--Give the direction and distance from the station to the center of each area of echoes or cell that is approximately circular, and the diameter of the area or cell.

* 1209.3. Areas.--Give the direction and distance of 3 or more points along an enveloping line which most nearly encloses a group of closely connected echoes. The average diameter of the individual echoes within

the area should be given as AVG D.

* 1209.4. Lines.--Echoes associated with fronts and squall lines will be evaluated by giving the direction and distance to as many points on the longitudinal center of the line of echoes as are necessary to establish the general shape and extent of the line. The two end points will suffice for those patterns that approximate straight lines. Record these data in progressive order from the uppermost end of the line to the other end.

1209.5. Scope-Center Echoes.--Precipitation at the station may cause a bright diffuse echo that completely covers the central portion of the scope. Make distance readings to the edges of the echo at several points for the determination of echo diameter. Do not record distance and direction for these echoes on Form 610-3. In "Remarks", indicate that the echo is centered at the station.

* 1209.6. Thin, Short-Line Echoes.--Echoes at long range from precipitation areas that are not as wide as the radar beam may appear as a short line of the same angular width as the beam. Give the direction and distance to the center of these echoes and record the diameter as the average of the apparent length and width.

1209.7. Direction of Movement.--Determine the direction from which the echo is moving, to sixteen points of the compass, based on at least two consecutive echo positions observed at about fifteen-minute intervals. Record the direction from which the echoes are moving by means of "arrow" symbols such as are used in aviation weather reports.

1209.71. The direction of echo movement may be determined by plotting the location of the center of the echo as observed at the successive intervals, on a plotting board, or an aeronautical chart covered with transparent material. Draw a line through the centers of both echoes. The bearing from the second position to the first is the direction of movement.

* 1209.8. Speed of Movement.--Determine and record the speed of movement of echoes to the nearest knot. It is important to report significant differences in echo speed which are observed simultaneously on different echo patterns.

1209.81. The speed of movement is equal to the distance in nautical miles that the echo has moved in successive intervals divided by the time in hours and fractions of an hour; e.g., the speed of movement between observations fifteen minutes apart equals the distance travelled divided by one quarter (i. e., multiplied by four).

* 1210. Altitude.--The altitude (height above mean sea level) of echoes will be determined at stations supplied with radar equipment having an antenna that can be elevated by the operator. All values of altitude refer to the uppermost limit of moisture that may be detected by radar. Therefore, it should not be assumed that altitude data refer to the tops of clouds. Moreover, altitude data at long ranges are inaccurate because the elevation angles are very small, the beam dimensions large, and because corrections are not made for deviations of the radar beam from normal propagation. At very close ranges, the vanishing point of an echo may occur at the leading edge of a storm, whereas the actual top of the storm may be considerably farther from the station and at a lower elevation angle. Because of the magnitude of these inaccuracies, determinations of altitude for entry on observational forms will be made only between the ranges of 15 to 75 miles.

* 1210. 1. Determine the apparent altitude of the echoes as follows:

1. Using manual control, center the antenna in azimuth on the most intense portion of the echo.

2. If the radar has the RHI feature, the angular elevation of the apparent top of the echo may be read directly and steps (3) and (4) omitted.

3. If the echo is so strong as to saturate the A-scope, reduce the gain until the echo is just below saturation.

4. Tilt the antenna and read the angle when the echo first disappears from the A-scope.

5. Subtract half the vertical beam width from the angle read in (3).

6. Determine the height above the antenna using Figure 11.

7. Add the height in(5) to the altitude of the antenna to determine the altitude of the echo.

1210. 2. If the measurement of the height of several echoes is required at one observation, the measurement of them all in one operation may be made as follows:

1. Cause the antenna to rotate in azimuth at an elevation angle of 0 degrees.

2. With the antenna rotating, elevate the antenna in half-degree steps to 5 degrees and in 1-degree steps thereafter, allowing the antenna to make a few complete scans as each elevation angle.

3. Note the range of each echo to be measured and the elevation angle at which it disappears from the PPI scope.

4. Subtract half the vertical beam width from the angles read in (3).

5. Determine the respective heights of the various echoes above the antenna using Figure 11.

6. Add these heights to the altitude of the antenna to determine the altitude of echoes.

1210.3. Enter the altitude of the echoes to the nearest hundred feet; e.g., 25,000 feet will be entered as 250.

* 1211. Remarks.--Enter under "Remarks" such data as will support and amplify the observation and such additional data as have not been reported by a surface-observation station. Authorized contractions will be used so far as possible in making entries. Remarks which are not transmitted will be entered in parentheses. Other required remarks are specified in ¶1209.4.

Examples of Remarks

Observed data: Squall line with northern end moving from the northwest at 20 knots and the southern end moving from the northwest at 55 knots.

Entry under remarks: SQLN NRN END ↘ 20 SRN END ↘ 55.

Observed data: Strong echo identified as tornado, 100 miles west of station, moving from west-southwest at 25 miles per hour.

Entry under remarks: TORNADO RPTD WITH STG ECHO 270/100 →↗ 25.

Observed data: Center of tropical storm at 60 degrees and range 110 miles, diameter six miles, moving from southeast at 28 knots.

Entry under remarks: EYE 060/110 D6 ↖ 28.

* 1211.1. Unusual Echo Formations.--Enter data pertaining to unusual echo formations or movement. Note that the definition of the fine structure of echoes may often be improved by reducing the receiver gain. When a very strong echo is detected, the receiver gain should be reduced and this echo analyzed carefully for evidence of bright cores or "hooked-shaped", "6-shaped", or "crescent-shaped" echoes which might be related to severe storms, such as hailstorms and tornadoes. Echoes or lines of echoes that appear to collide, are also examples of unusual echo formations and movements that should be noted in "Remarks".

1211.2. Hurricane Echoes.--The following procedures will apply for hurricane observation by radar:

1. Radar observations of the eye or center of a hurricane should be transmitted only if the eye or center is on the scope. No attempt should be made to give its position if it is off the edge of the scope (out of range of the radar).

2. Care should be taken that an eye or center position is not derived from a single instantaneous observation of the scope, but rather derived from a continuous and logical sequence of observations.

3. The hurricane eye or center should be determined and continuously substantiated by observation of the circulation of the precipitation cells surrounding it. No fix should be reported which is not substantiated by cyclonic circulation. When the circulation is about an area devoid of echoes, the fix will be reported as an "eye", otherwise as a "center". A positive fix on an eye or center will not be reported unless cyclonic circulation of echoes is observed over more than 180° around it; if such circulation is observed over 180° or less, the fix will be called "possible eye" or "possible

center", as the case may be.

4. The position of the eye or center should be reported at least once per hour in degrees and tenths of latitude and longitude. If an eye is reported, its dimensions should be included.

5. The presence of unusually strong convective-type echoes in the outer bands of the hurricane should be reported.

6. The velocity of prominent echoes in the circulation of the storm should be reported for possible relationship to the surface wind velocity. In this case the azimuth and range of the prominent echoes with respect to the station should be reported. Care should be taken that real motions only are reported and not apparent motions that might derive from the generation or degeneration of the cells.

7. When possible, the position of the major spiral bands should be reported. The reporting of major precipitation areas that sometimes are observed in one quadrant of the storm is particularly important.

8. If possible, the report should include height of the major cells in the convective outer bands of the storm and the height of the spiral bands and major precipitation areas.

9. Eye and center positions will not be transmitted on Service A teletypewriter circuits.

* 1211.3. Bright Band.--During relatively stable conditions, it is often possible to determine the approximate height of the 0°C. isotherm from the RHI scope by observing the height of the top of the "bright band". The bright band may be observed as a narrow horizontal layer of intensified radar signal a short distance below the 0°C. isotherm. The bright band effect is caused by several processes associated with the melting of snow or ice particles as they fall into warmer air. The reflectivity of the water-coated snow or ice particles of the bright band is much stronger than the snow or ice above and slightly stronger than the rain below. A reduction of the receiver gain may be necessary so the bright band will appear more distincly on the scope.

* 1211.31. The altitude of the top of the bright band will be observed as near the radar set as possible and entered to the nearest hundred feet

above mean sea level; e.g., top of observed bright band at 8,500 feet will be entered in the "Remarks" column as, BB 85.

1211.4. Operational Status.--Enter a contraction pertaining to the operational status of the equipment as required by the table below. In the following list, "PPI" refers to the scope (plan position indicator); the additional letters refer to "no echo" (NE), "Out of service for maintenance" (OM), etc. These contractions may be used separately or in combination with echo reports.

Status	Contraction
1. Equipment performance normal, echoes not observed.	PPINE
2. Equipment out of service for maintenance. (Follow the contraction with a figure to indicate the number of hours that equipment is expected to be inoperative.)	PPIOM
3. Equipment inoperative owing to breakdown.	PPINO
4. Normal operation is continuing or resumed.	PPIOK
5. Observation omitted for a reason other than those above.	PPINR

1212. Initials.--The observer's initials will be entered in this column.

1300. REPORTS

* 1301. Transmission Schedules.--Stations, mainly those in Arkansas, Kansas, Louisiana, Nebraska, Oklahoma, and Texas, whose RAREPS are regularly incorporated in the RAREP Summary, as prepared by the RADU, will transmit regular RAREPS at 05 minutes past the hour on the RAWARC circuit only. Additional RAREPS from these stations will be transmitted on the RAWARC circuit on an unscheduled basis. Stations whose RAREPS are not regularly incorporated in the Summary will be authorized to transmit their RAREPS on the Service A teletypewriter system in the HH:20 or HH:40 "scan" periods and on RAWARC, if available, in the HH:05 sequence collection. RAREPS of exceptional importance, such as those related to tornadoes, for example, may be appended

to the hourly aviation observation if necessary to obtain immediate distribution of the report. Transmit PPINE (no echoes) when the scope becomes clear after one or more RAREPS, and resume transmissions only when echoes are again observed, or in accordance with ¶1302(1).

* 1302. Special Data Transmitted.--The following data will be transmitted from all radar stations under the circumstances and at the times indicated, via communications facilities as described in ¶1301.

1. When the equipment fails, transmit the appropriate contraction "PPINO" or "PPIOM" (see ¶1211.3), once only.

2. When operation is resumed, transmit the contraction PPIOK, once only.

3. Once a day, an appropriate phrase contraction will be appended as a "Remark" to the 1300Z aviation observation or the 1305Z RAWARC collective to indicate the operational status of the radar equipment (see ¶1111(1b), 1211.3(2), (3), or (4)).

4. If the station is within an area for which severe local storms have been forecast, but no precipitation echoes are observed, the contraction PPINE will be transmitted hourly as long as the "no echo" condition prevails during the valid period of the forecast.

5. If precipitation echoes are reported by one radar station within the normal coverage area of a second station, but the second station observes no precipitation echoes, the second station will transmit the contraction "PPINE" hourly as long as the first station reports echoes in the coverage area of the second station.

1302.1. Communication Forms.--Copies of all radar reports will be delivered to CAA personnel for local use and to local airlines as necessary. Reports for transmission and broadcast by the CAA will be filed on Form 630-4 or other suitable message blank.

1303. Order and Content.--Data will be reported and transmitted in the order entered on Form 610-3 to the extent that they are available. This order is such that a report need not include an explanation of omitted data.

1303.1. All material will be taken from Form 610-3 in the units and contractions used in making entries on the form; e.g., data entered in nautical miles will be coded in nautical miles, and data entered in hundreds of feet will be coded in hundreds of feet. Omit remarks that have been reported in an aviation observation from the station transmitting the report.

* 1303.2. A sample RAREP follows to illustrate the spacing and separation of the elements. Note that the designator "SD" will identify radar reports (RAREPS).

DCA 080233E SD3 LN⊕MDT + SLOLY 311/52 190/9 FM MRB TO
10 S RIC 20W ↗ 25 ALT 240 PPIOM3

Breakdown of this message for identification follows:

CONTENTS OF RAREP	CODED DATA	EXPLANATION
1. Station identification	DCA	Washington National Airport
2. Date and time, LST	080233E	Eighth day of month, 2:33 a.m., Eastern Standard Time
3. The term "SD" followed by a serial number	SD3	To identify the observation as the third radar report of the day
4. Character of the echo	LN ⊕	Solid line of echoes
5. Intensity of the echo	MDT	Moderate intensity
6. Tendency of the echo intensity	+ SLOLY	Increasing slowly
7. Direction and distance to ends of the echo line	311/52 190/90	Ends of echo are located 52 nautical miles from Washington at an azimuth of 311 degrees true and 90 nautical miles from Washington at an azimuth of 190 degrees true

8. Location (optional)	MRB TO 10 S RIC	To locate echo with regard to specific locations. Echo extends from Martinsburg, W. Va. to 10 miles south of Richmond, Va.
9. Width	20 W	Echo is 20 miles wide
10. The direction from which, and the speed with which, the echo is moving	↗ 25	Moving from the southwest at 25 knots
11. Altitude of echo top	ALT 240	24,000 feet MSL
12. Remarks		As appropriate, see ¶1211
13. A contraction to report inoperative equipment or resumption of service	PPIOM3	Equipment out of service for maintenance for next three hours

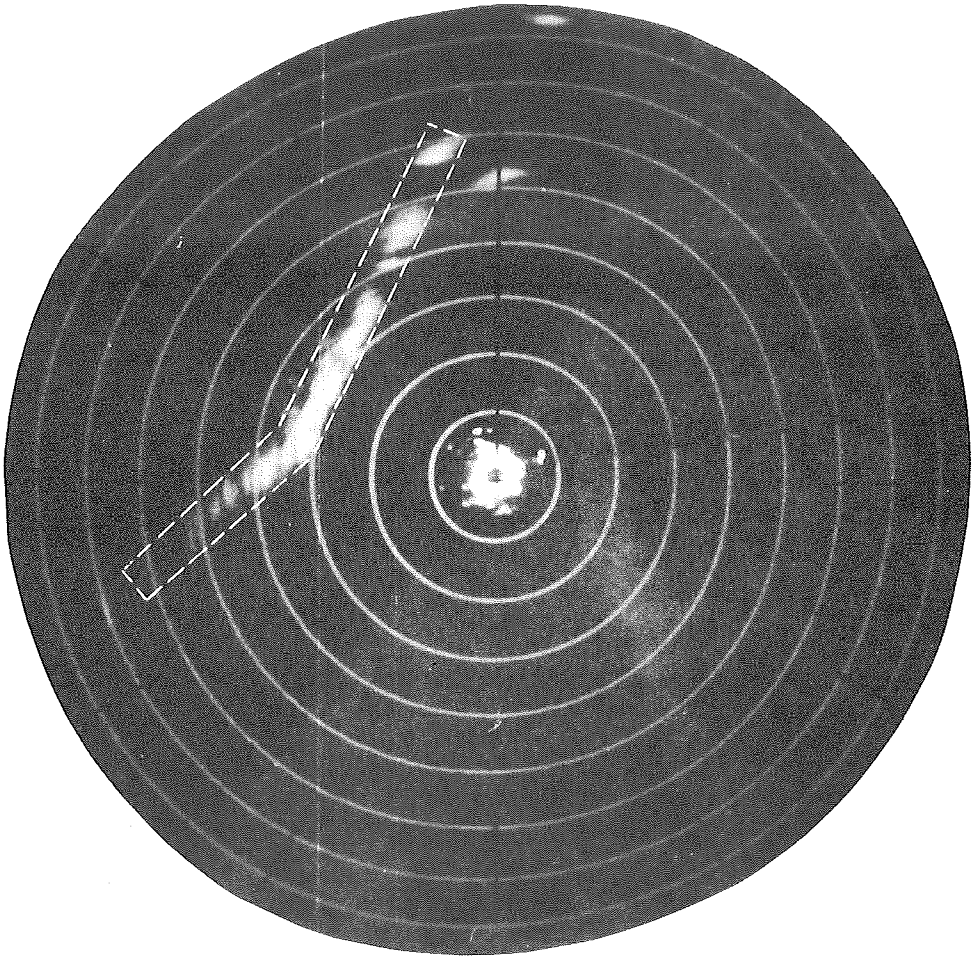


Fig. 2. Line of broken echoes.

The area of this line is estimated to be about nine-tenths covered with echoes. The line is therefore classified as "broken". The direction and distance to the ends as well as to the "knee" of the line and its average width are measured. There are also two isolated echoes on the PPI. The report might be evaluated as: Line of broken echoes of strong intensity; tendency-increasing; direction and distance to the end of the echo 350 degrees 120 n. miles and 253 degrees 127 n. miles and to the knee of the line 283 degrees 65 n. miles; 15 n. miles wide; northern end of the line moving from the northwest at 12 knots, the southern end moving from the northwest at 40 knots, tops of echoes at 24,000 feet MSL. A strong echo increasing in intensity at 6 degrees 168 n. miles, diameter of 10 n. miles, moving from the northwest at 12 knots; a strong echo increasing in intensity at 360 degrees 104 n. miles diameter 9 n. miles moving from the northwest at 12 knots.

This would be coded as: LN ⦶ STG + 350/120 283/65 253/127 15W NRN END ↘ 12 SRN END ↘ 40 ALT 240.

Fig. 3. Area of scattered echoes.

The echoes that appear on this scope cover less than half of the outlined area. The area is therefore classified as "scattered". The direction and distance to points outlining the area, as well as the average diameter of the echo are measured. The report might be evaluated as: Area of scattered echoes of moderate intensity; tendency-increasing; direction and distance to points outlining the area are 128 degrees 75 n. miles, 128 degrees 135 n. miles, 164 degrees 120 n. miles, 192 degrees 120 n. miles, and 182 degrees 55 n. miles; average diameter of the echoes is 8 n. miles; the area is moving from the SSE at 12 knots. A weak cell, increasing in intensity is located at 172 degrees 28 n. miles. Its diameter is 7 n. miles and is moving from the SSE at 15 knots.

This would be coded as: Area ⓘ MDT + 128/75 128/135 164/120 192/120 182/55. AVG D 8 ↑↖12. CELL WK + 172/28 D 7 ↑↖15.

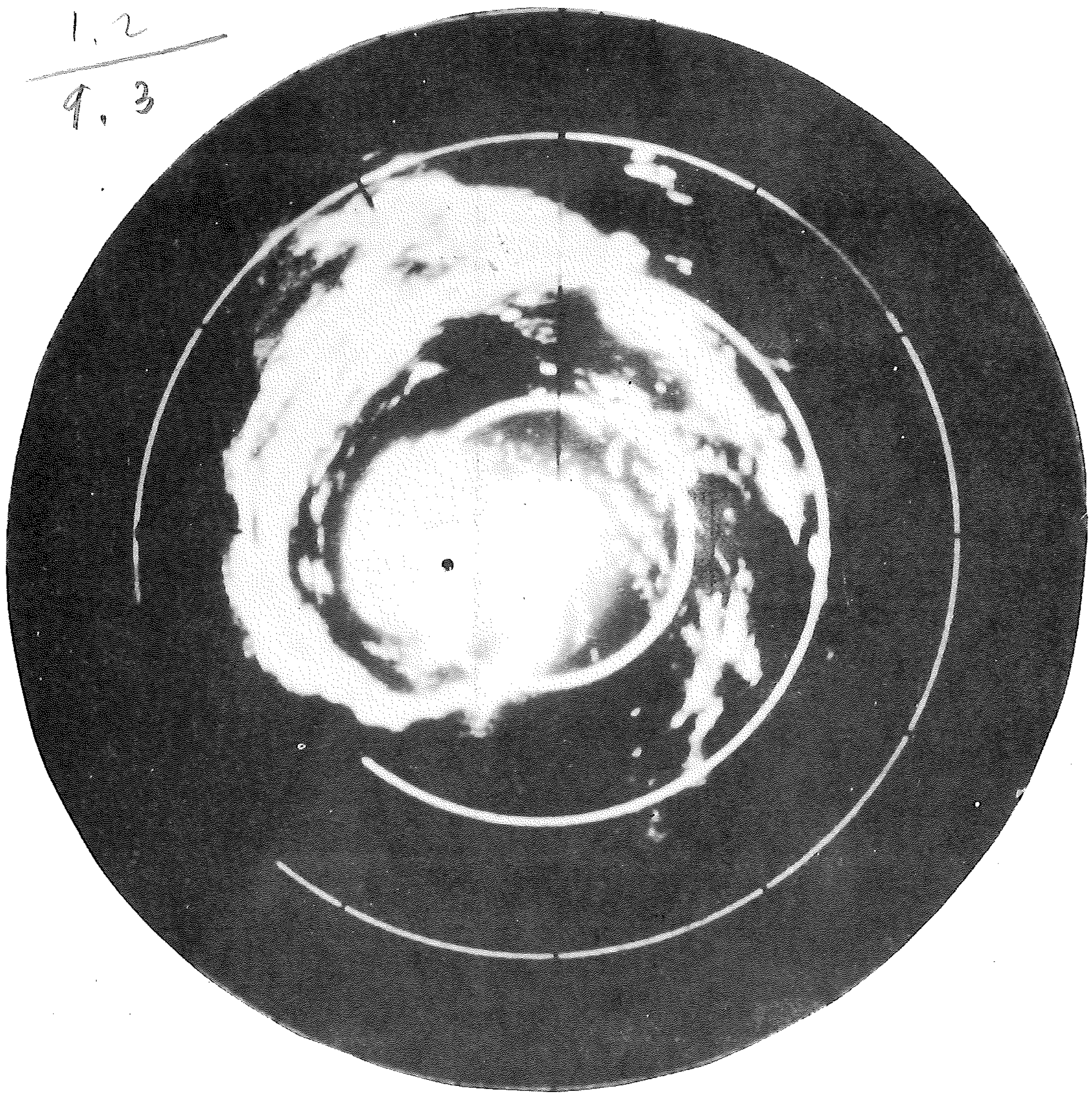


Fig. 4. Hurricane eye and spiral band echoes

Echoes of spiral precipitation bands resulting from a hurricane. The eye position will be reported since there is cyclonic circulation about an area devoid of echoes.

EYE 255/36 D4 ↖ 14.
SPRL BND + NO CHG 255/45 265/30 225/70 15W. SPRL BND + NO CHG 237/50 285/50 194/35 224/80 270/100 344/100 10-30W. SPRL BND + NO CHG 290/150 10/100 115/115 20W. SCTD SPRL BND MDT NO CHG 310/40 110/35 170/120 15W.

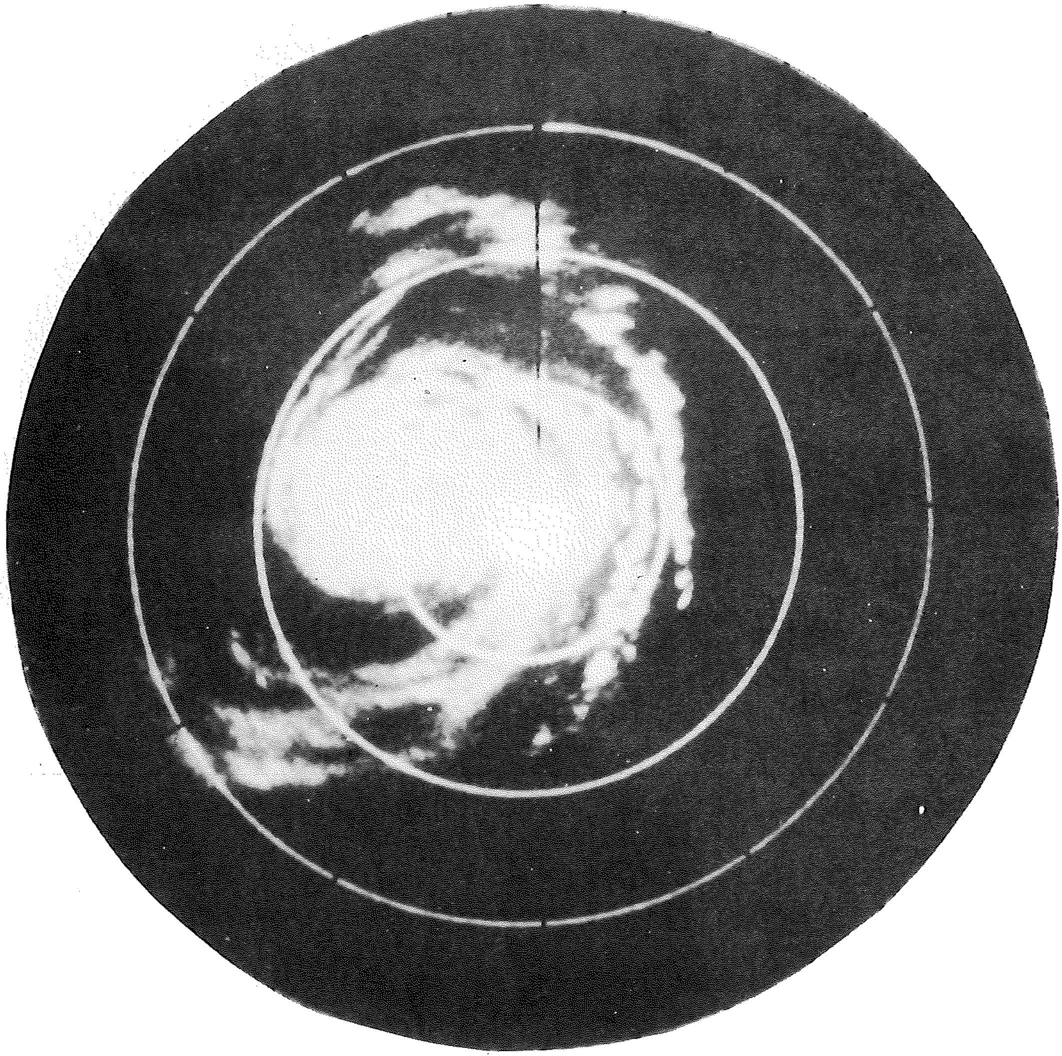


Fig. 5. Hurricane with no defined eye.

Echoes of precipitation showing cyclonic circulation. Since there is no area devoid of echoes, the "center" will be reported. At least once an hour the "eye" or "center" of a tropical storm will be reported in latitude and longitude.

This report would be coded as: CENTER 273/55 35.2N 77.4W ↑ 10.

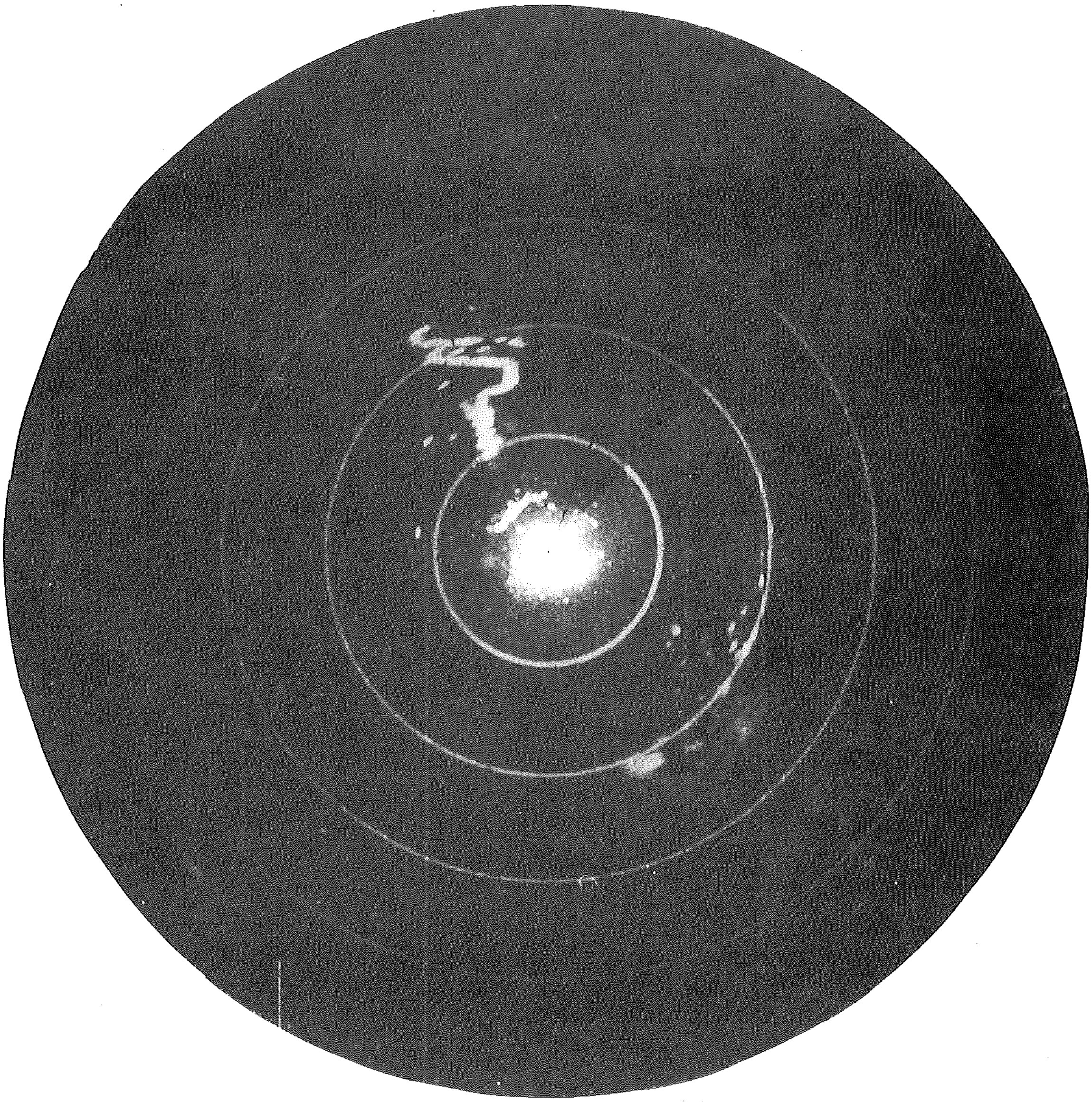


Fig. 6. Echoes from chaff.

Echoes from chaff are usually easily identifiable because of their unusual formations. These echoes, in the form of a question mark, are an example of this. Such echoes are not coded. Note, however, the area of scattered precipitation echoes in the southeast quadrant.

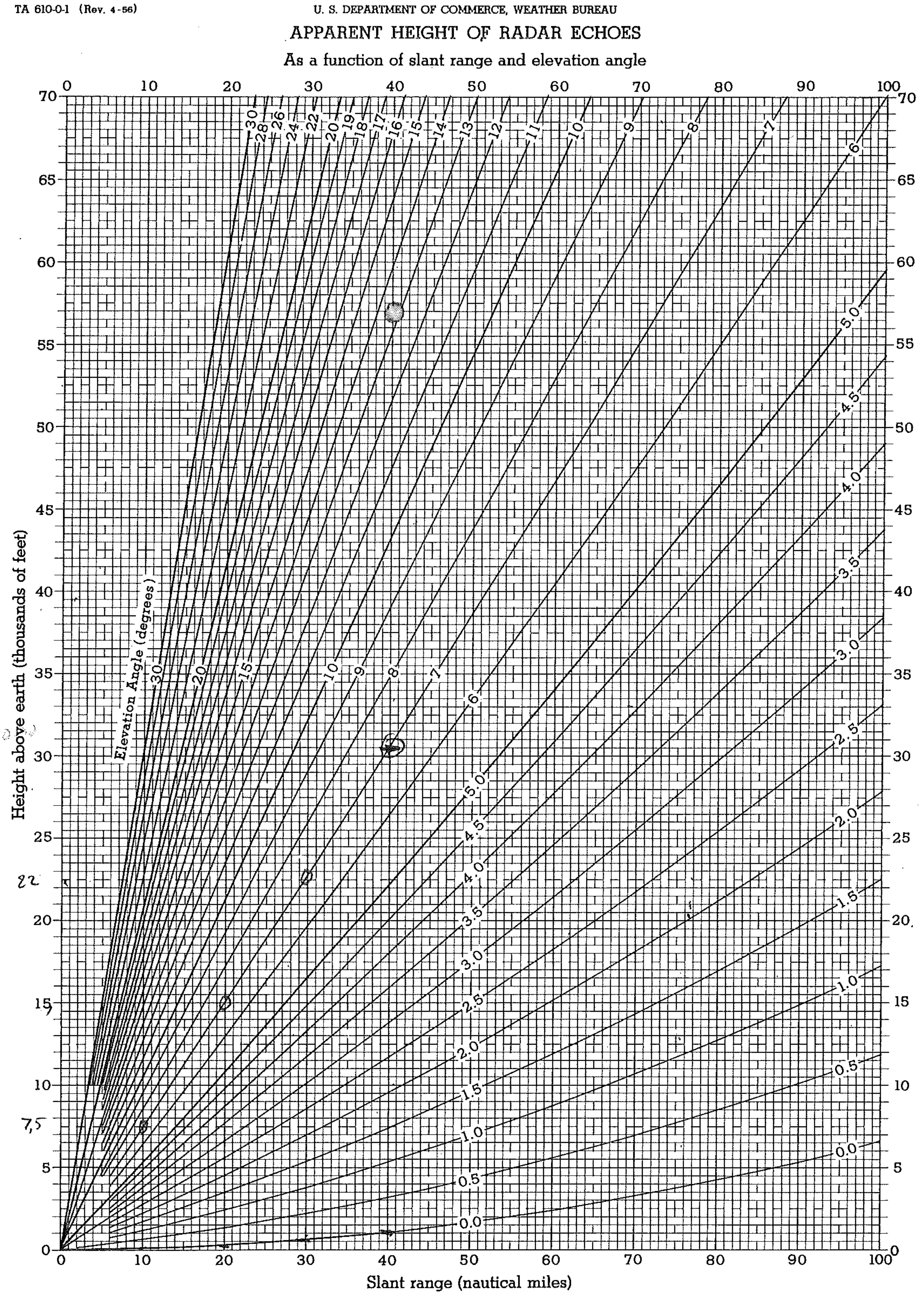


Fig. 7. Technical Aid 610-0-1, Apparent height of radar echoes.

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TRAINING GUIDE
FOR
RADAR METEOROLOGICAL OBSERVATIONS

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THE CHIEF OF NAVAL OPERATIONS

Weather Bureau Training Papers

No. 1. Hurricane Notes, July 1948.

No. 2. Lectures to Professional Interns, 1946–1947, March 1949.

No. 3. Introducing the New Observer to the Weather Bureau, April 1949.

No. 4. Training the New Observer, April 1949.

No. 5. Primary Training Manual for Supplementary Aeronautical Weather Reports, April 1949.

No. 6. Training Guide in Pilot Balloon Observations, March 1951; revised May 1, 1951.

No. 7. Training Guide in Rawins and Rabals, March 1, 1951.

No. 8. Training Guide in Radiosonde Observations, March 1, 1951; revised January 1952; revised June 1952; revised July 1953.

No. 9. Training Guide in Surface Aviation Observations, July 1951.

No. 10. Training Guide in Radar Meteorological Observations, September 1953.

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TRAINING GUIDE

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RADAR METEOROLOGICAL OBSERVATIONS

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1 October 1953

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INTRODUCTION

This guide has been prepared to assist in training observers and forecasters in the use of radar for weather search. The guide is intended to be used as a source of supplemental information by the observer-in-training while he is under the supervision of trained personnel at the station. In addition, it is intended that the guide should be used by forecasters to increase their knowledge of the possibilities and limitations of the use of radar in weather forecasting.

The guide consists of a summary of the basic principles of radar, general operational techniques, and examples of analysed weather situations as viewed by radar. Owing to the complicated nature of the equipment, detailed operational instructions have been omitted where it would be advisable for the observer to acquire the necessary knowledge by observation, personal training, and by reference to appropriate technical and maintenance manuals. This guide is specifically designed for use with the modified APS-2F radar, as used by the Weather Bureau. However, the general information is applicable to all types of radar.

References with the prefix "A15" refer to paragraphs or figures in Chapter A15 of the Addendum to Circular N, e.g., ¶ A15301. Reprints of Chapter A15 have been issued as separate manuals without changing the paragraph numbers. In the event of any seeming conflict between this manual and Chapter A15 of Circular N, the instructions of Chapter A15 will be followed.

We are indebted for some of the information in the guide to Technical Report No. 20, "The Use of Radar in Weather Forecasting", by Mr. Hal Foster of the Massachusetts Institute of Technology.

1.0. BASIC PRINCIPLES OF RADAR

1.1. General.--Radar (radio direction and ranging) equipment consists essentially of a directional radio transmitter and a radio receiver. The transmitter sends forth brief pulses of energy which are radiated from the antenna in a directed beam as the antenna rotates through 360° of azimuth. If the energy strikes any reflecting object, either meteorological or nonmeteorological, some of the reflected energy is picked up by the antenna, detected by the radar receiver, and indicated on the radar scopes (osciloscopes) as an "echo". The APS-2F radar has two scopes: the Plan Position Indicator (PPI) and the A-scope.

1.2. PPI-Scope.--The PPI-scope, with range and azimuth coordinates (see Fig. 1 and 2), presents a plot of the horizontal cross section of any echo of sufficient reflecting power that falls within the preselected range of the radar beam. When echo signals are detected and amplified, they are luminously displayed on the screen of the PPI-scope. A radial sweep line, beginning at the center of the screen and sweeping outward to its edge, revolves on the screen face like a spoke in a wheel. These revolutions are synchronized with the rotations of the antenna. When an echo signal is received, the sweep line brightens at some point along its length, depending upon the distance to the object and the range setting of the equipment. Estimation of distance is aided by electronic range markers on the indicator sweep line which, owing to the revolving action of the line, appear as concentric circles. These circles usually indicate radial distance in nautical miles from the center of the screen, which represents the position of the antenna. The long-persistence characteristic of the screen causes luminous spots to continue to glow until the sweep line completes its revolutions and again brightens the screen at these points. (Note: Nautical miles may be converted to statute miles by multiplying the distance on the scope by 1.15).

1.3. A-Scope.--The A-scope (see Fig. 3) indicates the signal strength against range along the sweep of the beam at the azimuth and elevation

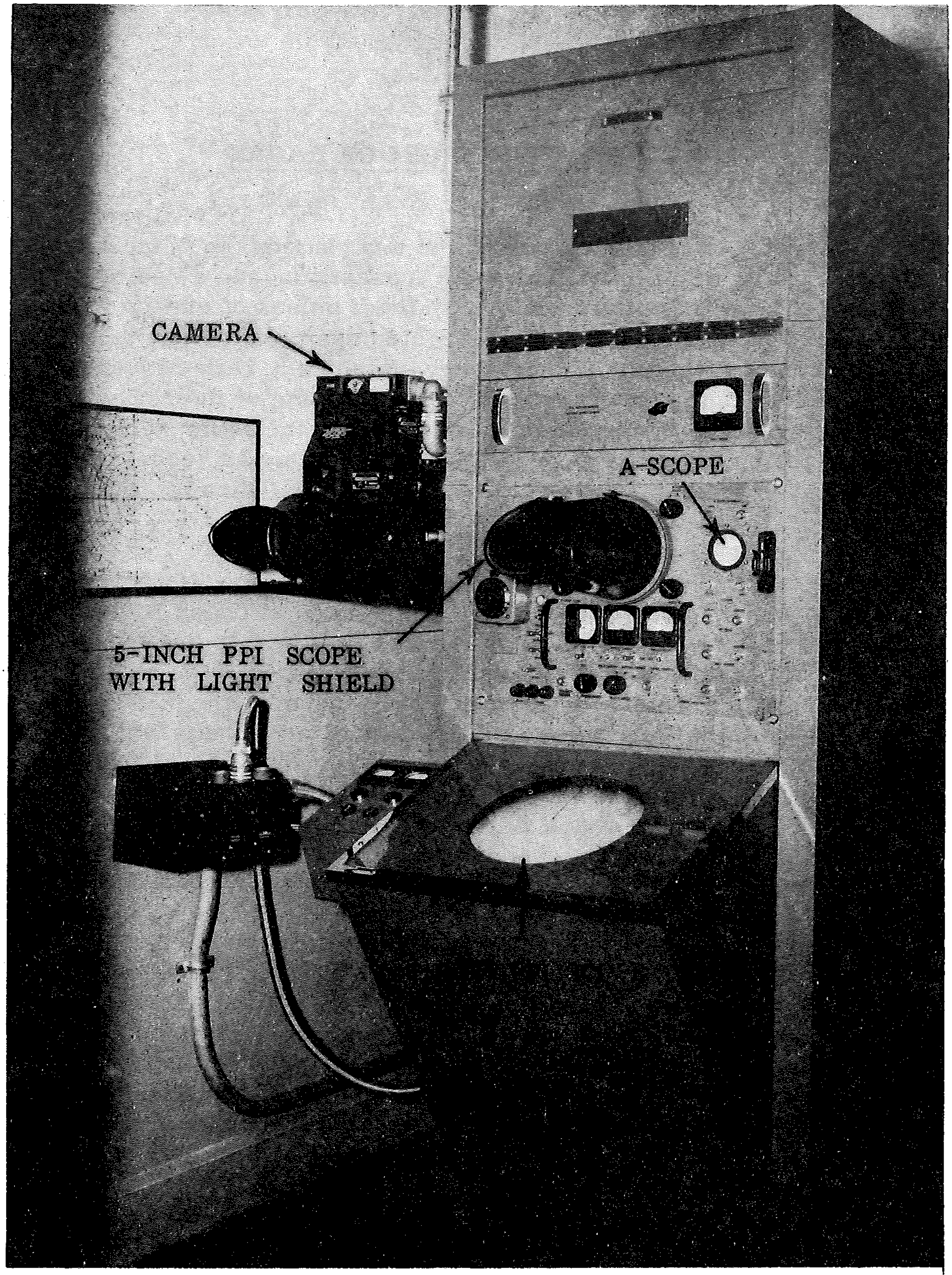

Fig. 1. Radar console with special camera attached.

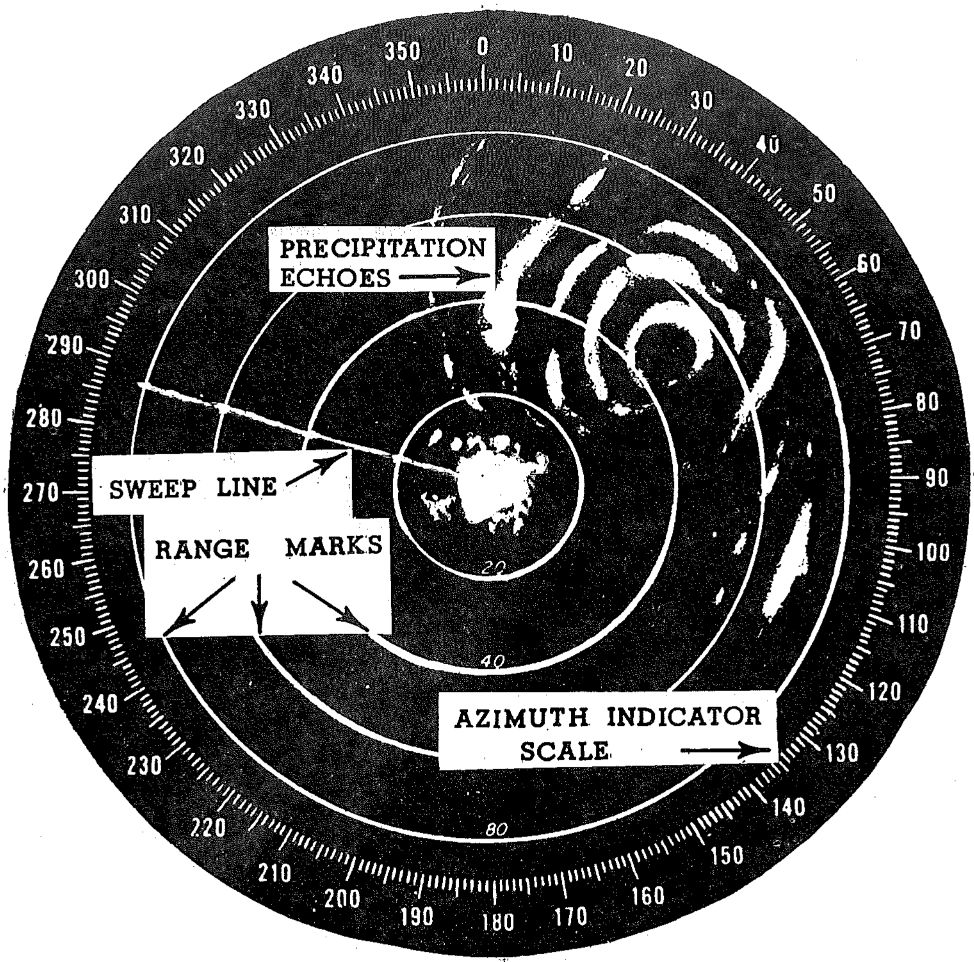

Fig. 2. Diagram of PPI-Scope.

As the sweep line revolves about the center of the scope it generates upon it continuous range marks corresponding to the range setting. The sweep line also indicates the location of an echo-producing target by brightening at a point on its length corresponding to the range of the object. The azimuth angle of this point corresponds to the azimuth angle of the target in relation to the radar antenna. At the points where the sweep line brightens, the screen of the scope continues to glow until the sweep line passes over the area again, thereby presenting a continuous picture of the target.

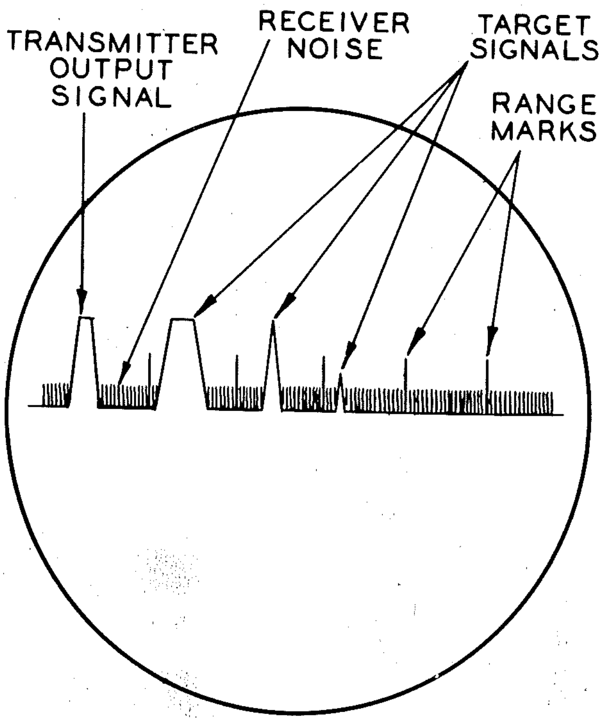

Fig. 3. Diagram of A-Scope.

The flat-topped target pulse indicates that a signal of saturation intensity is being received from a target at that range. The height of this pulse has been limited by the height of the A-scope screen. A reduction in receiver gain will reduce the height of the echo until the top becomes visible, when the true size of the echo can be determined. However, the receiver gain should not be reduced except for momentary intensity tests, if the reduction results in the loss of other echoes from the A-scope or PPI-scope. Returns from stationary targets near the station (ground clutter), not shown in the diagram, may obscure the pulse of the transmitter output signal. The range marks will represent the same distance as those on the PPI-scope and will change with the range selected.

angle at which the antenna is pointed at the time. The height of the signal above the baseline is a measurement of the strength of the reflected signal. Rapid fluctuations of the image may occur and cause a hazy appearance. This is an indication that the strength of the signal is changing rapidly as the antenna rotates. On the A-scope, receiver noise or interference has the appearance of "grass" along the baseline. It varies in height and may obscure small echoes. When the signal reaches a maximum and exhibits a flat-topped appearance on the A-scope, it is called a "saturated" signal (see Fig. A15-1). On the PPI-scope, a saturated signal appears as an echo of maximum brightness.

1.4. Meteorological Echoes.--The strength of meteorological echoes depends upon the size and quantity of the water drops in the area observed and the range of the echoes. It has been determined that the amount of scattering of the beam of energy from a spherical particle is proportional to the sixth power of the diameter of the particle. Accordingly, one drop of water 2.0 mm. in diameter will give a return equivalent to 4096 water drops of 0.5 mm. in diameter. For this reason, thundershowers, with their usual large raindrops, will give much brighter echoes than light rain with its relatively small drops. It is apparent that the radar will not detect all clouds, but will detect regions where the water drops are large enough to be classed as precipitation, although the precipitation may not reach the ground.

1.4.1. Owing to differences in the electrical characteristics of water and ice, the radar return for spherical particles of equal mass is approximately five times greater for water than for ice particles. The reflectivity of nonspherical ice particles does not vary greatly from that of spherical particles of the same mass. Therefore, the radar return from snow or sleet will usually be less than for rain of the same intensity of precipitation. For this reason, echoes received from areas above the freezing level may be weak and poorly defined. However, one exception to this rule has been noted, namely that large wet hailstones return a very bright echo.

1.4.2. In order to receive a detectable return from a small target at a range of 150 miles, for example, a great amount of energy must be transmitted in the radar beam. Owing to the large areas covered, only a very small portion of the transmitted power ever strikes a particular target. The energy which does strike a target is reflected nearly uniformly in all directions. Therefore, only a minute portion of the reflected energy will return to the radar antenna. It has been determined that this loss of reflected power is directly proportional to the fourth power of the range of the target. One result of this range attenuation effect is that an echo from an object at long range will not appear as bright as the echo from a similar object at a shorter range.

1.4.3. During periods of extremely heavy precipitation,radar equipment with a wave length of 3.2 cm. will be attenuated to some degree. Precipitation attenuation is defined as the loss of energy due to absorption and scattering by raindrops. The outbound energy suffers attenuation as it advances through the precipitation and, in the same manner, the returning reflected energy is attenuated as it returns to the antenna. Accordingly, precipitation patterns beyond areas of heavy rain may not appear on the PPI-scope of 3.2 cm. radar sets. However, precipitation attenuation is negligible for ten cm. sets. Note: APS-2F radar sets have a wave length of ten cm. Attenuation through snow is negligible at any wave length owing to the low index of absorption of ice.

1.5. Beam Width. -- The conical beam of energy transmitted from the 30-inch antenna usedon some APS-2F sets is approximately 9° in diameter. The beam from the 72-inch antenna used on modified sets is approximately 3.5° in diameter (see Fig. 4). The following table indicates the approximate diameter of the beams at various ranges.

Beam	Range, Miles				
	20	40	60	80	100
3.5°	6,500 ft.	13,000 ft.	19,000 ft.	36,000 ft.	33,000 ft.
9°	16,500 ft.	33,000 ft.	49,000 ft.	66, 000 ft.	82,000 ft.

It is evident from the table that two precipitation areas at a range of 100 miles will appear as one if they are less than 33,000 feet apart, when the 3.5° radar beam is used. These data indicate that the detailed definition of echoes decreases rapidly with distance. A solid line at long range may break into small individual echoes as the precipitation approaches the station. This occurrence is owing to the effect of the beam width and does not indicate a dissipating system, unless the intensity has decreased also as the line moved (see ¶ 3.3). Conversely, a line of scattered echoes at close range may appear to merge and become a solid line as the disturbance moves away from

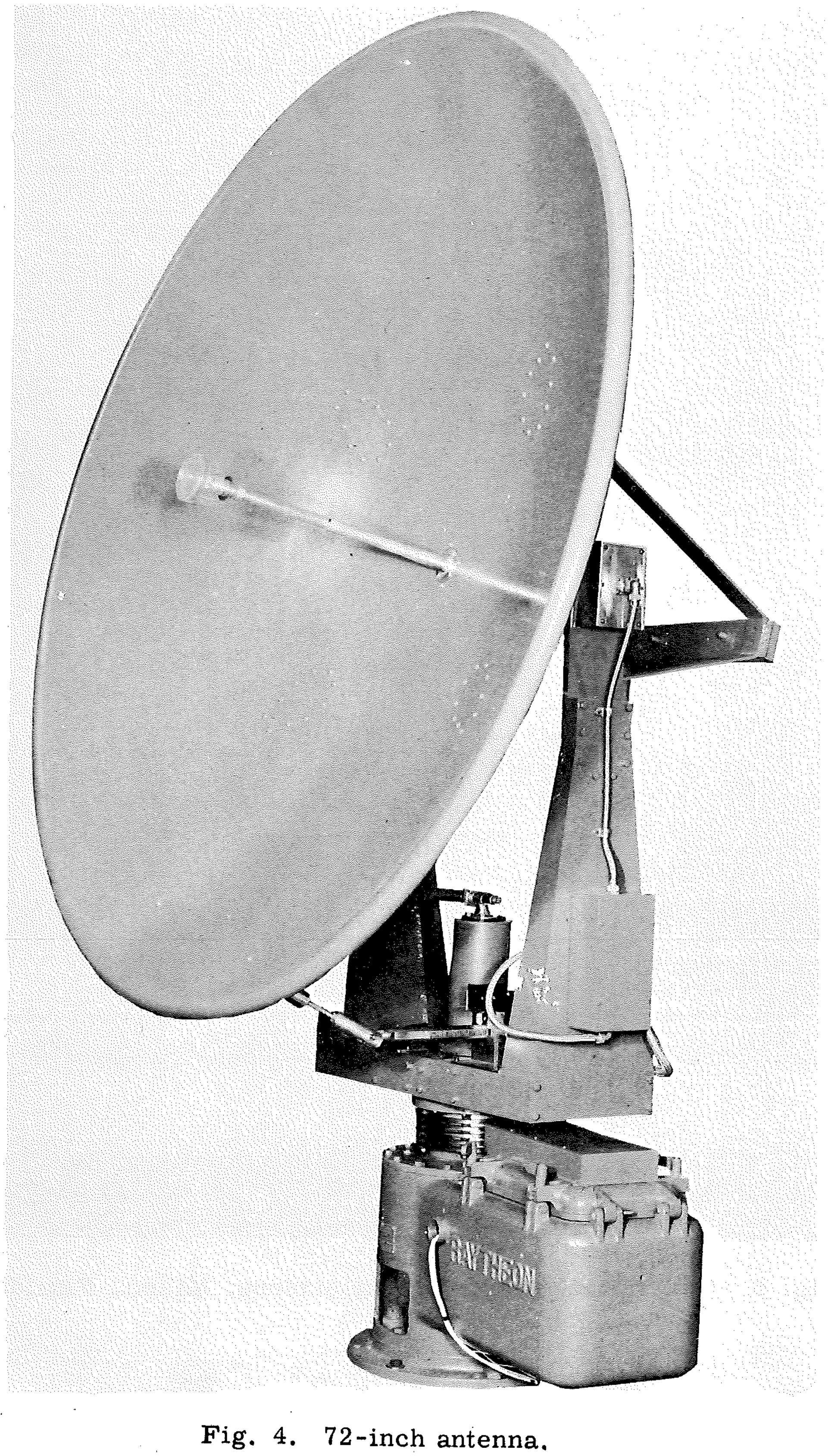

Fig. 4. 72-inch antenna.

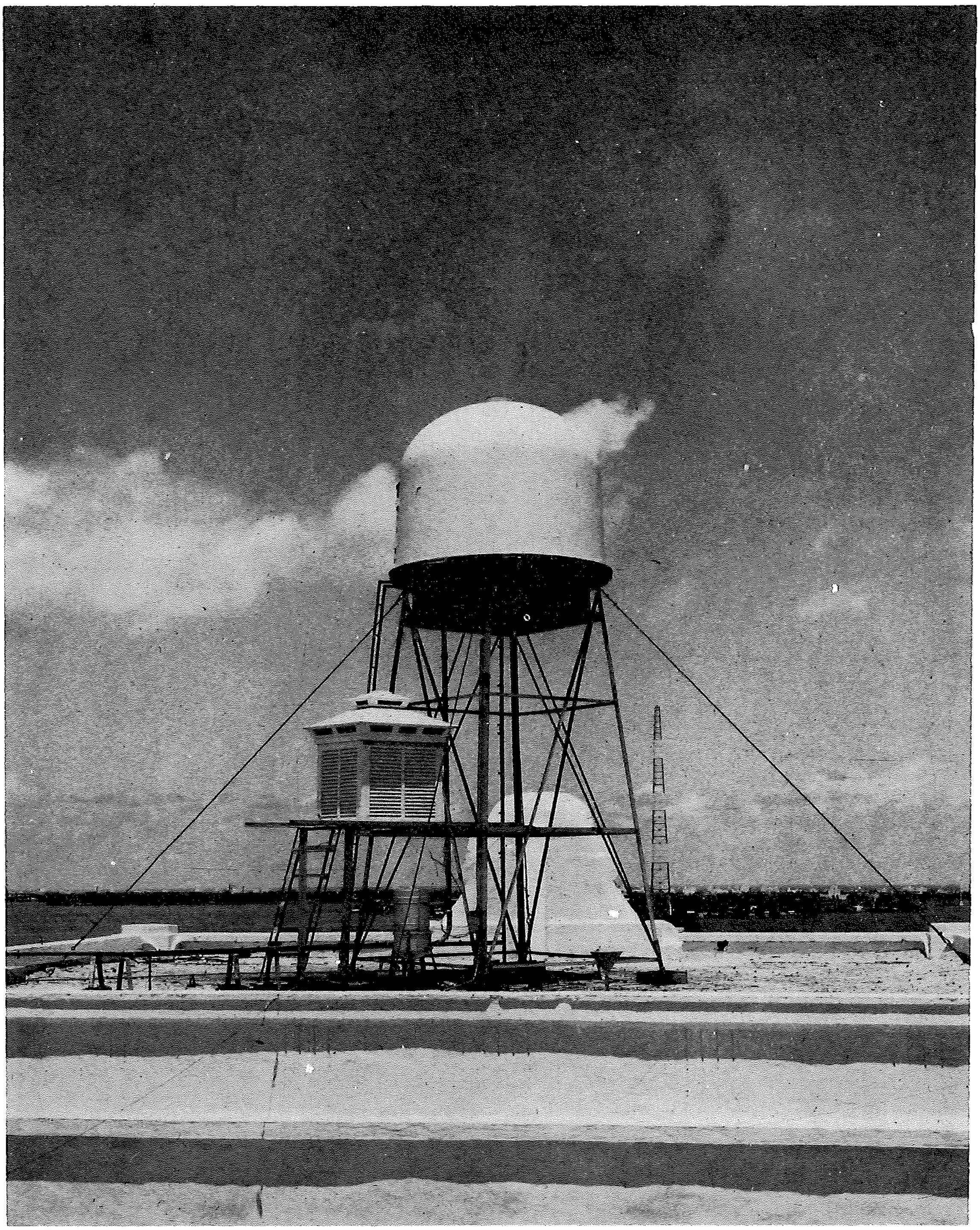

Fig. 5. Tower and dome for radar antenna, Miami, Florida.

the station. The loss of detail owing to beam width must always be taken into consideration by forecasters when comparing the character of echoes. However, observers should always report the character of an echo as it appears on the scope.

2.0. USE OF RADAR IN WEATHER OBSERVING AND FORECASTING

2.1. General.--Radar has been responsible for a big step forward in our knowledge of weather phenomena. It permits the meteorologist to study the inner structure of storms and thereby increases his forecasting ability. It also helps to prevent the unexpected, with a large saving in the loss of life and property. Experience in hurricane detection and warning has shown that the destruction caused by the storms can be reduced by 60% when warnings are given to the people in the areas where the storm is expected to strike. With respect to tornadoes, the saving of human lives will be most important.

2.2. Weather Patterns.--Briefly, storms and precipitation of interest to the radar operator usually occur as follows:

1. In bands of weather called "fronts" which move across the country from west to east.

2. In a squall line which may precede the fronts.

3. In isolated cells.

Each of these types of weather produces a typical echo pattern that can be distinguished on the radar scope. In other words, it is possible to tell whether the echo is from a single thunderstorm, or a line of thunderstorms, or an extensive area of precipitation (see Fig. 7 to 13). Since the intensity of the radar echoes depends upon the amount of precipitation accompanying the storm, it is also possible to estimate the severity of a particular disturbance from the brightness of its echo in comparison with other echoes at the same range. Therefore, by observing the radar scope, the observers can actually "see" the type and intensity of the weather approaching the station. This is extremely important in forecasting the exact area likely to be affected by severe storms, such as tornadoes. When tornadoes are forecast for a general area, as is the usual procedure when meteorological conditions are right for their development, each thunderstorm is watched carefully. If the thunderstorm becomes unusually intense, a tornado may develop from it. Under these conditions, the approach of a severe thunderstorm might result in the issuance of warnings to areas in the path of the storm.

2.3. Tornado Echoes.--It may not be possible to tell from the appearance of a radar echo whether a tornado is occurring in connection with a severe thunderstorm. However, when the presence of a tornado is verified by telephone calls to or from the affected area, its path can be watched on the radar scope and warnings issued to areas in the storm's path (see Fig. 12 and 12A). This method is more effective than observation by eyesight alone, since the storm may pass through the regions where it would not be reported until it actually entered a residential area.

2.4. Reports.--Radar weather reports are given by teletypewriter to other weather stations. These reports may be plotted on special maps and the movement and development of storms watched over the entire region (see Fig. 16). Pilots also make use of radar weather reports when making their flight plans, and when changing their plans while in flight to avoid weather disturbances.

3.0. RADAR OPERATION

References: (1) Handbook of Maintenance Instructions for U. S. Weather Bureau Search Radar

(2) Chapter A15 of Circular N, 6th Edition (revised), sections A15100 and A15200

3.1. General.--Detailed technical operational instructions will not be given in this text, since the complicated nature of the equipment requires that the operator receive personal training under the supervision of an experienced operator. A careful study of the reference material will be helpful.

3.2. Range Setting (See Fig. 2B of Maintenance Instructions).--The range should be adjusted to the lowest value possible for the echo being observed. For example, when the echo is within 25 miles of the station, more details will be evident if the range is set at 25 miles instead of at 50 or 150 miles. Unless a special calibration has been made, all Weather Bureau radars are calibrated in nautical miles. After the range switch has been turned to the desired value, it may be necessary to adjust the sweep amplitude in accordance with operating instructions. The sweep amplitude may be adjusted to expand the range scale and any echoes on the scope. One complete sweep of the PPI-scope will be required before the echoes will conform to the new range setting.

3.3. Adjustment of Receiver Gain.--The receiver gain may be adjusted to indicate the relative intensity of echoes. When the receiver gain is reduced the weakest echoes will fade out. Continued reduction will leave only the strongest echoes on the scope. In this way, the centers of greatest activity can be located for each area. Conversely, an increase in receiver gain may bring in echoes not observable at normal settings. In general, many details of the precipitation areas or storm cells may be disclosed by increasing and then decreasing the gain. Such details are not always apparent from variations in the intensity of the echoes at constant settings, especially at long ranges. For example, in frontal activity, the thundershowers may be hidden in the general mass of precipitation which may obscure a large area; however, when the receiver gain is reduced, the areas of light precipitation will fade out and the shower will become more apparent. This information will be useful as follows: a) in determining the true nature of the front, b) in guiding aircraft, c) in forecasting areas of maximum precipitation and high winds and, d) in research. However, allowances must be made for range attenuation when judging the strength of echoes (see ¶ 1.4.2). A slight increase in the background light on the scope may accompany the increase in receiver gain. This light, known as "electronic noise", may be subdued by reducing the scope intensity. This usually affects the background light to a greater extent than it affects the signal, since the background has a smaller amplitude than the signal.

3.3.1. Adjustment of the receiver gain will provide additional details on the A-scope. In general, the relative intensities of echoes can be judged with greater accuracy when the signal does not saturate the A-scope. A saturated signal extends to the top of the A-scope and becomes flat so that its true height or intensity cannot be compared with other echoes (see Fig. 3). When the receiver gain is reduced enough to prevent saturation of the scope, an estimation of relative intensities can be made by comparing the heights of echoes at comparable ranges. It should be noted that electronic noise will increase on the A-scope as the receiver gain is increased. At times the noise level may be high enough to obscure the true echoes. However, preference should be given to the appearance of the echoes on the PPI-scope.

3.4. Effects of Location. -- The location of the radar antenna near any obstruction with a higher elevation than the antenna's, such as towers, buildings, and hills, will result in the blocking off of targets beyond the obstruction. The blocking will extend through the azimuth angle subtended by the obstruction. For this reason, radar antennas are usually located on special towers above all prominent obstructions (see Fig. 5).

3.4.1. "Ground clutter" is present on the scopes of most radar sets. It consists of an irregular stationary echo covering the first few miles of range around the center of the scope (see Fig. 6 and 6A). The ground clutter is caused by a small amount of the transmitted pulse feeding back through the receiver and by echoes from local obstructions. The echoes will still be present, although reduced slightly, when the elevation angle of the antenna is increased.

3.4.2. Each station should prepare a map of all prominent hills, mountains, lakes, or coast lines within a range of 250 miles of the radar antenna (reference ¶ A15301). The location of buildings, towers, etc. more than five miles from the radar antenna need not be shown on the map unless echoes from these objects have been noticed on the scopes. Transparent overlays for the large PPI-scope can be constructed at each station if certain basic rules are followed. It is known that the range markers on most of the scopes are not linear. Therefore, it is necessary to have lock-in points on all of the range markers and to adjust the sweep sensitivity each time to fit the overlay. It is also important that the range markers be perfect circles. If they are ellipses, the technician can make the necessary adjustments to correct the trouble. Transparent overlays should be constructed as follows:

1. Obtain several sheets of clear plastic with a thickness of one-sixteenth inch or less.

2. For each range setting, cut an overlay the size of the large PPI scope from the plastic. The overlay should fill the face of the scope in order that the plastic will not slip sideways. Small strips of rubber tape placed at intervals on the outer edge of the overlay will help to prevent slippage and rotation.

3. Adjust the sweep sensitivity until the outermost range marker is at the outside edge of the scope.

4. Make reference marks on the overlay at 0° (north) on each range circle.

5. When precipitation echoes are not present, adjust the receiver gain of the radar to the average operating setting, and etch in the outlines of the various ground clutter echoes with a sharp instrument. Black ink may be applied to the etched lines. The location of towns, etc., may be marked on the overlays when the locations are checked with an aeronautical chart.

6. Repeat steps 3, 4, and 5 for each range setting using a new overlay each time. Clearly label each one.

The overlays should be used as follows:

1. Place the overlay, corresponding to the range setting in use, on the PPI-scope with the reference marks on 0°.

2. Adjust the sweep sensitivity until the range circles correspond to the respective reference marks on the overlay.

3. Change overlays to correspond to changes in the range setting.

3.5. Abnormal Echoes (Reference ¶ A15303).--Occasionally, under certain conditions, unusual echoes may appear on the radar scopes.

3.5.1. Ducting.--The phenomenon known as "ducting" results from propagation of the radar beam, which may be bent so that it intercepts targets which are normally below the horizon. Ducting usually occurs in connection with a sharp temperature inversion at low levels. A marked increase in temperature with height or decrease of humidity, or both, is necessary. Such conditions occur when warm dry air over-runs a shallow layer of cool moist air. If these conditions are present, echoes of hills, mountains, or other high objects, which are normally just below the horizon, may appear. Suspected echoes should be carefully checked. Since echoes resulting from ducting may be from stationary objects, the presentation on the PPI- and A-scopes will be steadier and sharper than precipitation echoes. Ducting may improve the detection of distant precipitation echoes, since the portion of the precipitation column below the horizon will return enough energy to increase the intensity of the normal echo.

3.5.3. Sea Return. -- Under certain conditions, stations near a coast line may experience echoes known as "sea return". These echoes appear very much like precipitation echoes on either the PPI- or A-scopes. However, the location of the echoes and their persistence in one section of the scope, if meteorological phenomena are not expected in that area, should identify the echoes as sea return.

4.0. OBSERVATION AND EVALUATION OF ECHOES

References: (1) Chapter A15 of Circular N, 6th Edition (Revised), sections A15100, A15200, and A15300

(2) Handbook of Maintenance Instructions for U. S. W. B. Search Radar, Fig. 2A and 2B

4.1. General. --Frequent radar observations are required in order that precipitation echoes can be detected at the earliest possible moment. When echoes are observed, continued observation is necessary to check their development and movement. Since a few minutes are required to start the radar equipment and place it in operation, instructions specify that the radar will not be turned off when echoes are present. However, when the scopes are not being watched continuously, the set may be placed in stand-by operation. This is accomplished by turning the transmitter filament switch to "Off" for a second and then back to "On". The scopes may be placed in operation again by momentarily pressing the transmitter high voltage switch to "Start" and then adjusting the range and receiver gain for best results (see ¶ 3.2 and 3.3).

4.2. Character of Echoes (Reference ¶ A15304). -- Echoes must be classified in order that a reasonable description of them can be transmitted over teletypewriter circuits. Therefore, radar-echo patterns are classified as scattered echoes, solid echoes, line of scattered echoes, solid line of echoes, and echoes in a spiral band.

4.2.1. Scattered Echoes.--A group of echoes close together, but not forming a line or spiral will be described as "scattered echoes". In general, the distance between the echoes must be less than the distance through the largest echo; otherwise, individual echoes should be described (see Fig. 8 and 9).

4.2.2. Solid Echo.--Individual echoes, either isolated or separated from other echoes by a distance greater than the distance through the largest echo in the group, will be described as a "solid echo" (see Fig. 7, 7A, 10, 12, and 12A). These echoes may have irregular outlines, but should not be actually separated into several echoes.

4.2.3. Line of Scattered Echoes.--Scattered echoes (see ¶ 4.2.1) in a curved or straight line (but not a spiral) will be described as a "line of scattered echoes" (see Fig. 7A, 9, 10, 11, 11A, 11B, and 11C). A line of scattered echoes may indicate squall lines or frontal activity.

4.2.4. Solid Line.-- A continuous echo forming a line or curve (but not a spiral band) will be described as a "solid line". The echo may have irregular edges but no definite breaks (see Fig. 11B).

4.2.5. Spiral Band.--When echoes appear in lines which spiral toward a center, they will be described as "spiral bands". These echoes are associated with hurricanes or severe tropical storms. A spiral band may be composed of scattered echoes or of one continuous echo. Some caution is necessary in describing echoes as spiral bands unless a tropical storm is expected or the formation remains evident for at least thirty minutes (see Fig. 13, 13A, and 13B).

4.3. Intensity (Reference ¶ A15305 and Fig. A15-1).--Estimation and classification of the echo intensity as weak, moderate, or strong will be made from the appearance of the echo on the A-scope and the PPI-scope with an average setting of the receiver gain (see ¶ 1.3). Allowance must be made for the distance from the radar and the weakening of the signal owing to range attenuation (see ¶ 1.4.2). When many echoes are present or when echoes are large, the receiver gain may be adjusted to indicate the most intense areas (see ¶ 3.3). Echoes which appear as only small spots on the A-scope at ranges of 50 miles or less should be classed as "weak". Weak echoes appear thin and grey on the PPI-scope. Owing to the effect of range attenuation any indication of an echo on the A-scope or PPI-scope at ranges of 50 miles or more should be classed as "moderate". Moderate and strong echoes may completely saturate the A-scope at close range. Some experience is necessary in determining the relative strength of echoes at ranges of less than 50 miles. However, echoes which saturate the A-scope at ranges of over 20 miles should always be classed as "strong". Exceptionally bright echoes, such as may be received from violent thunderstorms or heavy frontal activity, at ranges of less than 20 miles, should also be classed as "strong".

4.4. Tendency (Reference ¶ A15306).--Several consecutive observations of the intensity of an echo are necessary to determine the change in strength of the echo. This change is called the "tendency". After several observations of an echo, the tendency should be classed as slowly or rapidly increasing or decreasing, or as unchanged. Again, the effect of range attenuation must be considered, since the echo will become brighter on the scope if it approaches the station, or vice versa.

4.5. Position (Reference ¶ A15307 to A15307.41 and Fig. A15-2 to A15-10).--To facilitate recording and transmitting the size and location of echoes, patterns on the PPI-scope will be described as ellipses, circles, combinations of individual echoes, or spiral bands in accordance with the reference instructions. The azimuth angle, to sixteen points of the compass, and the range, in statute miles (nautical miles multiplied by 1.15), of each pattern will be given also. Note that the pattern may include a collection of scattered echoes or one solid echo. Although the observer will not be able to describe every small detail of each echo in the teletypewriter message when this system is used, a reasonably accurate picture can be reproduced from the average report. The circle or ellipse should represent the mean boundary of the area described. Some small projections on the echoes will be outside of the reported area and some clear areas will be on the inside. However, if the discrepancy appears unreasonable, the use of an additional circle or ellipse may give a better representation of the true echo. When the individual echoes in a group are too far apart to be described as one area (see ¶ A15307.3), each echo will be evaluated as a circle or ellipse. However, no attempt should be made to describe a portion of a spiral band as a circle or ellipse, since these bands should be described in detail (see ¶ A15307.4).

4.6. Orientation, Length, and Width (Reference ¶ A15308 through A15311).--When echoes are evaluated as an ellipse, the orientation of the major axis will be determined to sixteen points of the compass (see Fig. 7 and 7A). The length of the major axis will be determined to the nearest statute mile. The width or diameter of each echo also will be determined to the nearest statute mile. If possible, the echo should be located with reference to cities, mountains, or air-navigation facilities.

4.7. Direction and Speed of Movement (Reference ¶ A15312 and A15313). --The direction and speed of movement of the brightest portion of each echo can be determined by plotting the location at one observation and noting the amount and direction of movement at the following observation, about 15 or 30 minutes later (see Fig. 11 to 11C). It may be necessary to adjust the receiver gain to determine the brightest portion of the echoes (see ¶ 3.3).

4.8. Height (Reference ¶ A15314). --A chart for estimating the height of radar echoes is furnished to all radar stations (see Fig. 14). The height of the top of radar echoes is important to forecasters and to research activities. The top of the echoes may be indefinite owing to an increase in the amount of ice or snow particles above the freezing level, and owing to the echoes from nearby precipitation areas obscuring the top of the true center of the cloud. For these reasons, height determinations will be made only between the range of 15 to 50 miles.

4.8.1. Radars of the APS-2F type have a beam width of 3.5° when 72-inch antennas are used, and a beam width of 9° when the original 30-inch antennas are used. Therefore, observers with this type of radar equipment will subtract 1.8° or 4.5°, as appropriate, from the elevation angles when determining the height of echoes.

4.8.2. The antenna can be tilted to a maximum of 20° above the horizontal. The elevation angle will be indicated on the "tilt indicator" The angle is varied by manipulation of the "tilt" switch.

4.8.3. Example. --

Given: An echo at a range of 40 nautical miles. When the antenna is tilted, the signal fades out at an indicated elevation angle of 7.5°.

40 nautical miles x 1.15 = 46 statute miles

$$7.5° - \frac{3.5}{2} = 5.7° \text{ (for } 3.5° \text{ beam)}$$

Using the chart in Fig. 14, the height is found to be 25,000 feet.

4.9. Remarks (See ¶ A15315).--The remarks portion of the message is reserved primarily for information that cannot be coded in the main report. In general, the observer should include such additional information as he believes will help forecasters or pilots in their evaluation of the radar reports.

5.0. ENTRIES ON FORMS

5.1. General (Reference section A15500).-- A complete report of every observation will be entered on Form 610.3-1, "Radar Weather Observations, Land Station," in accordance with the reference instructions (see Fig. 15). An entry is required for each scheduled observation regardless of whether echoes are observed (see ¶ A15524). Special remarks or comments may be entered on the form and enclosed in parentheses to indicate that they were not transmitted. For example, the remark may explain that the observation was taken at the request of the district forecaster. Other remarks, not transmitted, refer to the use of the radar camera, adjustment on the equipment, etc.

6.0. TRANSMISSION OF RADAR REPORTS

6.1. General (Reference, section A15600).--Radar reports are given special distribution on Service A. However, RAREPS describing thundershowers, frontal activity, or tropical storms should be appended as remarks to aviation weather observations.

7.0. VERIFICATION OF RADAR ECHOES

7.1. General.--When severe storms are suspected in connection with an unusual radar echo, telephone calls should be made to the community in the vicinity of the storm to obtain information regarding the disturbance. In the event that the storm is severe, warning should be passed to other communities in the storm's path. Such warnings should be issued in accordance with standard Weather Bureau procedure.

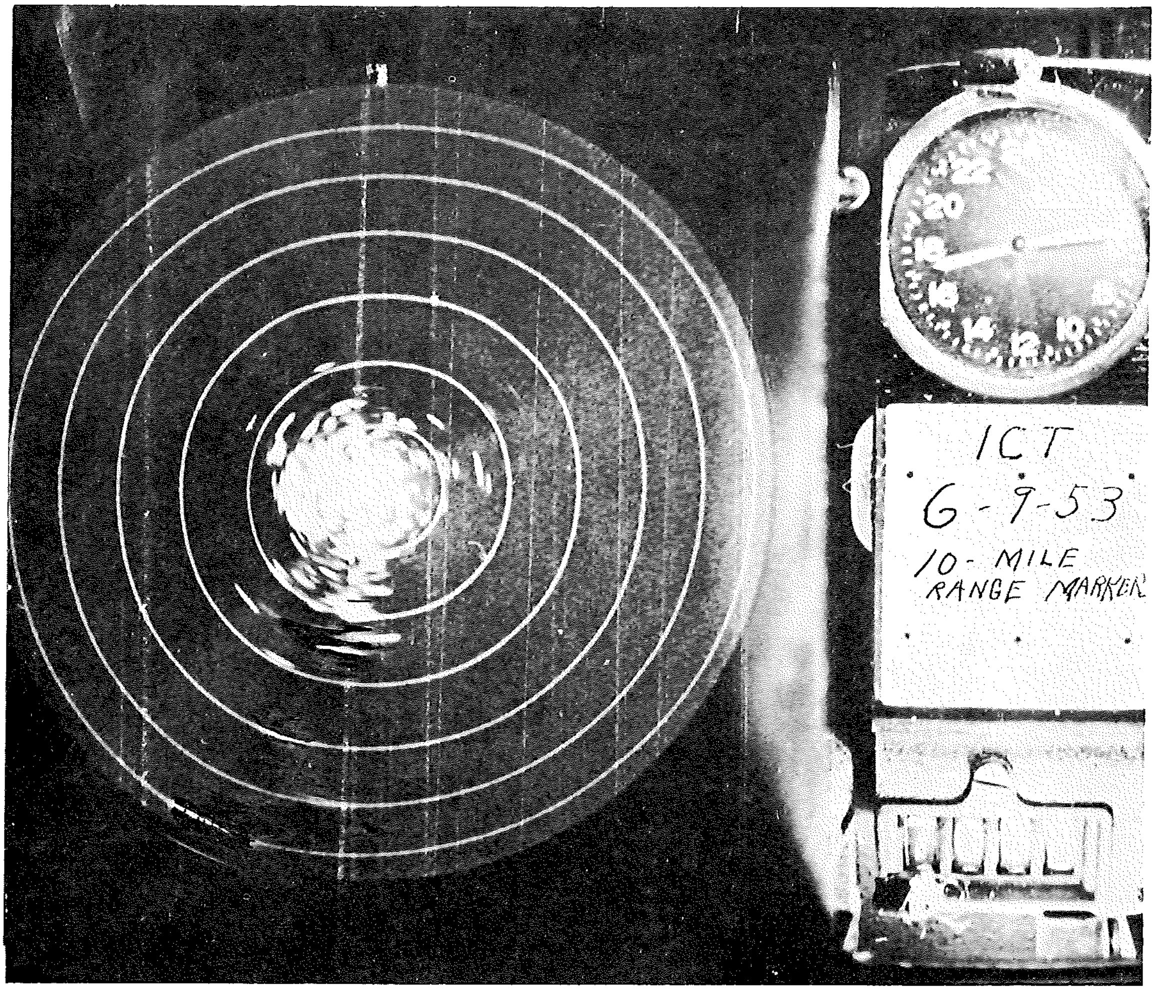

Fig. 6. Ground Clutter.

Permanent objects around the station produce echoes near the center of the scope, as shown in this photograph of the PPI-scope at Wichita, Kansas. These echoes are called "ground clutter". The observer should be familiar with the location and average brightness of the echoes contributing to the ground clutter pattern (see ¶ 3.4.2). Since azimuth markings are not visible on the illustrations, a white dash has been placed on the upper edge of the scopes to indicate north. These range markers are ten miles apart. It is 70 miles from the center to the outer edge of the scope. When only ground clutter appears at an observation it should be recorded as PPINE. This report will be transmitted if this is the first clear scope report following one or more reports of echoes (see ¶ A15610).

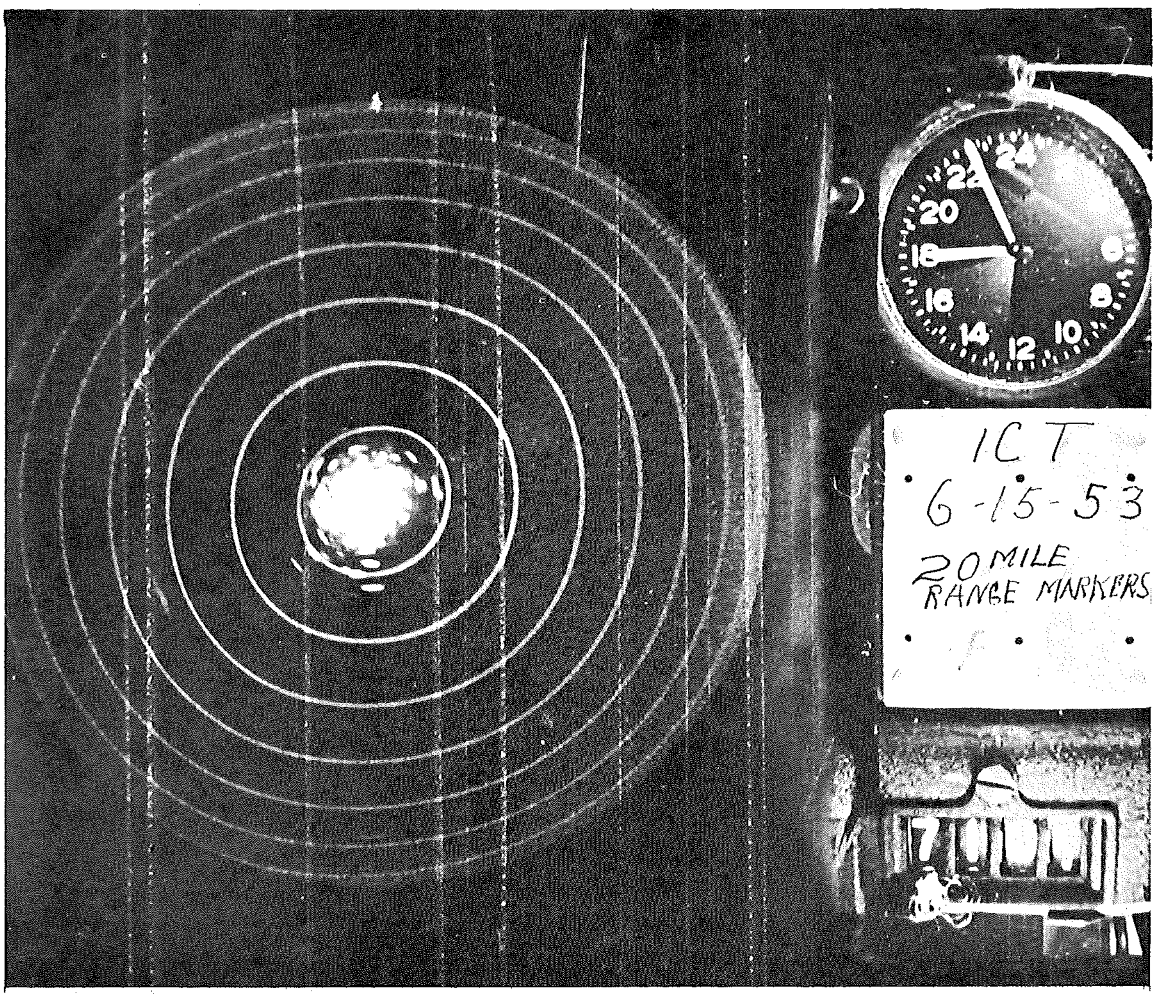

Fig. 6A. Ground Clutter.
Ground clutter may completely obscure all precipitation echoes within ten or more miles of the station. On this illustration the range marks are 20 miles apart. Most Weather Bureau radar scopes indicate distances in nautical miles, which must be converted to statute miles by the observer (see ¶ 3.2 and 4.8.3). Note: These illustrations have been selected for subject matter and the clock time shown on them does not indicate necessarily the required time of observations.

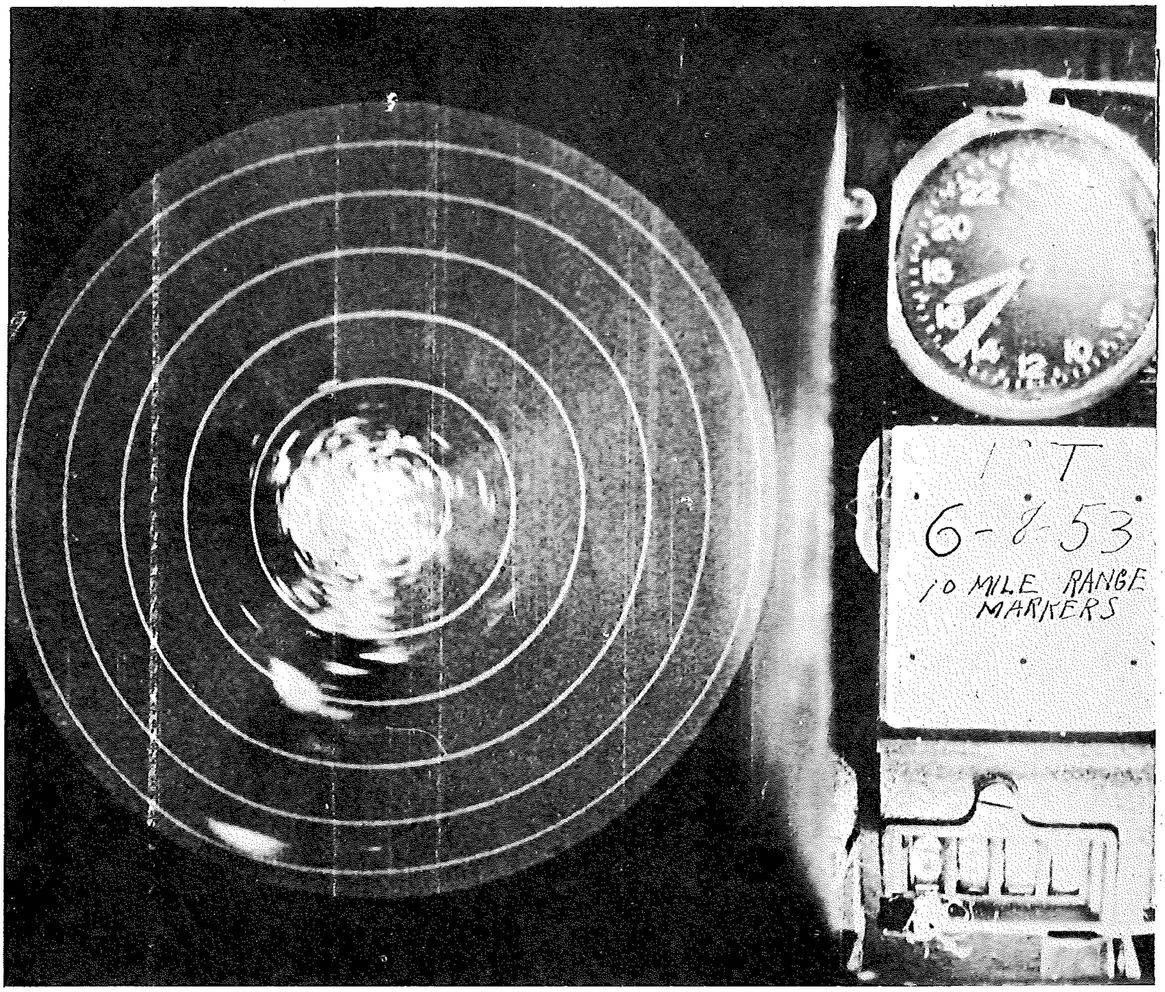

Fig. 7. Echoes Evaluated as Ellipses.

These echoes have been evaluated as ellipses, since the length of each echo is at least twice the width. Compare the ground clutter with Fig. 6. The two precipitation echoes are fairly bright for their range, indicating moderate intensity. The echo intensity should be checked on the A-scope also. A small area of light precipitation is developing at the end of the echo at 30 miles range (see Fig. 7A). The report would be coded as: ICT 081637C RAREP2 SLD MDT INCRG SSW/35 (30 nautical miles x 1.15 = 35 statute miles) VCNTY WELLINGTON ORNTD SE-NW 14 LONG 4 WIDE MOVG FM SW/18 HGT 210 SLD MDT INCRG SSW/63 ORNTD ESE-WNW 12 LONG 5 WIDE MOVG FM SW/20. (Remarks, if any, regarding pilot reports, verified hail, etc., are added to the end of the report.)

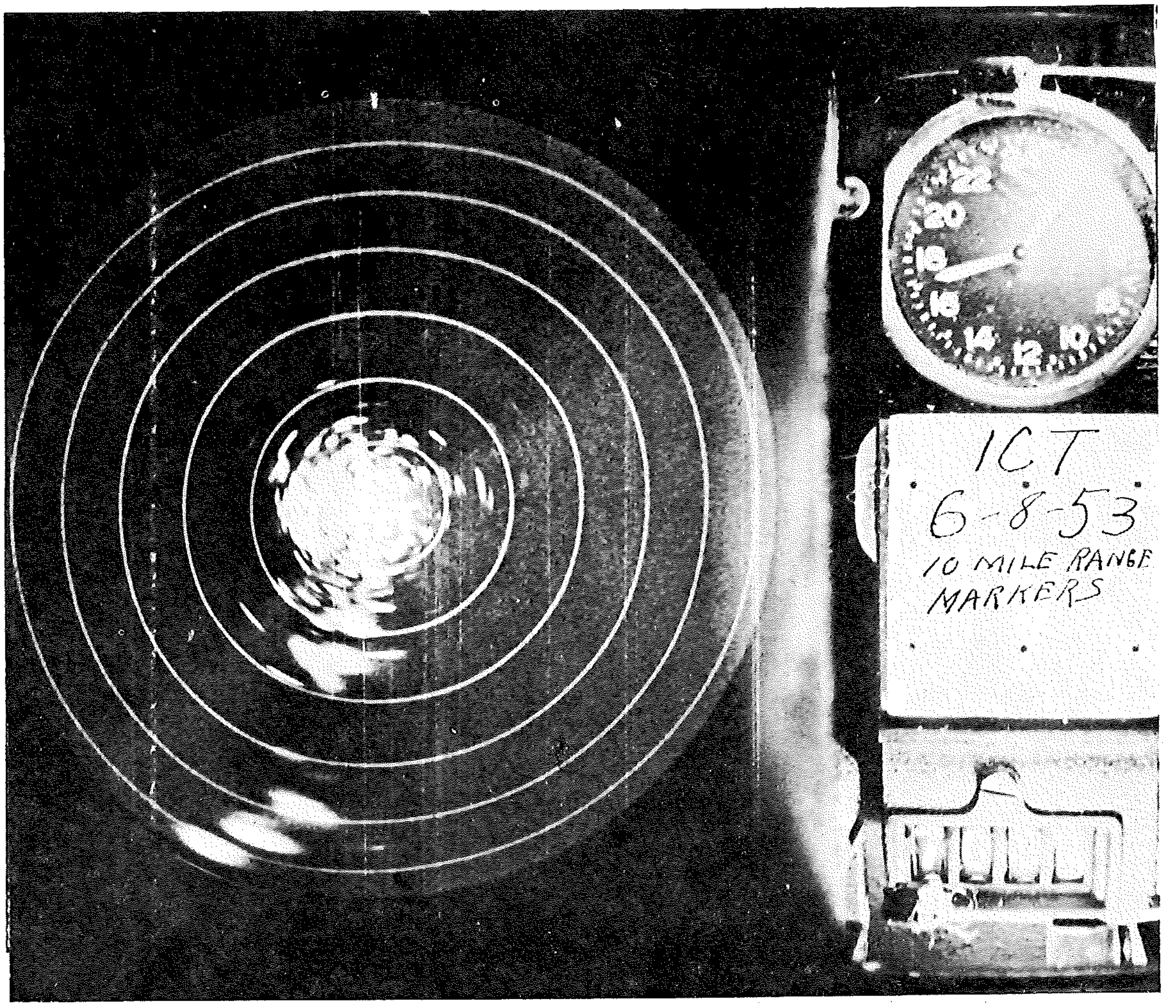

Fig. 7A. Echoes Evaluated as Ellipses.
This observation was taken 30 minutes after the observation illustrated in Fig. 7. The innermost echo (SSW/29) has increased in size and two more precipitation areas have developed or moved into range in the southwestern quadrant. The A-scope should be checked to confirm apparent increases in intensity (see Fig. 3). Owing to their proximity to each other, the three echoes in the lower portion of the scope will be evaluated as a group of scattered echoes (see ¶ A15307.1). Coded as: ICT 081706C RAREP3 SLD STG INCRG SSW/29 ORNTD ESE-WNW 15 LONG 7 WIDE MOVG FM SW/10 HGT 300 LINE SCTD STG INCRG SSW/63 ORNTD SW-NE 37 LONG 17 WIDE MOVG FM WSW/17.

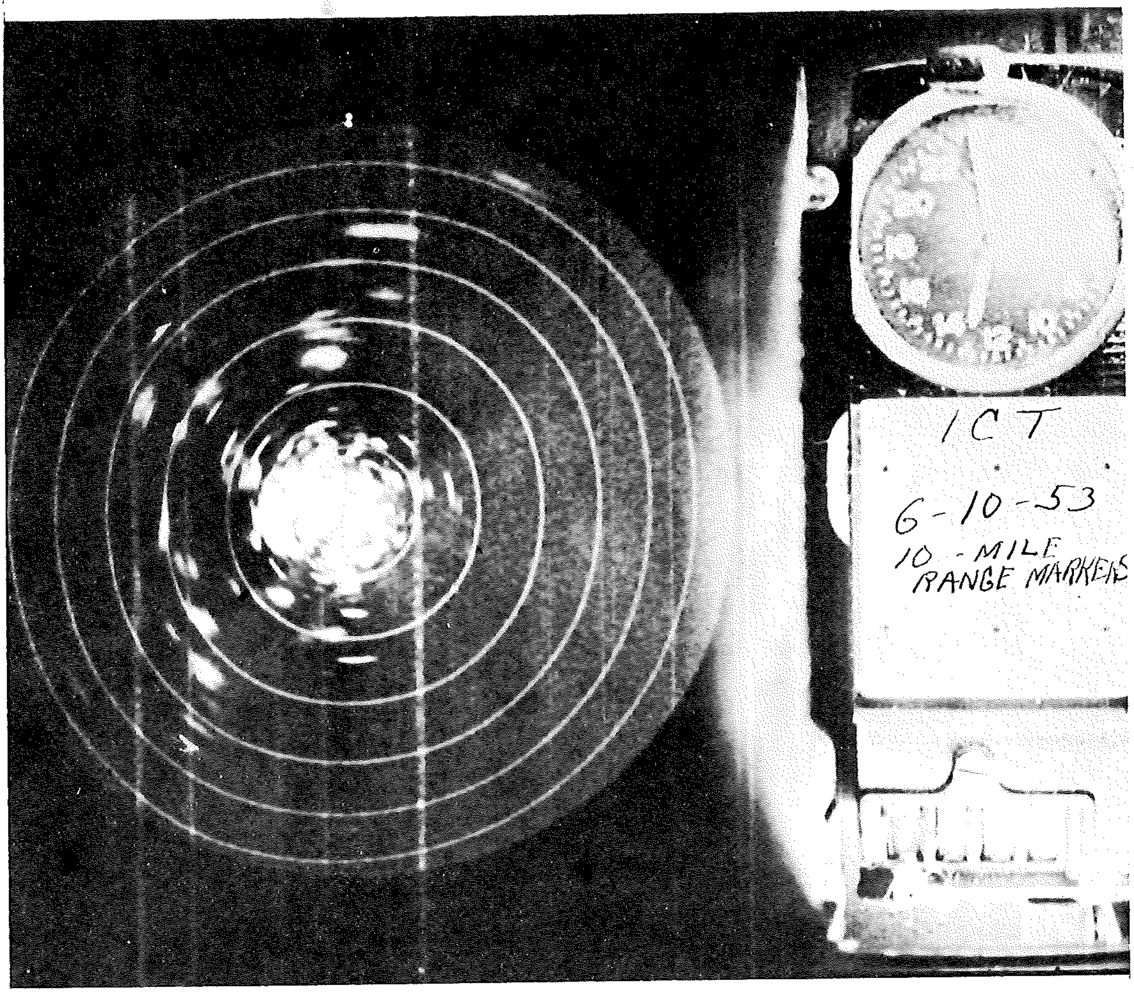

Fig. 8. Numerous Small Echoes.
These echoes are very small and too numerous and widely scattered to justify individual descriptions (see ¶ A15309). The echoes are located in the southwest and northwest quadrants and are scattered over an area extending from the station outward to an average distance of 54 statute miles. Code as: ICT 101258C RAREP6 SCTD MDT NO CHG MANY SML SCTD THRUT AREA XTNDG FM STN TO 54 MI RADIUS SW THRU W TO NNE MOVG FM SW/12.

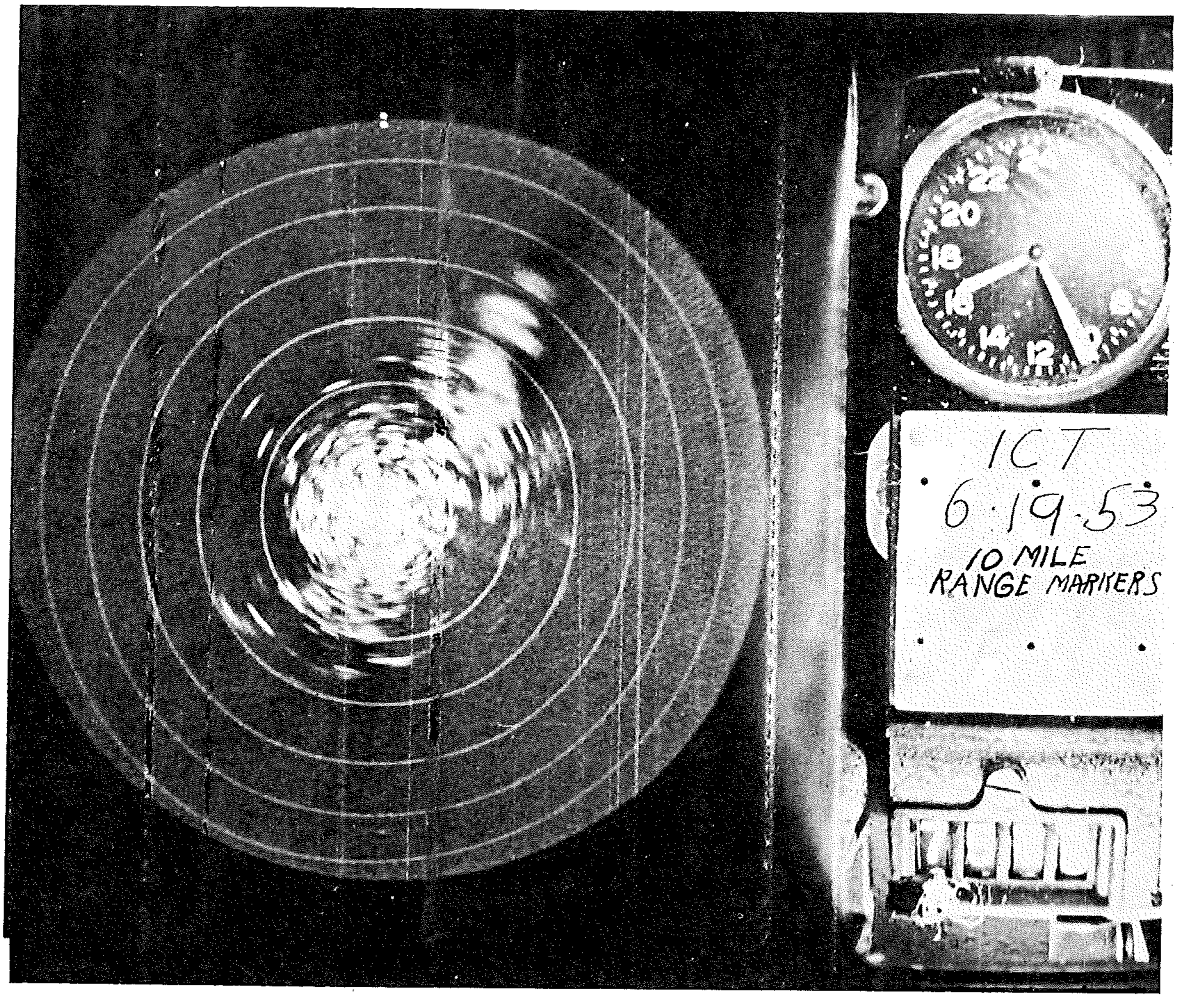

Fig. 9. Line of Scattered Echoes.

The most significant meteorological feature of a group of echoes should be retained, and, if possible, coded in one group. In this case, the larger echoes form a line of considerable importance to forecasters. The small scattered echoes may be added to the report as separate groups. Note that the ground clutter has increased owing to an increase of receiver gain; however, some precipitation echoes intermingle with the ground clutter (see Fig. 6). Code as: ICT 191626C RAREP7 LINE SCTD MDT NO CHG NNE/29 ORNTD SSW-NNE 40 LONG 12 WIDE MOVG FM NW/15 SCTD WK NO CHG E/29 DIAM 14 MOVG FM NW/15 SCTD MDT NO CHG N/28 ORNTD N-S 11 LONG 9 WIDE MOVG FM NW/15.

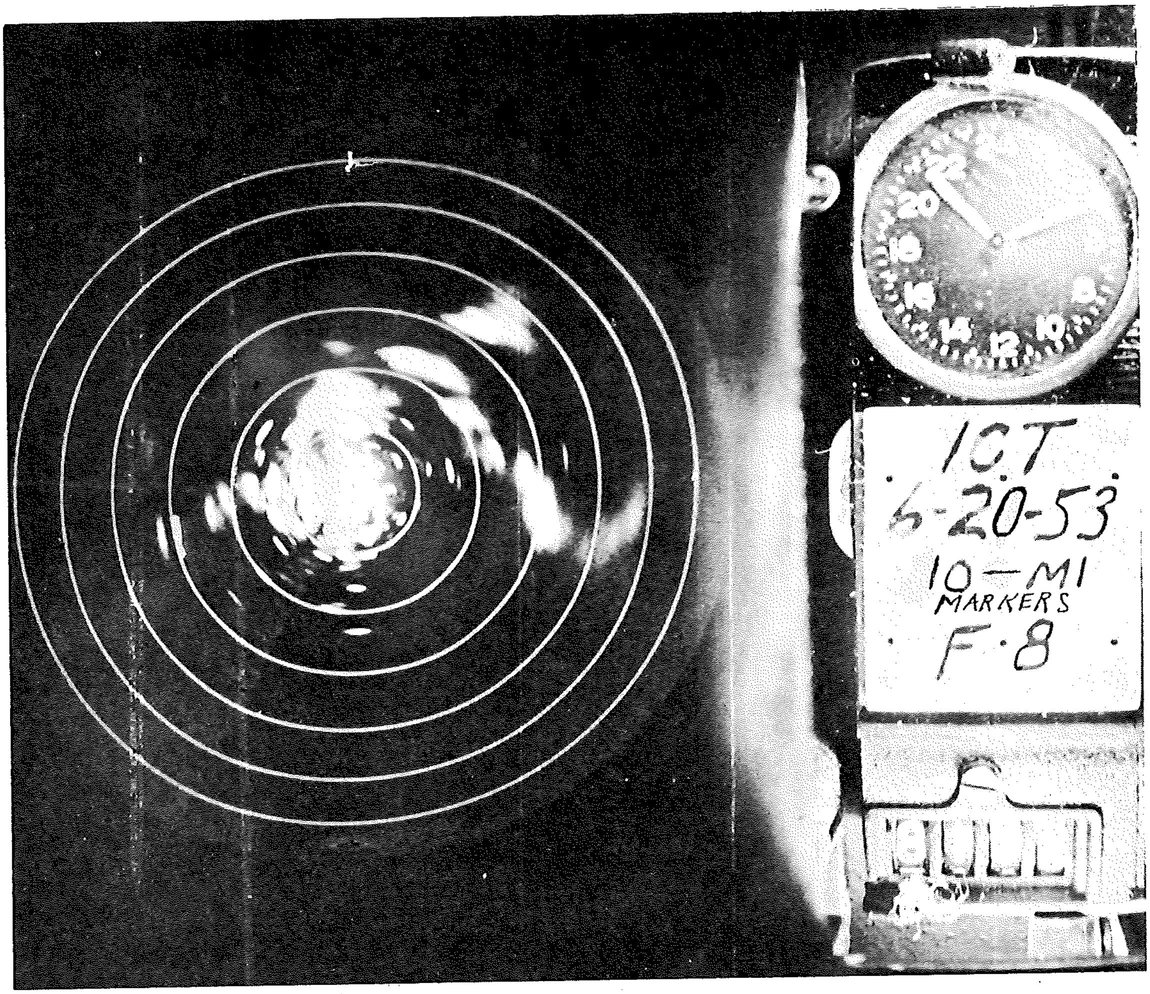

Fig. 10. Squall Line Echoes.

Echoes similar to these often accompany squall line activity. Several very small echoes have not been described in the report because they are relatively unimportant in a group of larger scattered echoes. Coded as: ICT 202111C RAREP9 SLD MDT INCRG SLOLY N/17 DIAM 15 MOVG FM N/18 LINE SCTD MDT INCRG SLOLY ENE/26 VCNTY EL DORADO ORNTD NW-SE 46 LONG 6 WIDE MOVG FM N/18 HGT 300 SLD MDT NO CHG NE/39 DIAM 11 MOVG FM N/18 SLD LINE WK DCRG SLOLY E/49 ORNTD SW-NE 15 LONG 8 WIDE MOVG FM N/18 LINE SCTD MDT NO CHG W/10 ORNTD SW-NE 15 LONG 3 WIDE MOVG FM N/18 SCTD WK NO CHG WSW/35 DIAM 3 MOVG FM N/18.

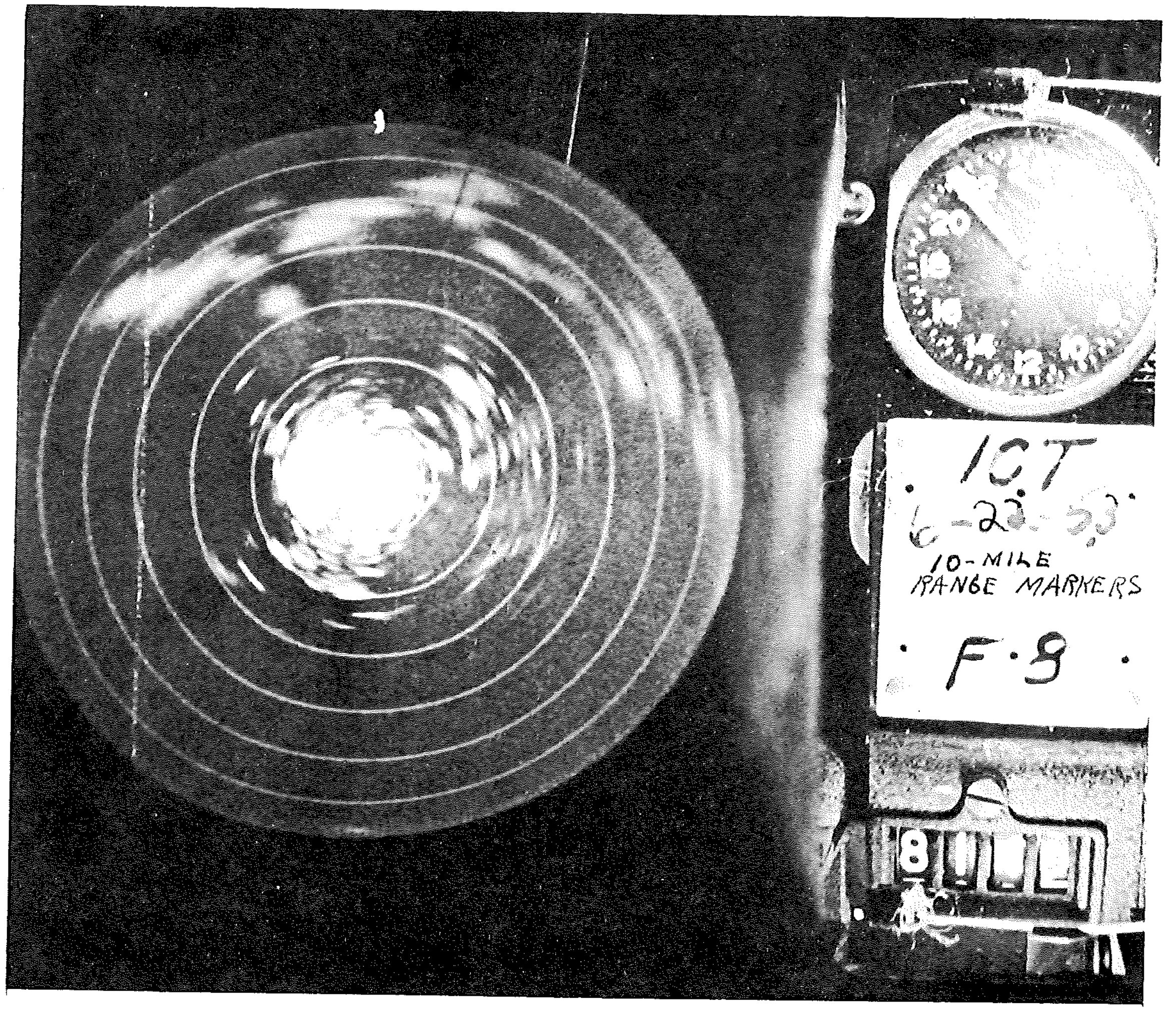

Fig. 11. Frontal Echoes.

A front with weak to moderate precipitation echoes is approaching the station from the north. The receiver gain has been increased to bring in the frontal echoes resulting in an increase in the amount of ground clutter (see Fig. 9). Two ellipses are used to describe the main portion of the front. Code as: ICT 220154C RAREP2 LINE SCTD MDT NO CHG NNW 52 ORNTD WSW-ENE 102 LONG 16 WIDE MOVG FM NW/25 LINE SCTD WK INCRG SLOLY NE 58 ORNTD NW-SE 85 LONG 13 WIDE STNRY SLD WK INCRG SLOLY NW/39 DIAM 6 MOVG FM N/25 SCTD WK DCRG E/25 ORNTD NNW-SSE 53 LONG 11 WIDE STNRY.

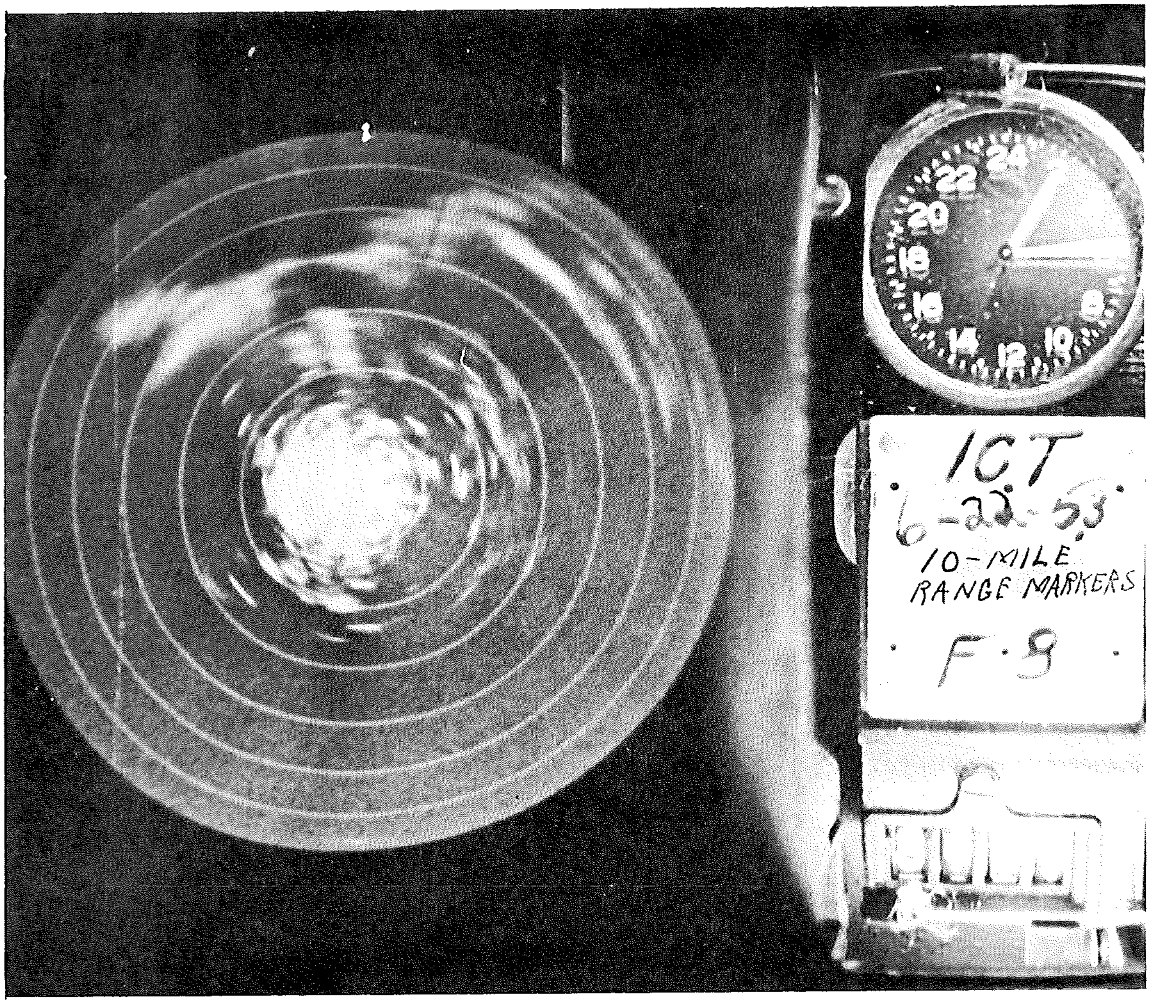

Fig. 11A. Frontal Echoes.

A portion of the front northwest of the station has advanced with a speed greater than 30 miles per hour. Therefore a special observation is required (see ¶ A15120(3)(b)). The section of the front northeast of the station appears to be weakening and to be moving from the southwest. A small wave may be forming on the front. Code as: ICT 220214C RAREP3 LINE SCTD MDT NO CHG N/46 ORNTD WSW-ENE 108 LONG 18 WIDE MOVG FM NW/32 HGT 220 LINE SCTD MDT DCRG NE/63 ORNTD NW-SE 82 LONG 13 WIDE MOVG FM SW/8 SCTD MDT INCRG N/29 DIAM 13 MOVG FM NW/25 HGT 200 SCTD WK NO CHG ENE/24 ORNTD NNW-SSE 40 LONG 10 WIDE NO MOVMT (Remarks) PTN FRONT NW STN MOVG RPDLY.

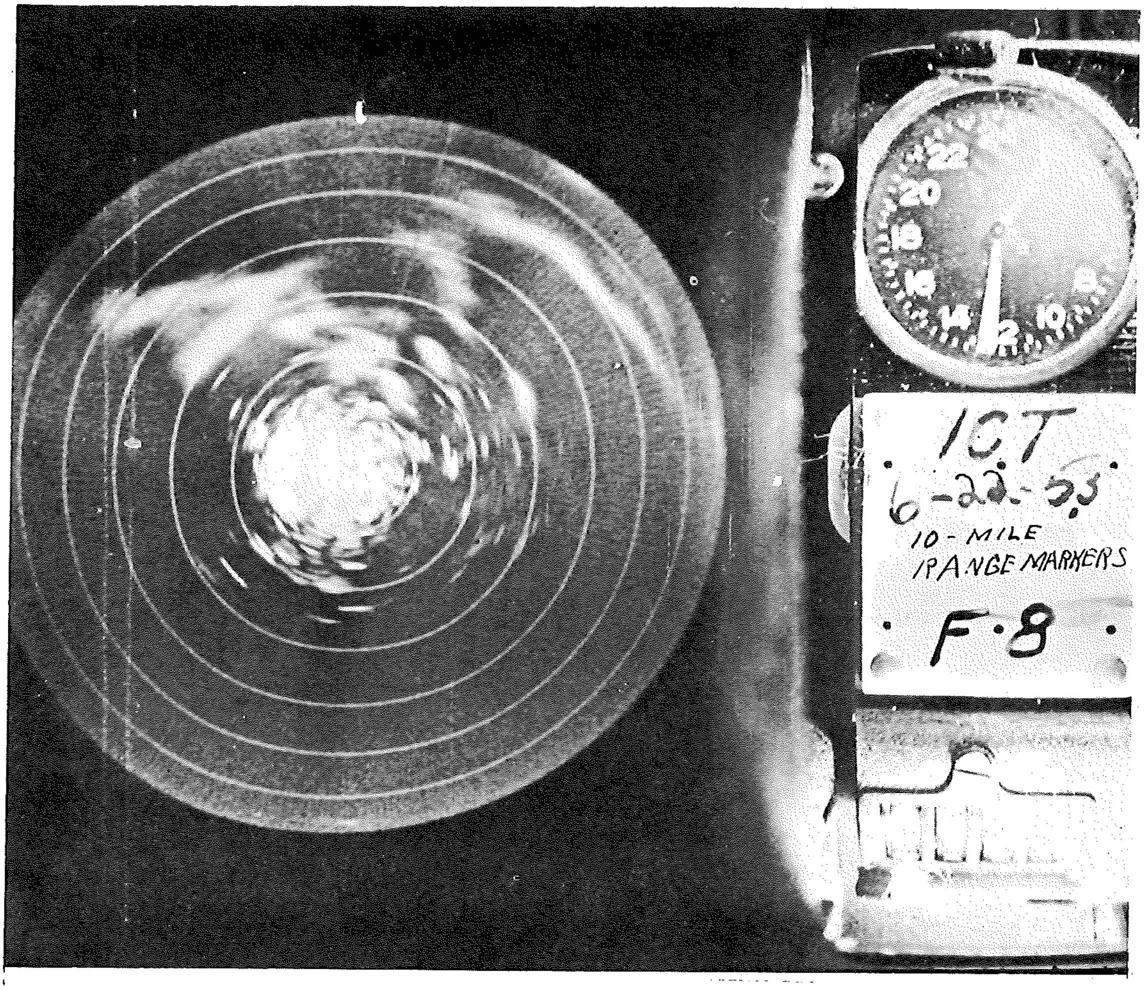

Fig. 11B. Frontal Echoes.

The fast moving sector of the front, also shown in Fig. 11 and 11A, has moved close to the station and the apparent wave to the north-northeast has become very sharp. The northern portion of the wave is weakening and moving out of range. The S-shaped front may be coded as: ICT 220231C RAREP4 LINE SCTD MDT INCRG N/22 HUTCHINSON TO NEWTON TO EL DORADO ORNTD WNW-ESE 110 LONG 24 WIDE MOVG FM NNW/25 HGT 240 SLD LINE WK DCRG NNE/41 ORNTD N-S 14 LONG 8 WIDE MOVG FM NW/25 SLD LINE MDT DCRG NE/60 ORNTD NW-SE 94 LONG 6 WIDE MOVG FM W/18.

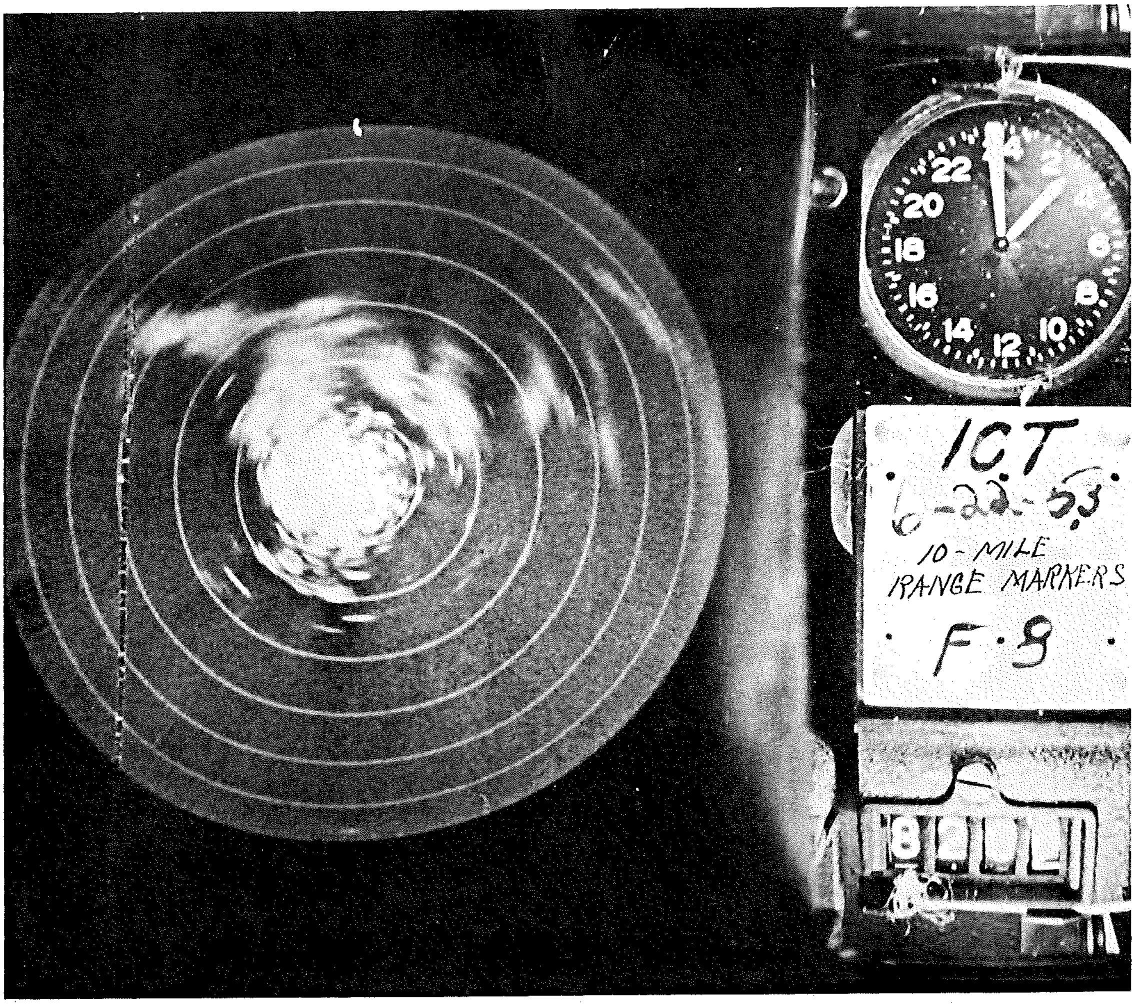

Fig. 11C. Frontal Echoes.

This observation was taken approximately one-half hour after the observation in Fig. 11B. The apparent wave has nearly disappeared from the scope. The heavy portion of the front may be described as one broad ellipse in order to preserve the frontal picture in the report. Code as: ICT 220258C RAREP5 LINE SCTD STG NO CHG N/20 ORNTD E-W 100 LONG 23 WIDE MOVG FM NW/25 LINE SCTD WK DCRG ENE/47 ORNTD N-S 25 LONG 3 WIDE MOVG FM NW/45 LINE SCTD WK DCRG NE/66 ORNTD NW-SE 42 LONG 3 WIDE MOVG FM NW/45.

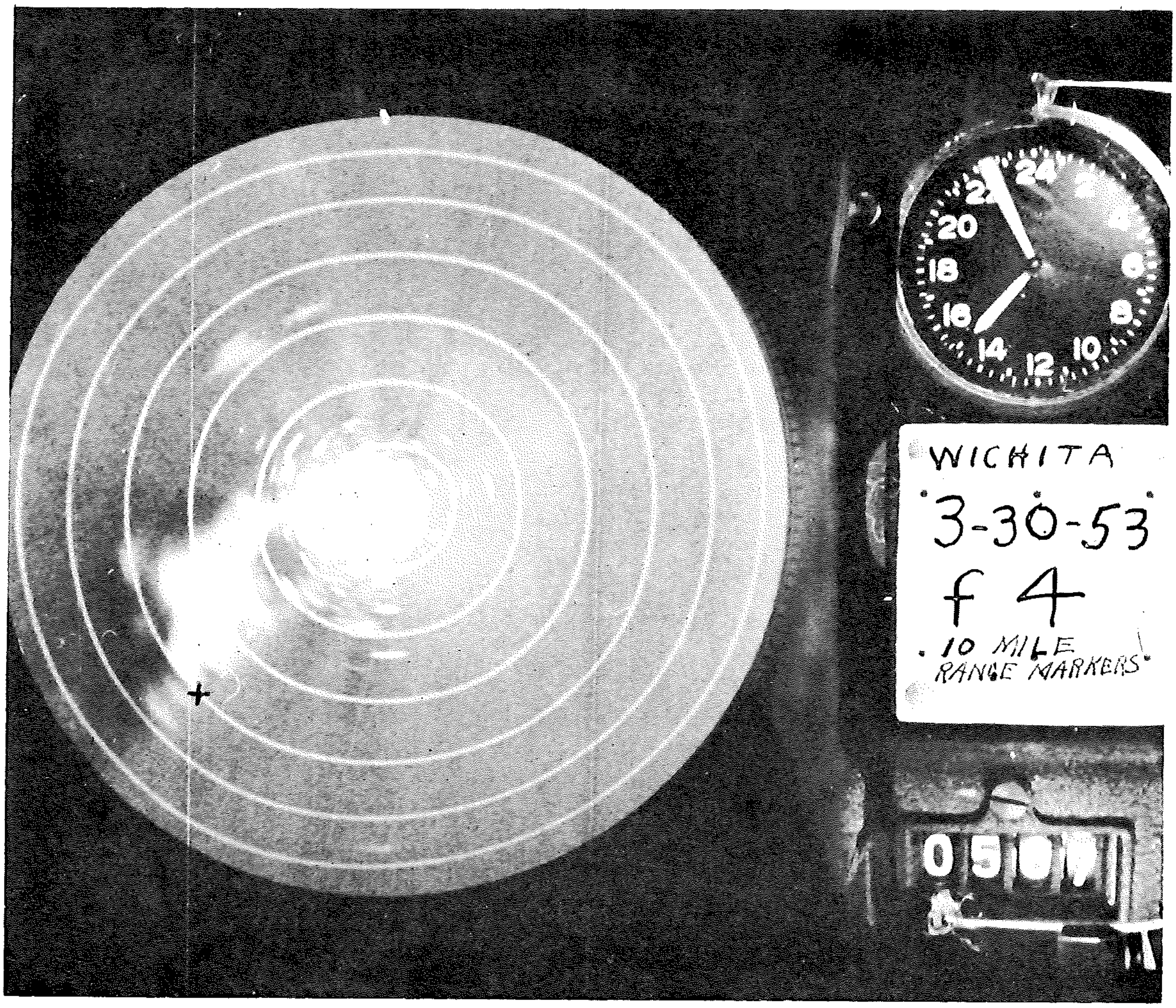

Fig. 12. Echo Accompanying a Tornado

Telephone calls verified the occurrence of a tornado at point "X" in connection with this thunderstorm. Warnings were given to areas in the path of the storm (see ¶ 2.1 and 7.1). RAREPS should be transmitted as "remarks" appended to special aviation weather operations in addition to their regular distribution (see ¶ A15611). Code as:ICT 301456C RAREP8 SLD STG NO CHG SW/34 OVR ANNESS DIAM 42 MOVG FM SW/25 HGT 300 SCTD WK DCRG NW/38 ORNTD SW-NE 23 LONG 5 WIDE MOVMT UNKN TORNADO LCTD SW/46 VCNTY HARPER 1445C.

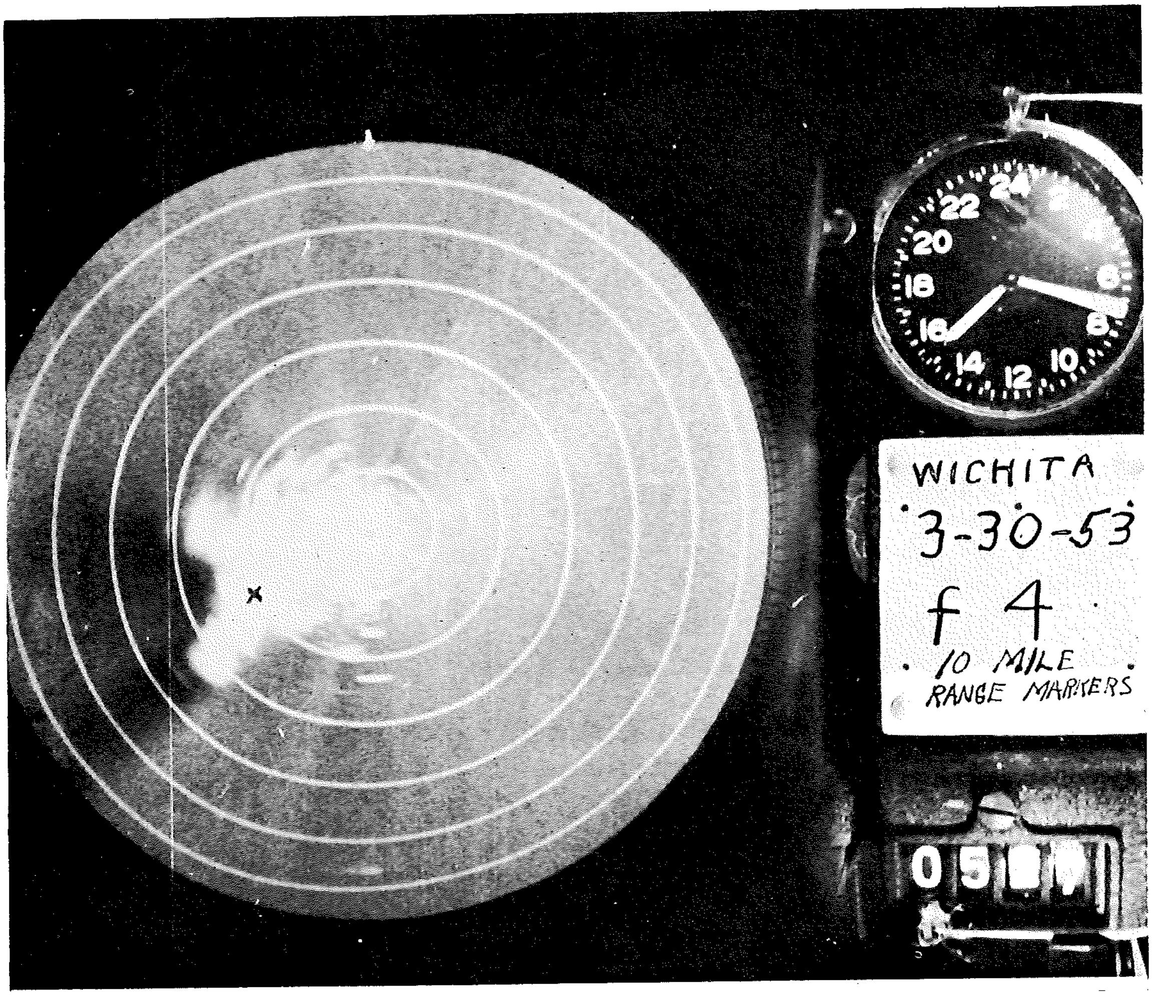

Fig. 12A. Echo Accompanying a Tornado.

As in Fig. 12. A telephone call located a tornado at point "X". Since more than one tornado may accompany a large area of thunderstorms, this may not be the same tornado as was reported in Fig. 12. In general, warnings should be given for the areas in the path of the thunderstorm, as the movement of a tornado funnel may be erratic. This report may be coded as: ICT 301518C RAREP9 SLD STG NO CHG WSW/21 DIAM 34 MOVG FM SW/25 TORNADO LCTD WSW/23 1515C.

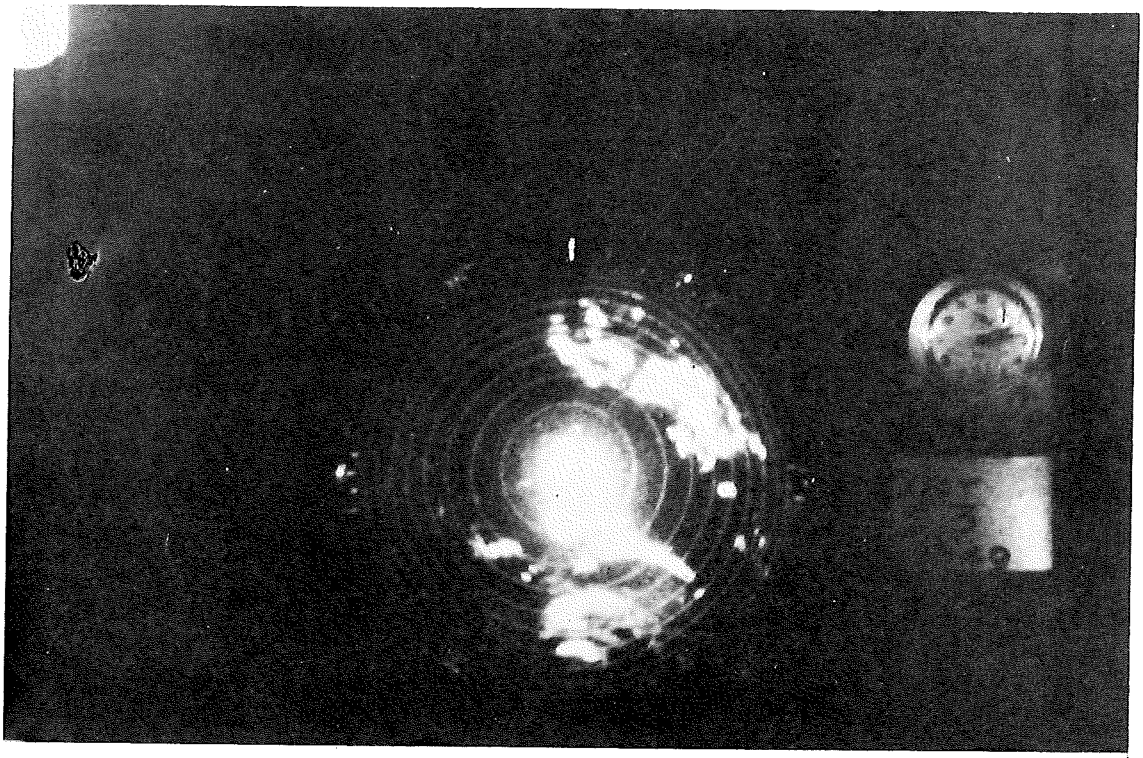

Fig. 13. Spiral Precipitation Bands.

These echoes are from precipitation bands associated with a hurricane approaching Freeport, Texas. These range markers are 20 statute miles apart. The spiral bands are located in the lower half of the scope, with the "eye" rather indefinite but apparently located near the bottom edge (see ¶ A15307.4). A general description of the storm and the location of the center should be given in aviation weather observations (see ¶ A15611). The report might be coded as: FREEPORT 031414C RAREP5 LINE SCTD STG NO CHG NE/90 ORNTD NW-SE 220 LONG 60 WIDE MOVG FM SSW/20 SLD SPRL BND STG NO CHG AZRAN 17/65 15/70 14/120 20 WIDE SLD SPRL BND STG NO CHG AZRAN 19/110 17/90 16/140 40 WIDE SLD SPRL BND STG NO CHG AZRAN 18/140 17/145 18 WIDE BNDS MOVG FM SSW/20 CNTR VCNTY 160 MI S.

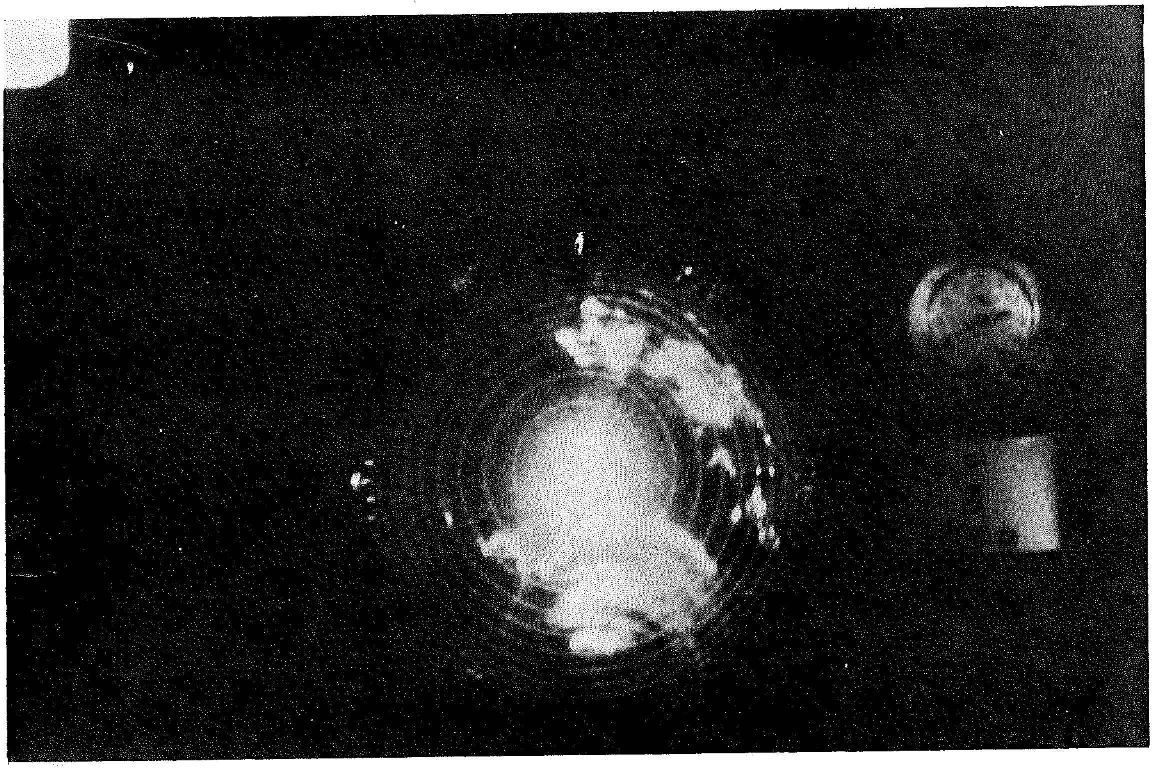

Fig. 13A. Spiral Precipitation Bands.

The hurricane bands are not as distinct as in Fig. 13, owing to a coverage of light precipitation between the bands. A slight reduction of the receiver gain may improve the definition of the bands in such cases (see ¶ 3.3). It was verified that all the precipitation occurring in connection with this storm was confined to the northeast quadrant of the hurricane, as shown by the precipitation bands in these photographs. Report coded as: FREEPORT 031440C RAREP6 LINE SCTD STG DCRG SLOLY NE/100 ORNTD NW-SE 285 LONG 70 WIDE MOVG FM SSW/20 SLD SPRL BND STG NO CHG AZRAN 13/130 16/40 22/75 20 WIDE SLD SPRL BND STG NO CHG AZRAN 17/70 20/70 10 WIDE SLD SPRL BND STG NO CHG AZRAN 16/150 17/85 20/110 30 WIDE SLD SPRL BND STG NO CHG AZRAN 17/130 20/110 15 WIDE SLD SPRL BND STG NO CHG AZRAN 17/140 18/140 20 WIDE BNDS MOVG FM SSW/20 CNTR VCNTY 150 MI S LGT PCPN AT STN AND BTN SPRL BNDS.

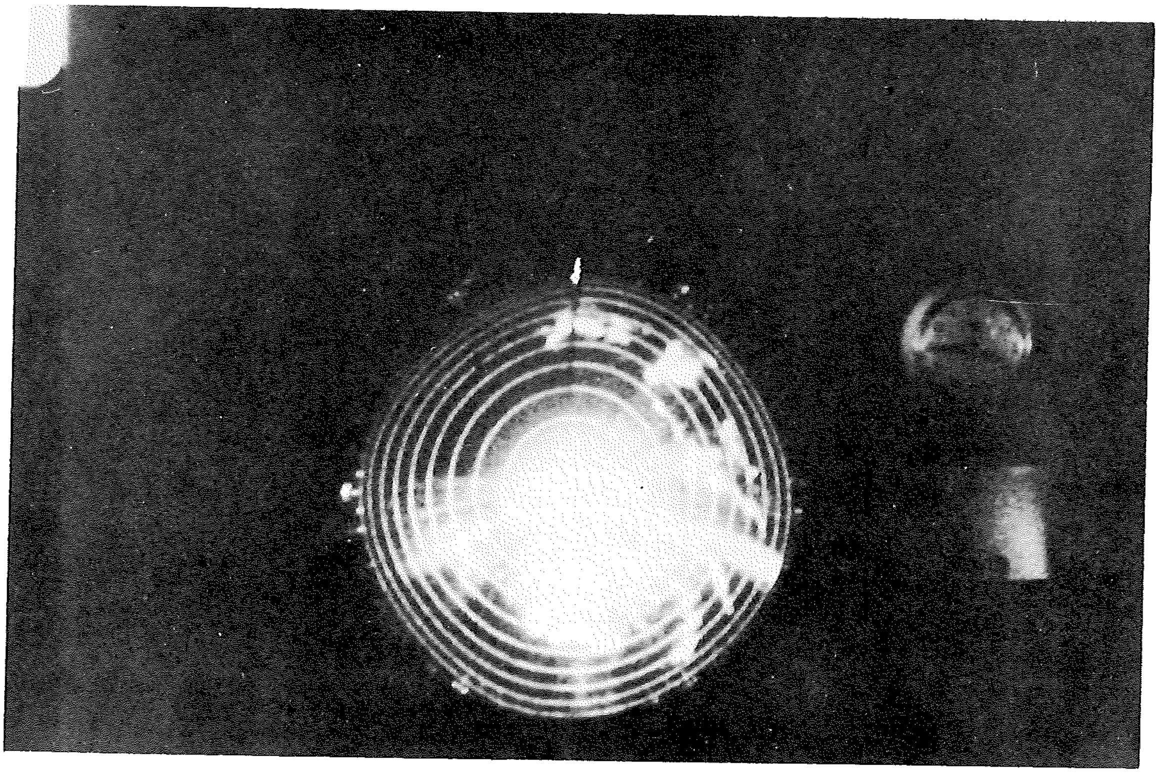

Fig. 13B. Spiral Precipitation Bands.
Moderate rain at the station and between the bands of heavy precipitation in the hurricane area obscures the central portion of the spiral bands. The radar station was closed down a few minutes after this observation was taken owing to dangerously strong winds. The individual spiral bands cannot be described in this case. However, a general description is possible. It is coded as: FREEPORT 031545C RAREP9 STG INDFT SPRL BNDS OF HURCN FILL SE QUAD FM STN TO ABT 170 MI CNTRD ABT 130 MI S OF STN MOVG FM S/20 LINE SCTD MDT DCRG SLOLY NNE/120 ORNTD NW-SE 150 LONG 45 WIDE MOVG FM S/20 HVY R STG WND AT STN OBSNS DSCONTD TIL HURCN CNDS IPV.

APPARENT HEIGHT OF RADAR ECHOES

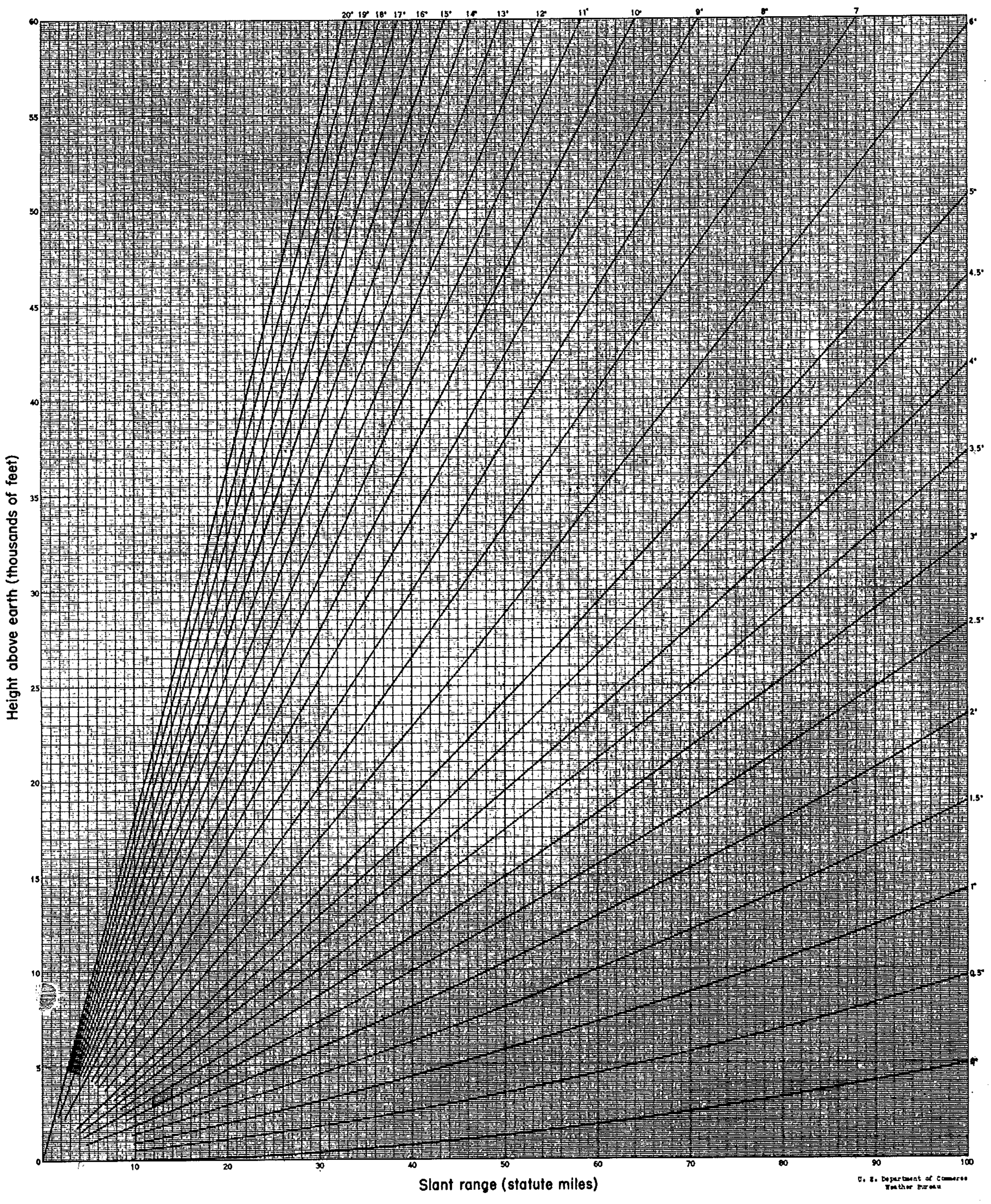

Fig. 14. Height Computation Chart.

The height of the echo above the level of the station is found at the intersection of the curve representing the elevation angle and the ordinate representing the slant range. The height of the 0° curve above the baseline indicates the curvature of the earth. This value is not subtracted from the height of the echo.

RADAR WEATHER OBSERVATIONS, LAND STATION

Station WICHITA, KAN. Type of Radar APS-2F Month and Year JUNE 1953

Date	Time C S.T.	RAREP No.	Description of Return: Character	Intensity	Tendency	Position of Echo: Distance	Direction	Orientation	Location	Length	Width or diameter	Movement: Direction	Speed (mph)	Height 100's ft. (MSL)	Remarks (Enter data not transmitted in parentheses)	Operational status	Initials
04	1005															PPINE	DW
04	1305															PPINE	DW
04	1605															PPINE	FW
04	1645	1	LINE SCTD	MDT	INCRG	100	NNW	NE-SW	BEAVER TO MANCHESTER	75	15				(camera on 1645C)		FW
04	1728	2	LINE SCTD	MDT	NO CHG	80	NW	NE-SW	HODSON TO GYPSUM	80	15	NW	20				FW
—			SLD	MDT	NO CHG	50	N		NR MARION		5	NW	20				FW
04	1825	3	SLD	MDT	NO CHG	80	NW		NR CHASE		6	NW	20				FW
—			SLD LINE	MDT	DCRG	120	NW	E-W	RUSSELL TO WESTFALL	40	5	UNK					FW
04	1907	4													(camera off 1907C)	PPINE	FW
04	2030	5	LINE SCTD	MDT	INCRG	60	WNW	NW-SE	SLYVIA TO ARLINGTON	18	8				(camera on 2028 C)		FW
04	2125	6	SLD	MDT	NO CHG	75	NW		NR FALUN		8	SW	30				FW
04	2150	7	SLD LINE	STG	NO CHG	120	SW	NW-SE	NR CURTIS	15	4						FW
04	2225	8	SLD LINE	STG	NO CHG	100	SW	NW-SE	NR WAYNOKA	20	7	NE	25		(camera off 2230 C)		FW
04	23[illegible]6	9	SLD LINE	STG	NO CHG	70	SW	NW-SE		20	8	NE	60				ZZ
04	2335	10	SLD LINE	STG	NO CHG	45	SW	NNW-SSE	20 W ARGONIA	20	10	NE	50	480			ZZ
05	0008	1	SLD LINE	STG	NO CHG	20	SW	NW-SE		20	7	NE	50				ZZ
05	0107	2	LINE SCTD	MDT	DCRG	30	S	N-S		120	50	NE	35				ZZ
05	0212	3	SLD LINE	MDT	NO CHG	50	SE	N-S		100	10	UNK		260	(camera on 0214C)		ZZ
—			SLD LINE	MDT	INCRG	30	W	N-S		120	15	UNK		250			ZZ
05	0350	4	SCTD	MDT	INCRG SLOLY		COMPLETE	CIRCLE	AROUND ICT	RADIUS	70	MI	FROM		STATION		ZZ
05	0432	5	SLD LINE	MDT	NO CHG	35	SE	NE-SW		80	20	UNK		280			ZZ
05	0505	6	SLD LINE	MDT	DCRG	50	SSE	NE-SW		70	20	NW	20				ZZ
05	0532	7	LINE SCTD	WK	DC RG RPDLY	60	SSE	NE-SW		100	30	UNK			(camera off 0531C)		ZZ
05	0605	8														PPINE	DW
05	0755	9	LINE SCTD	WK	DCRG	80	NW	NNE-SSW	N GREATBEND TO NE PRATT	50	6	UNK					DW
—			SLD LINE	WK	DCRG	85	SE	NE-SW	E COFFEYVILLE	20	5	UNK					DW
05	0835	10														PPINE	DW
05	1130	11	SLD LINE	WK	UNK	90	SE	NE-SW	NR BARTLESVILLE	20	5	UNK					DW
05	1200	12														PPINE	DW
05	1405															PPINE	FW
05	1554	13	SLD	STG	UNK	50	S		NR BRAMAN		20	SW	10	320	(camera on 1554 C)		FW

Direction to 16 points of the compass.
Distance to the nearest statute mile.

Length and width to nearest statute mile.

Fig. 15. Recording form for radar weather observations.

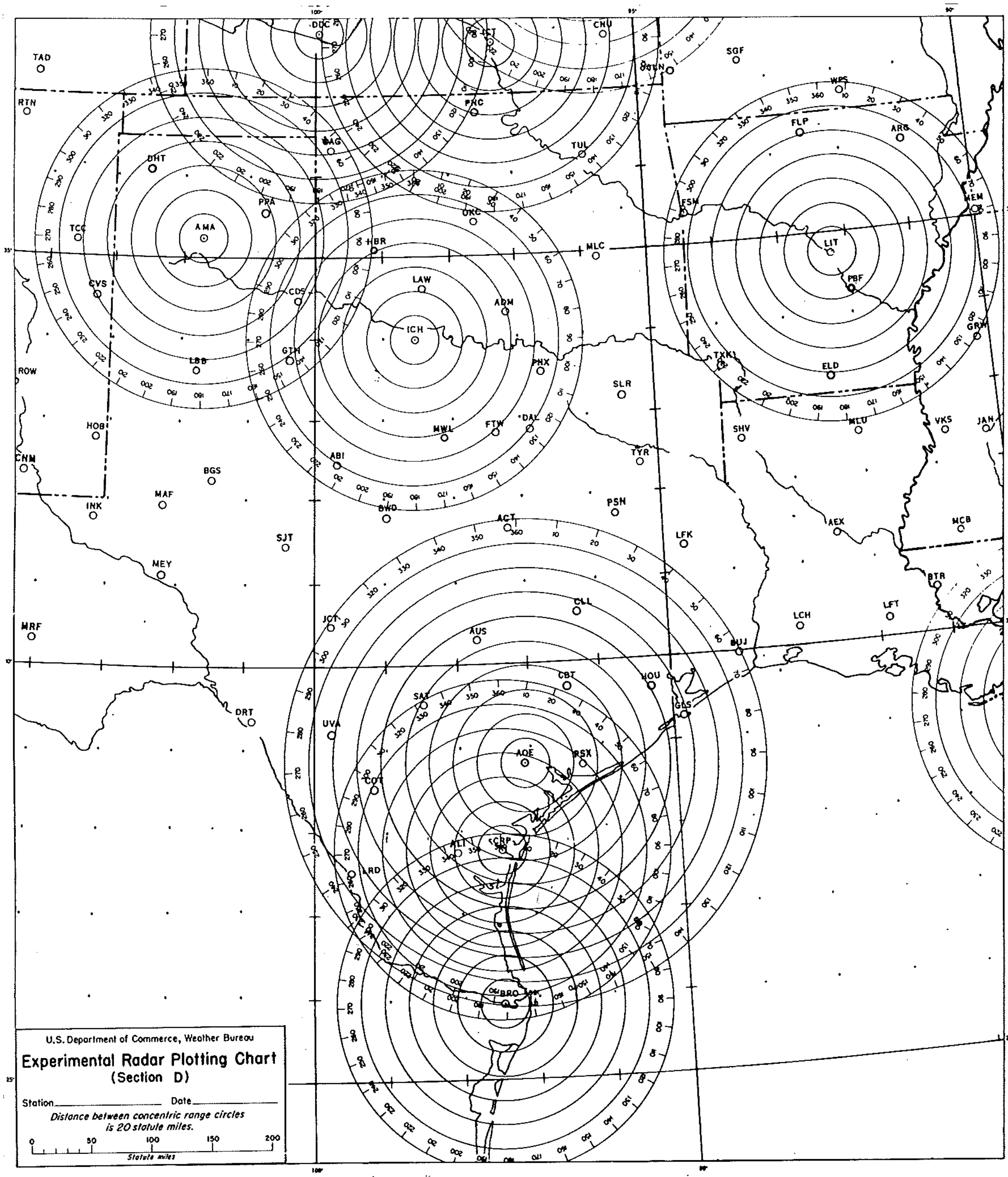

Fig. 16. Radar Plotting Chart.
Similar charts have been prepared for other sections to facilitate the plotting of radar reports.

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U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

Training Paper No. 10

Training Guide in Radar Meteorological Observations

Weather Bureau Training Papers

No. 1. Hurricane Notes, July 1948.

No. 2. Lectures to Professional Interns, 1946–1947, March 1949.

No. 3. Introducing the New Observer to the Weather Bureau, April 1949.

No. 4. Training the New Observer, April 1949.

No. 5. Primary Training Manual for Supplementary Aeronautical Weather Reports, April 1949.

No. 6. Training Guide in Pilot Balloon Observations, March 1951; revised May 1, 1951.

No. 7. Training Guide in Rawins and Rabals, March 1, 1951.

No. 8. Training Guide in Radiosonde Observations, March 1, 1951; revised January 1952; revised June 1952; revised July 1953.

No. 9. Training Guide in Surface Aviation Observations, July 1951.

No. 10. Training Guide in Radar Meteorological Observations, September 1953.

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, Secretary
WEATHER BUREAU
F. W. Reichelderfer, Chief

Training Paper No. 10

Training Guide in Radar Meteorological Observations

Prepared by
Station Facilities and Meteorological Observations Division

Washington, D. C.
September 1953

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LIST OF ILLUSTRATIONS

INTRODUCTION

This guide has been prepared to assist in training observers and forecasters in the use of radar for weather search. The guide is intended to be used as a source of supplemental information by the observer-in-training while he is under the supervision of trained personnel at the station. In addition, it is intended that the guide should be used by forecasters to increase their knowledge of the possibilities and limitations of the use of radar in weather forecasting.

The guide consists of a summary of the basic principles of radar, general operational techniques, and examples of analysed weather situations as viewed by radar. Owing to the complicated nature of the equipment, detailed operational instructions have been omitted where it would be advisable for the observer to acquire the necessary knowledge by observation, personal training, and by reference to appropriate technical and maintenance manuals. This guide is specifically designed for use with the modified APS-2F radar, as used by the Weather Bureau. However, the general information is applicable to all types of radar .

References with the prefix "A15" refer to paragraphs or figures in Chapter A15 of the Addendum to Circular N, e.g., ¶ A15301. Reprints of Chapter A15 have been issued as separate manuals without changing the paragraph numbers. In the event of any seeming conflict between this manual and Chapter A15 of Circular N, the instructions of Chapter A15 will be followed.

We are indebted for some of the information in the guide to Technical Report No. 20, "The Use of Radar in Weather Forecasting", by Mr. Hal Foster of the Massachusetts Institute of Technology.

1.0. BASIC PRINCIPLES OF RADAR

1.1. General.--Radar (radio direction and ranging) equipment consists essentially of a directional radio transmitter and a radio receiver. The transmitter sends forth brief pulses of energy which are radiated from the antenna in a directed beam as the antenna rotates through 360° of azimuth. If the energy strikes any reflecting object, either meteorological or nonmeteorological, some of the reflected energy is picked up by the antenna, detected by the radar receiver, and indicated on the radar scopes (osciloscopes) as an "echo". The APS-2F radar has two scopes: the Plan Position Indicator (PPI) and the A-scope.

1.2. PPI-Scope.--The PPI-scope, with range and azimuth coordinates (see Fig. 1 and 2), presents a plot of the horizontal cross section of any echo of sufficient reflecting power that falls within the preselected range of the radar beam. When echo signals are detected and amplified, they are luminously displayed on the screen of the PPI-scope. A radial sweep line, beginning at the center of the screen and sweeping outward to its edge, revolves on the screen face like a spoke in a wheel. These revolutions are synchronized with the rotations of the antenna. When an echo signal is received, the sweep line brightens at some point along its length, depending upon the distance to the object and the range setting of the equipment. Estimation of distance is aided by electronic range markers on the indicator sweep line which, owing to the revolving action of the line, appear as concentric circles. These circles usually indicate radial distance in nautical miles from the center of the screen, which represents the position of the antenna. The long-persistence characteristic of the screen causes luminous spots to continue to glow until the sweep line completes its revolutions and again brightens the screen at these points. (Note: Nautical miles may be converted to statute miles by multiplying the distance on the scope by 1.15).

1.3. A-Scope.--The A-scope (see Fig. 3) indicates the signal strength against range along the sweep of the beam at the azimuth and elevation

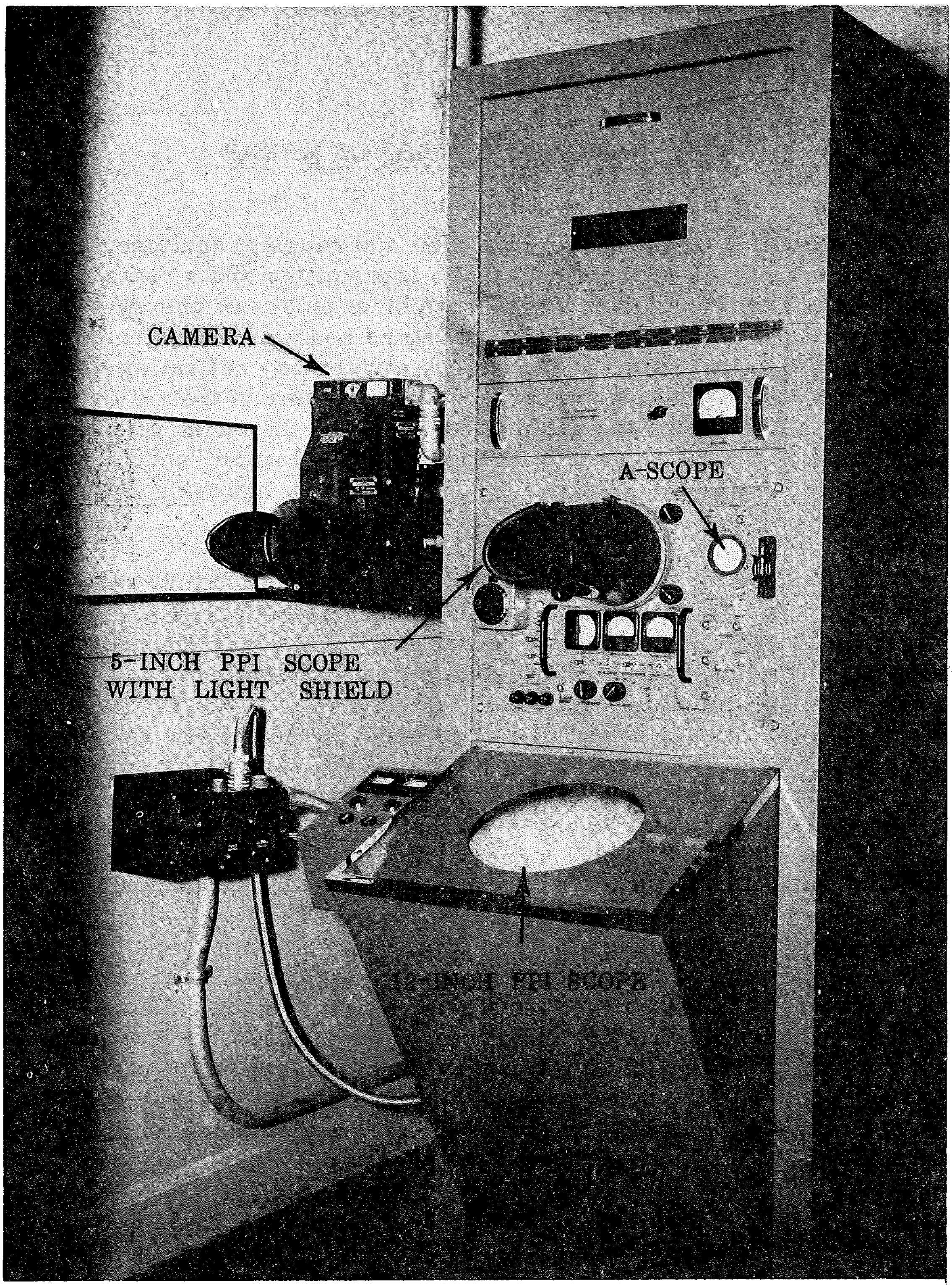

Fig. 1. Radar console with special camera attached.

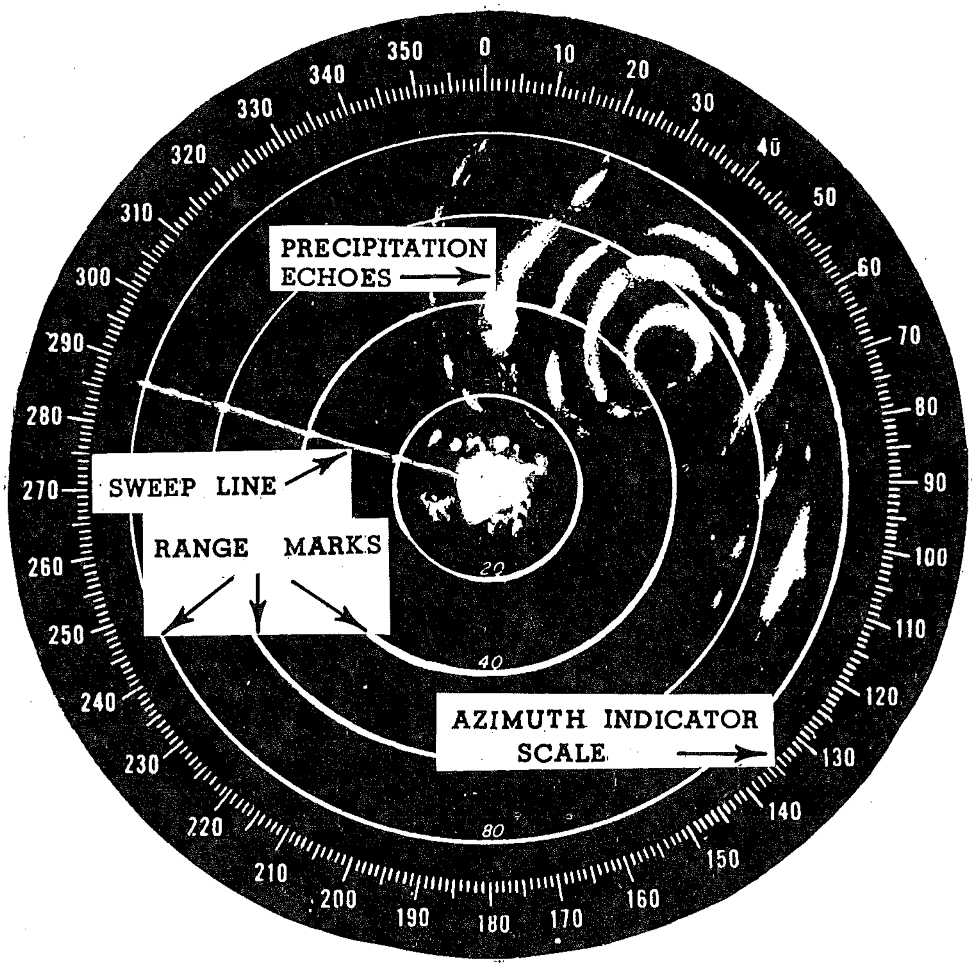

Fig. 2. Diagram of PPI-Scope.

As the sweep line revolves about the center of the scope it generates upon it continuous range marks corresponding to the range setting. The sweep line also indicates the location of an echo-producing target by brightening at a point on its length corresponding to the range of the object. The azimuth angle of this point corresponds to the azimuth angle of the target in relation to the radar antenna. At the points where the sweep line brightens, the screen of the scope continues to glow until the sweep line passes over the area again, thereby presenting a continuous picture of the target.

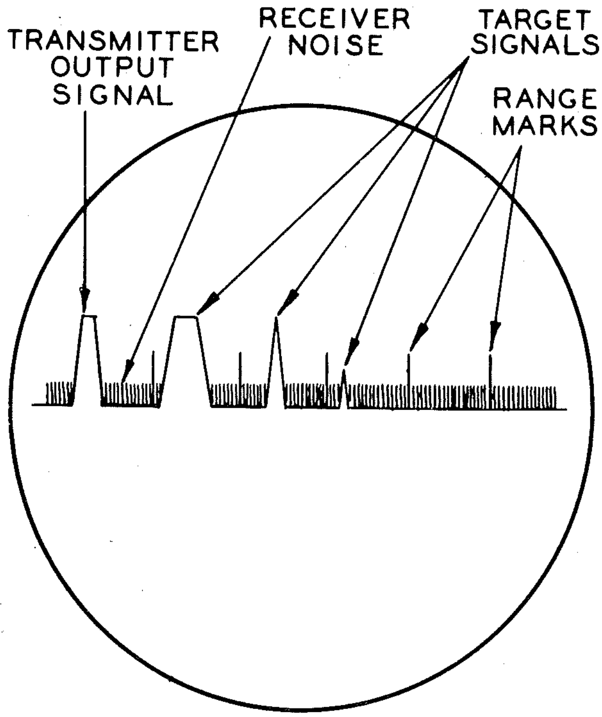

Fig. 3. Diagram of A-Scope.

The flat-topped target pulse indicates that a signal of saturation intensity is being received from a target at that range. The height of this pulse has been limited by the height of the A-scope screen. A reduction in receiver gain will reduce the height of the echo until the top becomes visible, when the true size of the echo can be determined. However, the receiver gain should not be reduced except for momentary intensity tests, if the reduction results in the loss of other echoes from the A-scope or PPI-scope. Returns from stationary targets near the station (ground clutter), not shown in the diagram, may obscure the pulse of the transmitter output signal. The range marks will represent the same distance as those on the PPI-scope and will change with the range selected.

angle at which the antenna is pointed at the time. The height of the signal above the baseline is a measurement of the strength of the reflected signal. Rapid fluctuations of the image may occur and cause a hazy appearance. This is an indication that the strength of the signal is changing rapidly as the antenna rotates. On the A-scope, receiver noise or interference has the appearance of "grass" along the baseline. It varies in height and may obscure small echoes. When the signal reaches a maximum and exhibits a flat-topped appearance on the A-scope, it is called a "saturated" signal (see Fig. A15-1). On the PPI-scope, a saturated signal appears as an echo of maximum brightness.

1.4. Meteorological Echoes.--The strength of meteorological echoes depends upon the size and quantity of the water drops in the area observed and the range of the echoes. It has been determined that the amount of scattering of the beam of energy from a spherical particle is proportional to the sixth power of the diameter of the particle. Accordingly, one drop of water 2.0 mm. in diameter will give a return equivalent to 4096 water drops of 0.5 mm. in diameter. For this reason, thundershowers, with their usual large raindrops, will give much brighter echoes than light rain with its relatively small drops. It is apparent that the radar will not detect all clouds, but will detect regions where the water drops are large enough to be classed as precipitation, although the precipitation may not reach the ground.

1.4.1. Owing to differences in the electrical characteristics of water and ice, the radar return for spherical particles of equal mass is approximately five times greater for water than for ice particles. The reflectivity of nonspherical ice particles does not vary greatly from that of spherical particles of the same mass. Therefore, the radar return from snow or sleet will usually be less than for rain of the same intensity of precipitation. For this reason, echoes received from areas above the freezing level may be weak and poorly defined. However, one exception to this rule has been noted, namely that large wet hailstones return a very bright echo.

1.4.2. In order to receive a detectable return from a small target at a range of 150 miles, for example, a great amount of energy must be transmitted in the radar beam. Owing to the large areas covered, only a very small portion of the transmitted power ever strikes a particular target. The energy which does strike a target is reflected nearly uniformly in all directions. Therefore, only a minute portion of the reflected energy will return to the radar antenna. It has been determined that this loss of reflected power is directly proportional to the fourth power of the range of the target. One result of this range attenuation effect is that an echo from an object at long range will not appear as bright as the echo from a similar object at a shorter range.

1.4.3. During periods of extremely heavy precipitation, radar equipment with a wave length of 3.2 cm. will be attenuated to some degree. Precipitation attenuation is defined as the loss of energy due to absorption and scattering by raindrops. The outbound energy suffers attenuation as it advances through the precipitation and, in the same manner, the returning reflected energy is attenuated as it returns to the antenna. Accordingly, precipitation patterns beyond areas of heavy rain may not appear on the PPI-scope of 3.2 cm. radar sets. However, precipitation attenuation is negligible for ten cm. sets. Note: APS-2F radar sets have a wave length of ten cm. Attenuation through snow is negligible at any wave length owing to the low index of absorption of ice.

1.5. Beam Width. -- The conical beam of energy transmitted from the 30-inch antenna used on some APS-2F sets is approximately 9° in diameter. The beam from the 72-inch antenna used on modified sets is approximately 3.5° in diameter (see Fig. 4). The following table indicates the approximate diameter of the beams at various ranges.

Beam	Range, Miles				
	20	40	60	80	100
3.5°	6,500 ft.	13,000 ft.	19,000 ft.	36,000 ft.	33,000 ft.
9°	16,500 ft.	33,000 ft.	49,000 ft.	66,000 ft.	82,000 ft.

It is evident from the table that two precipitation areas at a range of 100 miles will appear as one if they are less than 33,000 feet apart, when the 3.5° radar beam is used. These data indicate that the detailed definition of echoes decreases rapidly with distance. A solid line at long range may break into small individual echoes as the precipitation approaches the station. This occurrence is owing to the effect of the beam width and does not indicate a dissipating system, unless the intensity has decreased also as the line moved (see ¶ 3.3). Conversely, a line of scattered echoes at close range may appear to merge and become a solid line as the disturbance moves away from

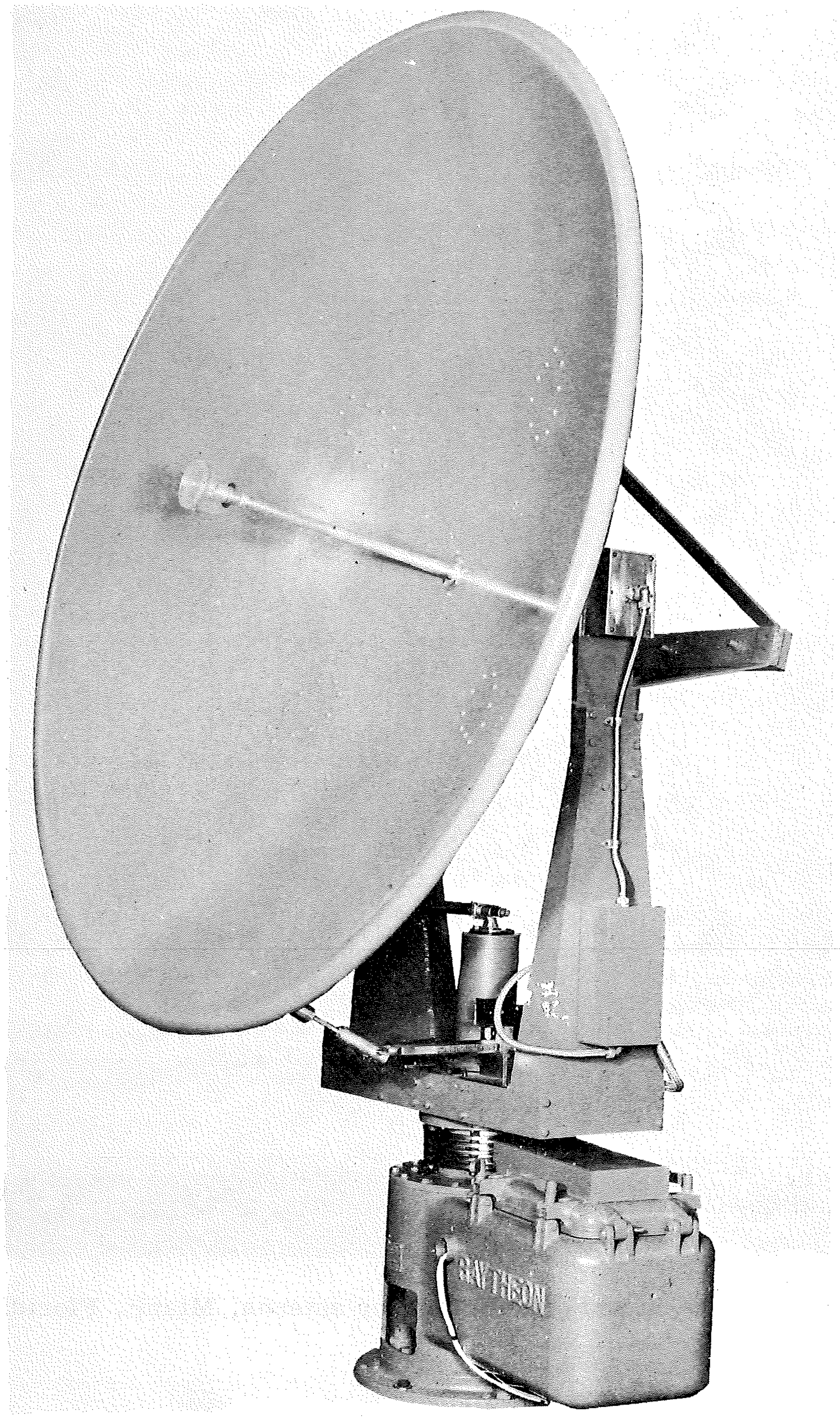

Fig. 4. 72-inch antenna.

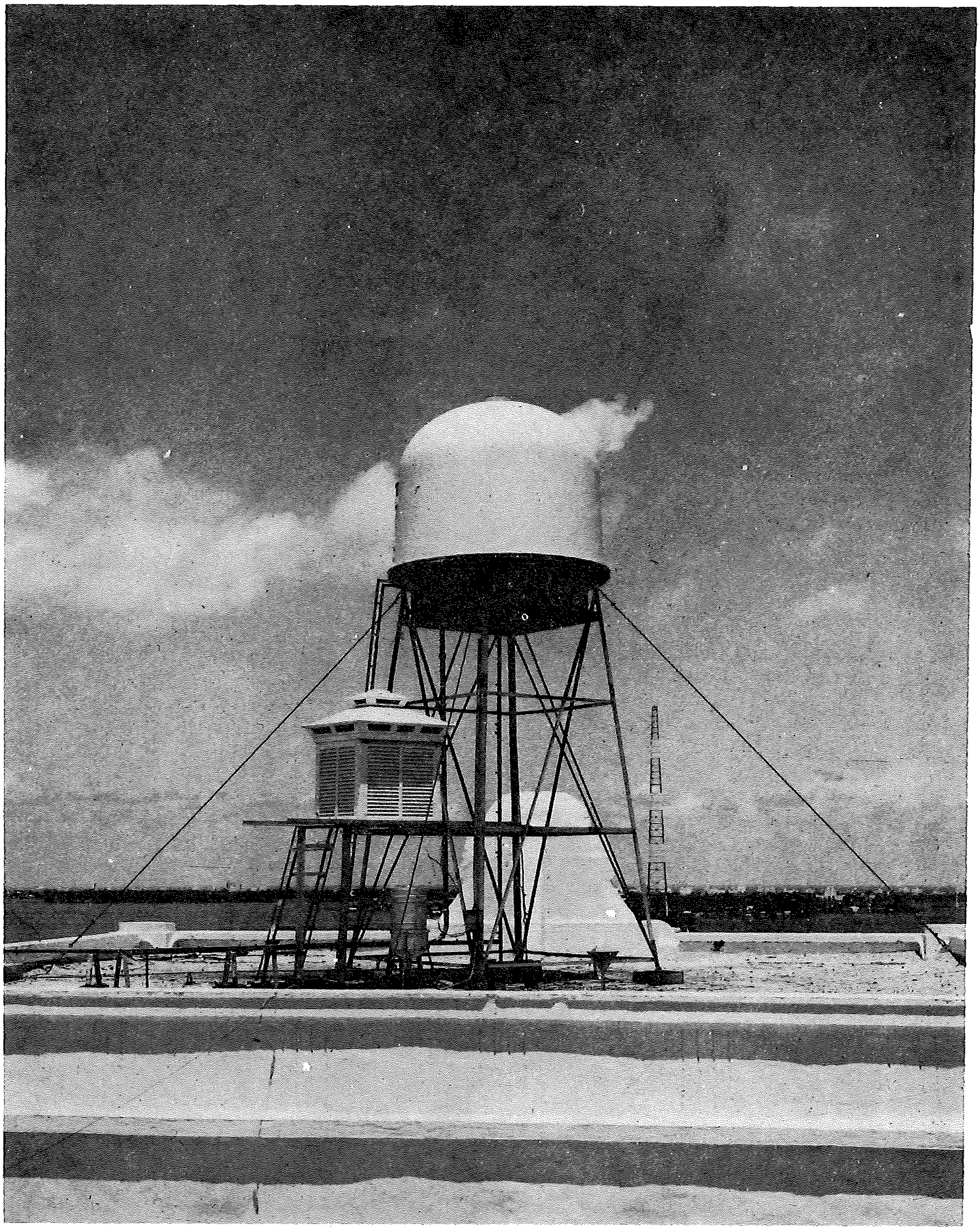

Fig. 5. Tower and dome for radar antenna, Miami, Florida.

the station. The loss of detail owing to beam width must always be taken into consideration by forecasters when comparing the character of echoes. However, observers should always report the character of an echo as it appears on the scope.

2.0. USE OF RADAR IN WEATHER OBSERVING AND FORECASTING

2.1. General. --Radar has been responsible for a big step forward in our knowledge of weather phenomena. It permits the meteorologist to study the inner structure of storms and thereby increases his forecasting ability. It also helps to prevent the unexpected, with a large saving in the loss of life and property. Experience in hurricane detection and warning has shown that the destruction caused by the storms can be reduced by 60% when warnings are given to the people in the areas where the storm is expected to strike. With respect to tornadoes, the saving of human lives will be most important.

2.2. Weather Patterns. --Briefly, storms and precipitation of interest to the radar operator usually occur as follows:

1. In bands of weather called "fronts" which move across the country from west to east.
2. In a squall line which may precede the fronts.
3. In isolated cells.

Each of these types of weather produces a typical echo pattern that can be distinguished on the radar scope. In other words, it is possible to tell whether the echo is from a single thunderstorm, or a line of thunderstorms, or an extensive area of precipitation (see Fig. 7 to 13). Since the intensity of the radar echoes depends upon the amount of precipitation accompanying the storm, it is also possible to estimate the severity of a particular disturbance from the brightness of its echo in comparison with other echoes at the same range. Therefore, by observing the radar scope, the observers can actually "see" the type and intensity of the weather approaching the station. This is extremely important in forecasting the exact area likely to be affected by severe storms, such as tornadoes. When tornadoes are forecast for a general area, as is the usual procedure when meteorological conditions are right for their development, each thunderstorm is watched carefully. If the thunderstorm becomes unusually intense, a tornado may develop from it. Under these conditions, the approach of a severe thunderstorm might result in the issuance of warnings to areas in the path of the storm.

2.3. Tornado Echoes.--It may not be possible to tell from the appearance of a radar echo whether a tornado is occurring in connection with a severe thunderstorm. However, when the presence of a tornado is verified by telephone calls to or from the affected area, its path can be watched on the radar scope and warnings issued to areas in the storm's path (see Fig. 12 and 12A). This method is more effective than observation by eyesight alone, since the storm may pass through the regions where it would not be reported until it actually entered a residential area.

2.4. Reports.--Radar weather reports are given by teletypewriter to other weather stations. These reports may be plotted on special maps and the movement and development of storms watched over the entire region (see Fig. 16). Pilots also make use of radar weather reports when making their flight plans, and when changing their plans while in flight to avoid weather disturbances.

3.0. RADAR OPERATION

References: (1) Handbook of Maintenance Instructions for U. S. Weather Bureau Search Radar

(2) Chapter A15 of Circular N, 6th Edition (revised), sections A15100 and A15200

3.1. General.--Detailed technical operational instructions will not be given in this text, since the complicated nature of the equipment requires that the operator receive personal training under the supervision of an experienced operator. A careful study of the reference material will be helpful.

3.2. Range Setting (See Fig. 2B of Maintenance Instructions).--The range should be adjusted to the lowest value possible for the echo being observed. For example, when the echo is within 25 miles of the station, more details will be evident if the range is set at 25 miles instead of at 50 or 150 miles. Unless a special calibration has been made, all Weather Bureau radars are calibrated in nautical miles. After the range switch has been turned to the desired value, it may be necessary to adjust the sweep amplitude in accordance with operating instructions. The sweep amplitude may be adjusted to expand the range scale and any echoes on the scope. One complete sweep of the PPI-scope will be required before the echoes will conform to the new range setting.

3.3. Adjustment of Receiver Gain.--The receiver gain may be adjusted to indicate the relative intensity of echoes. When the receiver gain is reduced the weakest echoes will fade out. Continued reduction will leave only the strongest echoes on the scope. In this way, the centers of greatest activity can be located for each area. Conversely, an increase in receiver gain may bring in echoes not observable at normal settings. In general, many details of the precipitation areas or storm cells may be disclosed by increasing and then decreasing the gain. Such details are not always apparent from variations in the intensity of the echoes at constant settings, especially at long ranges. For example, in frontal activity, the thundershowers may be hidden in the general mass of precipitation which may obscure a large area; however, when the receiver gain is reduced, the areas of light precipitation will fade out and the shower will become more apparent. This information will be useful as follows: a) in determining the true nature of the front, b) in guiding aircraft, c) in forecasting areas of maximum precipitation and high winds and, d) in research. However, allowances must be made for range attenuation when judging the strength of echoes (see ¶ 1.4.2). A slight increase in the background light on the scope may accompany the increase in receiver gain. This light, known as "electronic noise", may be subdued by reducing the scope intensity. This usually affects the background light to a greater extent than it affects the signal, since the background has a smaller amplitude than the signal.

3.3.1. Adjustment of the receiver gain will provide additional details on the A-scope. In general, the relative intensities of echoes can be judged with greater accuracy when the signal does not saturate the A-scope. A saturated signal extends to the top of the A-scope and becomes flat so that its true height or intensity cannot be compared with other echoes (see Fig. 3). When the receiver gain is reduced enough to prevent saturation of the scope, an estimation of relative intensities can be made by comparing the heights of echoes at comparable ranges. It should be noted that electronic noise will increase on the A-scope as the receiver gain is increased. At times the noise level may be high enough to obscure the true echoes. However, preference should be given to the appearance of the echoes on the PPI-scope.

3.4. Effects of Location. -- The location of the radar antenna near any obstruction with a higher elevation than the antenna's, such as towers, buildings, and hills, will result in the blocking off of targets beyond the obstruction. The blocking will extend through the azimuth angle subtended by the obstruction. For this reason, radar antennas are usually located on special towers above all prominent obstructions (see Fig. 5).

3.4.1. "Ground clutter" is present on the scopes of most radar sets. It consists of an irregular stationary echo covering the first few miles of range around the center of the scope (see Fig. 6 and 6A). The ground clutter is caused by a small amount of the transmitted pulse feeding back through the receiver and by echoes from local obstructions. The echoes will still be present, although reduced slightly, when the elevation angle of the antenna is increased.

3.4.2. Each station should prepare a map of all prominent hills, mountains, lakes, or coast lines within a range of 250 miles of the radar antenna (reference ¶ A15301). The location of buildings, towers, etc. more than five miles from the radar antenna need not be shown on the map unless echoes from these objects have been noticed on the scopes. Transparent overlays for the large PPI-scope can be constructed at each station if certain basic rules are followed. It is known that the range markers on most of the scopes are not linear. Therefore, it is necessary to have lock-in points on all of the range markers and to adjust the sweep sensitivity each time to fit the overlay. It is also important that the range markers be perfect circles. If they are ellipses, the technician can make the necessary adjustments to correct the trouble. Transparent overlays should be constructed as follows:

1. Obtain several sheets of clear plastic with a thickness of one-sixteenth inch or less.

2. For each range setting, cut an overlay the size of the large PPI scope from the plastic. The overlay should fill the face of the scope in order that the plastic will not slip sideways. Small strips of rubber tape placed at intervals on the outer edge of the overlay will help to prevent slippage and rotation.

3. Adjust the sweep sensitivity until the outermost range marker is at the outside edge of the scope.

4. Make reference marks on the overlay at 0° (north) on each range circle.

5. When precipitation echoes are not present, adjust the receiver gain of the radar to the average operating setting, and etch in the outlines of the various ground clutter echoes with a sharp instrument. Black ink may be applied to the etched lines. The location of towns, etc., may be marked on the overlays when the locations are checked with an aeronautical chart.

6. Repeat steps 3, 4, and 5 for each range setting using a new overlay each time. Clearly label each one.

The overlays should be used as follows:

1. Place the overlay, corresponding to the range setting in use, on the PPI-scope with the reference marks on 0°.

2. Adjust the sweep sensitivity until the range circles correspond to the respective reference marks on the overlay.

3. Change overlays to correspond to changes in the range setting.

3.5. Abnormal Echoes (Reference ¶ A15303).--Occasionally, under certain conditions, unusual echoes may appear on the radar scopes.

3.5.1. Ducting.--The phenomenon known as "ducting" results from propagation of the radar beam, which may be bent so that it intercepts targets which are normally below the horizon. Ducting usually occurs in connection with a sharp temperature inversion at low levels. A marked increase in temperature with height or decrease of humidity, or both, is necessary. Such conditions occur when warm dry air overruns a shallow layer of cool moist air. If these conditions are present, echoes of hills, mountains, or other high objects, which are normally just below the horizon, may appear. Suspected echoes should be carefully checked. Since echoes resulting from ducting may be from stationary objects, the presentation on the PPI- and A-scopes will be steadier and sharper than precipitation echoes. Ducting may improve the detection of distant precipitation echoes, since the portion of the precipitation column below the horizon will return enough energy to increase the intensity of the normal echo.

3.5.3. Sea Return.--Under certain conditions, stations near a coast line may experience echoes known as "sea return". These echoes appear very much like precipitation echoes on either the PPI- or A-scopes. However, the location of the echoes and their persistence in one section of the scope, if meteorological phenomena are not expected in that area, should identify the echoes as sea return.

4.0. OBSERVATION AND EVALUATION OF ECHOES

References: (1) Chapter A15 of Circular N, 6th Edition (Revised), sections A15100, A15200, and A15300

(2) Handbook of Maintenance Instructions for U. S. W. B. Search Radar, Fig. 2A and 2B

4.1. General.--Frequent radar observations are required in order that precipitation echoes can be detected at the earliest possible moment. When echoes are observed, continued observation is necessary to check their development and movement. Since a few minutes are required to start the radar equipment and place it in operation, instructions specify that the radar will not be turned off when echoes are present. However, when the scopes are not being watched continuously, the set may be placed in stand-by operation. This is accomplished by turning the transmitter filament switch to "Off" for a second and then back to "On". The scopes may be placed in operation again by momentarily pressing the transmitter high voltage switch to "Start" and then adjusting the range and receiver gain for best results (see ¶ 3.2 and 3.3).

4.2. Character of Echoes (Reference ¶ A15304).--Echoes must be classified in order that a reasonable description of them can be transmitted over teletypewriter circuits. Therefore, radar-echo patterns are classified as scattered echoes, solid echoes, line of scattered echoes, solid line of echoes, and echoes in a spiral band.

4.2.1. Scattered Echoes.--A group of echoes close together, but not forming a line or spiral will be described as "scattered echoes". In general, the distance between the echoes must be less than the distance through the largest echo; otherwise, individual echoes should be described (see Fig. 8 and 9).

4.2.2. Solid Echo.--Individual echoes, either isolated or separated from other echoes by a distance greater than the distance through the largest echo in the group, will be described as a "solid echo" (see Fig. 7, 7A, 10, 12, and 12A). These echoes may have irregular outlines, but should not be actually separated into several echoes.

4.2.3. Line of Scattered Echoes.-- Scattered echoes (see ¶ 4.2.1) in a curved or straight line (but not a spiral) will be described as a "line of scattered echoes" (see Fig. 7A, 9, 10, 11, 11A, 11B, and 11C). A line of scattered echoes may indicate squall lines or frontal activity.

4.2.4. Solid Line.-- A continuous echo forming a line or curve (but not a spiral band) will be described as a "solid line". The echo may have irregular edges but no definite breaks (see Fig. 11B).

4.2.5. Spiral Band.--When echoes appear in lines which spiral toward a center, they will be described as "spiral bands". These echoes are associated with hurricanes or severe tropical storms. A spiral band may be composed of scattered echoes or of one continuous echo. Some caution is necessary in describing echoes as spiral bands unless a tropical storm is expected or the formation remains evident for at least thirty minutes (see Fig. 13, 13A, and 13B).

4.3. Intensity (Reference ¶ A15305 and Fig. A15-1).-- Estimation and classification of the echo intensity as weak, moderate, or strong will be made from the appearance of the echo on the A-scope and the PPI-scope with an average setting of the receiver gain (see ¶ 1.3). Allowance must be made for the distance from the radar and the weakening of the signal owing to range attenuation (see ¶ 1.4.2). When many echoes are present or when echoes are large, the receiver gain may be adjusted to indicate the most intense areas (see ¶ 3.3). Echoes which appear as only small spots on the A-scope at ranges of 50 miles or less should be classed as "weak". Weak echoes appear thin and grey on the PPI-scope. Owing to the effect of range attenuation any indication of an echo on the A-scope or PPI-scope at ranges of 50 miles or more should be classed as "moderate". Moderate and strong echoes may completely saturate the A-scope at close range. Some experience is necessary in determining the relative strength of echoes at ranges of less than 50 miles. However, echoes which saturate the A-scope at ranges of over 20 miles should always be classed as "strong". Exceptionally bright echoes, such as may be received from violent thunderstorms or heavy frontal activity, at ranges of less than 20 miles, should also be classed as "strong".

4.4. Tendency (Reference ¶ A15306).--Several consecutive observations of the intensity of an echo are necessary to determine the change in strength of the echo. This change is called the "tendency". After several observations of an echo, the tendency should be classed as slowly or rapidly increasing or decreasing, or as unchanged. Again, the effect of range attenuation must be considered, since the echo will become brighter on the scope if it approaches the station, or vice versa.

4.5. Position (Reference ¶ A15307 to A15307.41 and Fig. A15-2 to A15-10).--To facilitate recording and transmitting the size and location of echoes, patterns on the PPI-scope will be described as ellipses, circles, combinations of individual echoes, or spiral bands in accordance with the reference instructions. The azimuth angle, to sixteen points of the compass, and the range, in statute miles (nautical miles multiplied by 1.15), of each pattern will be given also. Note that the pattern may include a collection of scattered echoes or one solid echo. Although the observer will not be able to describe every small detail of each echo in the teletypewriter message when this system is used, a reasonably accurate picture can be reproduced from the average report. The circle or ellipse should represent the mean boundary of the area described. Some small projections on the echoes will be outside of the reported area and some clear areas will be on the inside. However, if the discrepancy appears unreasonable, the use of an additional circle or ellipse may give a better representation of the true echo. When the individual echoes in a group are too far apart to be described as one area, (see ¶ A15307.3), each echo will be evaluated as a circle or ellipse. However, no attempt should be made to describe a portion of a spiral band as a circle or ellipse, since these bands should be described in detail (see ¶ A15307.4).

4.6. Orientation, Length, and Width (Reference ¶ A15308 through A15311).--When echoes are evaluated as an ellipse, the orientation of the major axis will be determined to sixteen points of the compass (see Fig. 7 and 7A). The length of the major axis will be determined to the nearest statute mile. The width or diameter of each echo also will be determined to the nearest statute mile. If possible, the echo should be located with reference to cities, mountains, or air-navigation facilities.

4.7. Direction and Speed of Movement (Reference ¶ A15312 and A15313).--The direction and speed of movement of the brightest portion of each echo can be determined by plotting the location at one observation and noting the amount and direction of movement at the following observation, about 15 or 30 minutes later (see Fig. 11 to 11C). It may be necessary to adjust the receiver gain to determine the brightest portion of the echoes (see ¶ 3.3).

4.8. Height (Reference ¶ A15314).--A chart for estimating the height of radar echoes is furnished to all radar stations (see Fig. 14). The height of the top of radar echoes is important to forecasters and to research activities. The top of the echoes may be indefinite owing to an increase in the amount of ice or snow particles above the freezing level, and owing to the echoes from nearby precipitation areas obscuring the top of the true center of the cloud. For these reasons, height determinations will be made only between the range of 15 to 50 miles.

4.8.1. Radars of the APS-2F type have a beam width of 3.5° when 72-inch antennas are used, and a beam width of 9° when the original 30-inch antennas are used. Therefore, observers with this type of radar equipment will subtract 1.8° or 4.5°, as appropriate, from the elevation angles when determining the height of echoes.

4.8.2. The antenna can be tilted to a maximum of 20° above the horizontal. The elevation angle will be indicated on the "tilt indicator" The angle is varied by manipulation of the "tilt" switch.

4.8.3. Example.--

Given: An echo at a range of 40 nautical miles. When the antenna is tilted, the signal fades out at an indicated elevation angle of 7.5°.

40 nautical miles x 1.15 = 46 statute miles

$7.5° - \frac{3.5}{2} = 5.7°$ (for 3.5° beam)

Using the chart in Fig. 14, the height is found to be 25,000 feet.

4.9. Remarks (See ¶ A15315).--The remarks portion of the message is reserved primarily for information that cannot be coded in the main report. In general, the observer should include such additional information as he believes will help forecasters or pilots in their evaluation of the radar reports.

5.0. ENTRIES ON FORMS

5.1. General (Reference section A15500).--A complete report of every observation will be entered on Form 610.3-1, "Radar Weather Observations, Land Station," in accordance with the reference instructions (see Fig. 15). An entry is required for each scheduled observation regardless of whether echoes are observed (see ¶ A15524). Special remarks or comments may be entered on the form and enclosed in parentheses to indicate that they were not transmitted. For example, the remark may explain that the observation was taken at the request of the district forecaster. Other remarks, not transmitted, refer to the use of the radar camera, adjustment on the equipment, etc.

6.0. TRANSMISSION OF RADAR REPORTS

6.1. General (Reference, section A15600).--Radar reports are given special distribution on Service A. However, RAREPS describing thundershowers, frontal activity, or tropical storms should be appended as remarks to aviation weather observations.

7.0. VERIFICATION OF RADAR ECHOES

7.1. General.--When severe storms are suspected in connection with an unusual radar echo, telephone calls should be made to the community in the vicinity of the storm to obtain information regarding the disturbance. In the event that the storm is severe, warning should be passed to other communities in the storm's path. Such warnings should be issued in accordance with standard Weather Bureau procedure.

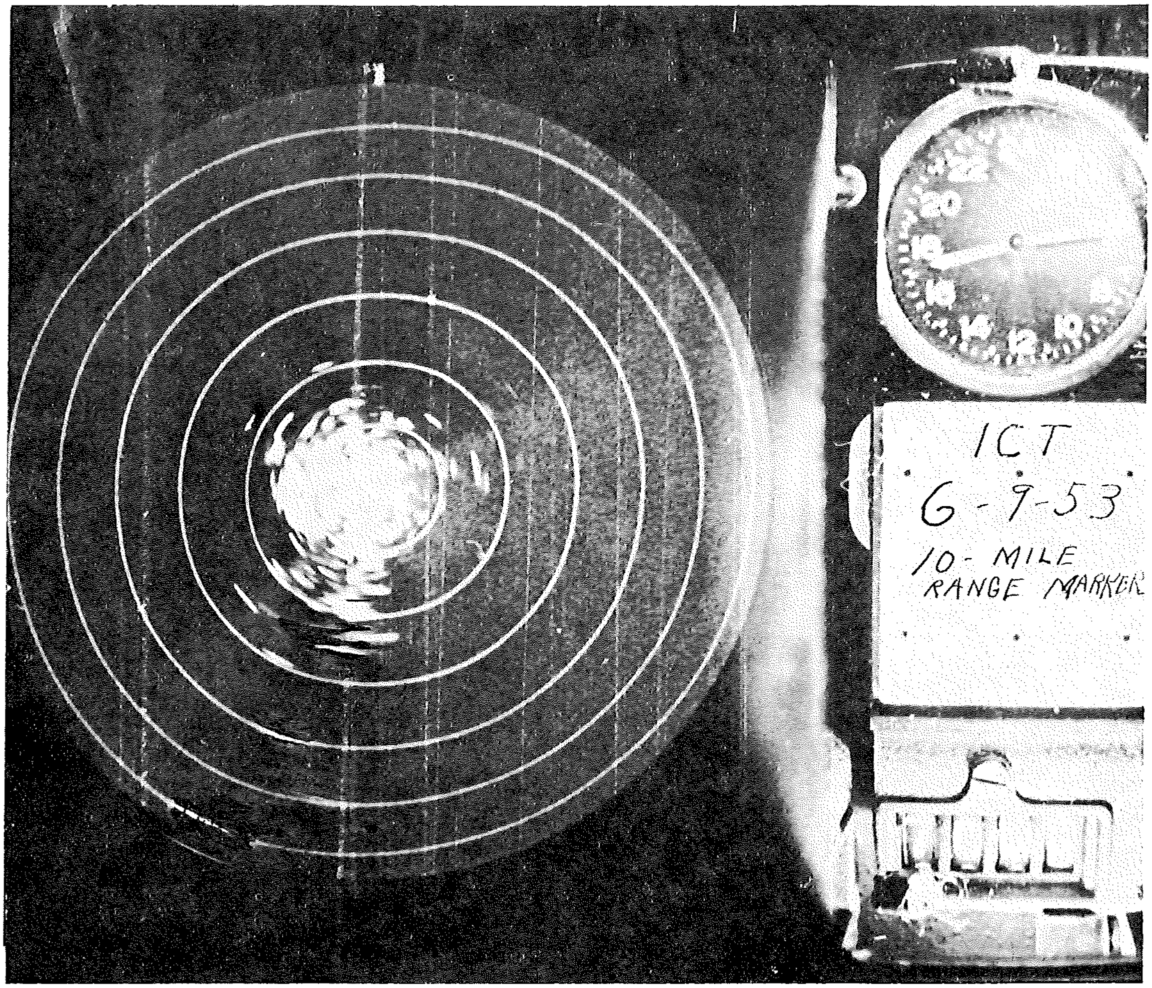

Fig. 6. Ground Clutter.

Permanent objects around the station produce echoes near the center of the scope, as shown in this photograph of the PPI-scope at Wichita, Kansas. These echoes are called "ground clutter". The observer should be familiar with the location and average brightness of the echoes contributing to the ground clutter pattern (see ¶ 3.4.2). Since azimuth markings are not visible on the illustrations, a white dash has been placed on the upper edge of the scopes to indicate north. These range markers are ten miles apart. It is 70 miles from the center to the outer edge of the scope. When only ground clutter appears at an observation it should be recorded as PPINE. This report will be transmitted if this is the first clear scope report following one or more reports of echoes (see ¶ A15610).

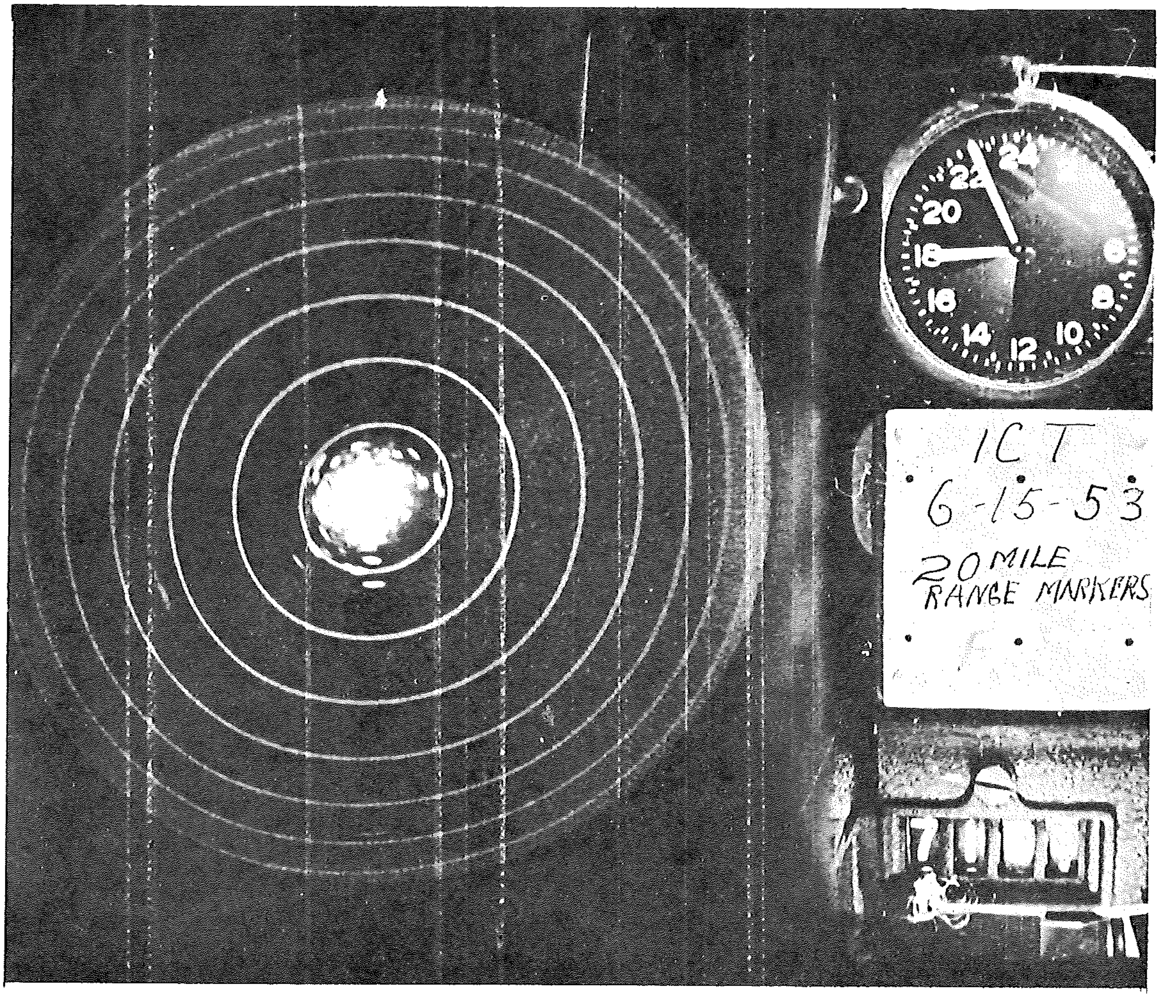

Fig. 6A. Ground Clutter.

Ground clutter may completely obscure all precipitation echoes within ten or more miles of the station. On this illustration the range marks are 20 miles apart. Most Weather Bureau radar scopes indicate distances in nautical miles, which must be converted to statute miles by the observer (see ¶ 3.2 and 4.8.3). Note: These illustrations have been selected for subject matter and the clock time shown on them does not indicate necessarily the required time of observations.

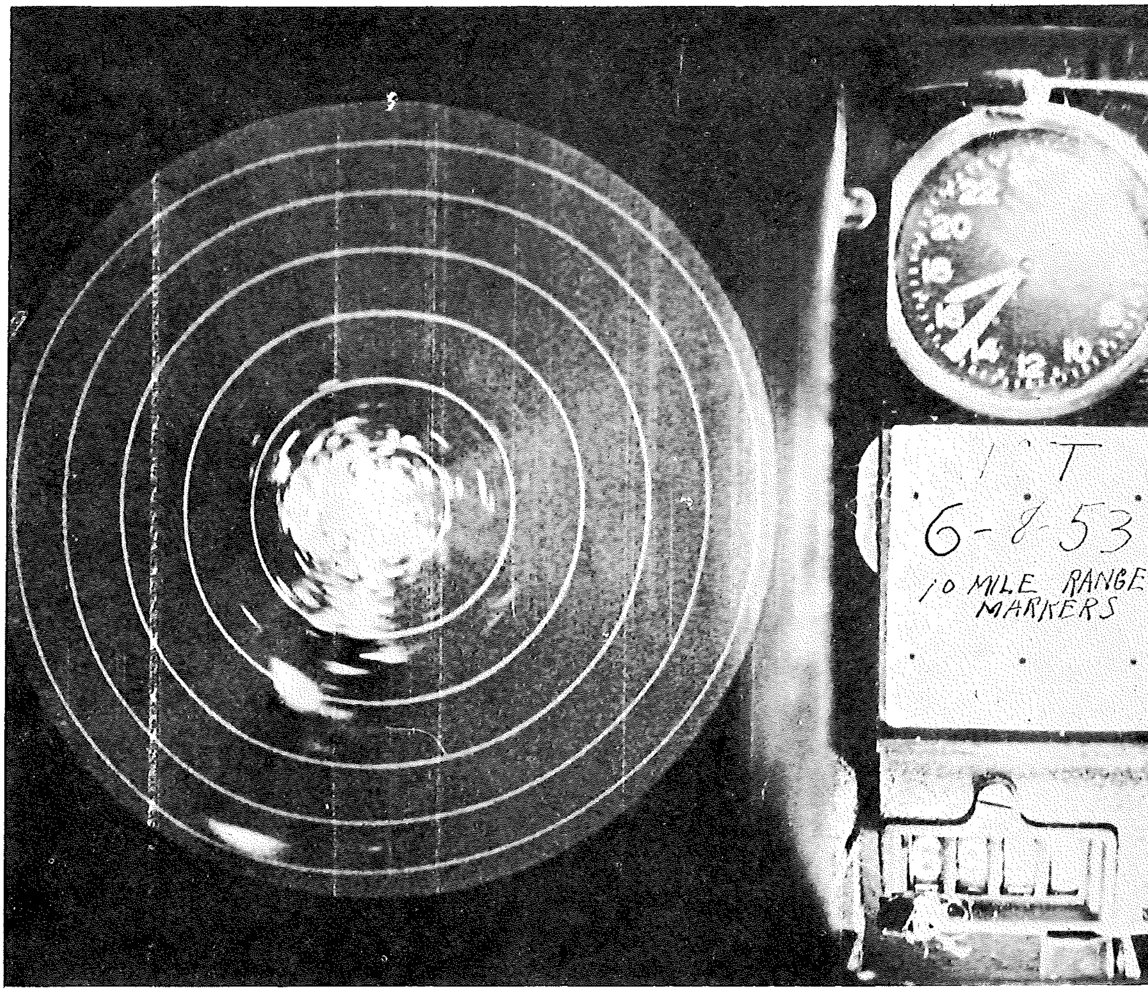

Fig. 7. Echoes Evaluated as Ellipses.

These echoes have been evaluated as ellipses, since the length of each echo is at least twice the width. Compare the ground clutter with Fig. 6. The two precipitation echoes are fairly bright for their range, indicating moderate intensity. The echo intensity should be checked on the A-scope also. A small area of light precipitation is developing at the end of the echo at 30 miles range (see Fig. 7A). The report would be coded as: ICT 081637C RAREP2 SLD MDT INCRG SSW/35 (30 nautical miles x 1.15 = 35 statute miles) VCNTY WELLINGTON ORNTD SE-NW 14 LONG 4 WIDE MOVG FM SW/18 HGT 210 SLD MDT INCRG SSW/63 ORNTD ESE-WNW 12 LONG 5 WIDE MOVG FM SW/20. (Remarks, if any, regarding pilot reports, verified hail, etc., are added to the end of the report.)

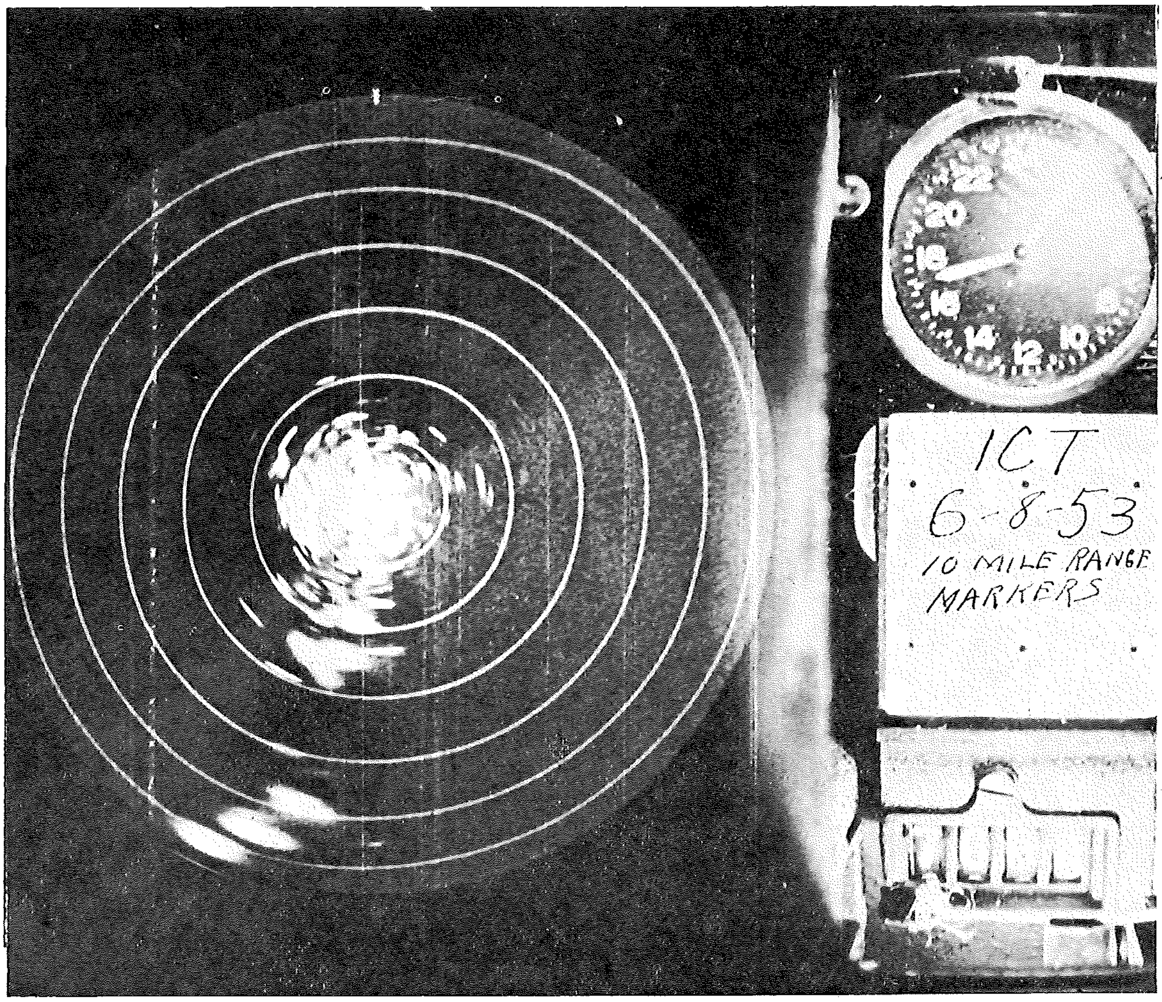

Fig. 7A. Echoes Evaluated as Ellipses.
This observation was taken 30 minutes after the observation illustrated in Fig. 7. The innermost echo (SSW/29) has increased in size and two more precipitation areas have developed or moved into range in the southwestern quadrant. The A-scope should be checked to confirm apparent increases in intensity (see Fig. 3). Owing to their proximity to each other, the three echoes in the lower portion of the scope will be evaluated as a group of scattered echoes (see ¶ A15307.1). Coded as: ICT 081706C RAREP3 SLD STG INCRG SSW/29 ORNTD ESE-WNW 15 LONG 7 WIDE MOVG FM SW/10 HGT 300 LINE SCTD STG INCRG SSW/63 ORNTD SW-NE 37 LONG 17 WIDE MOVG FM WSW/17.

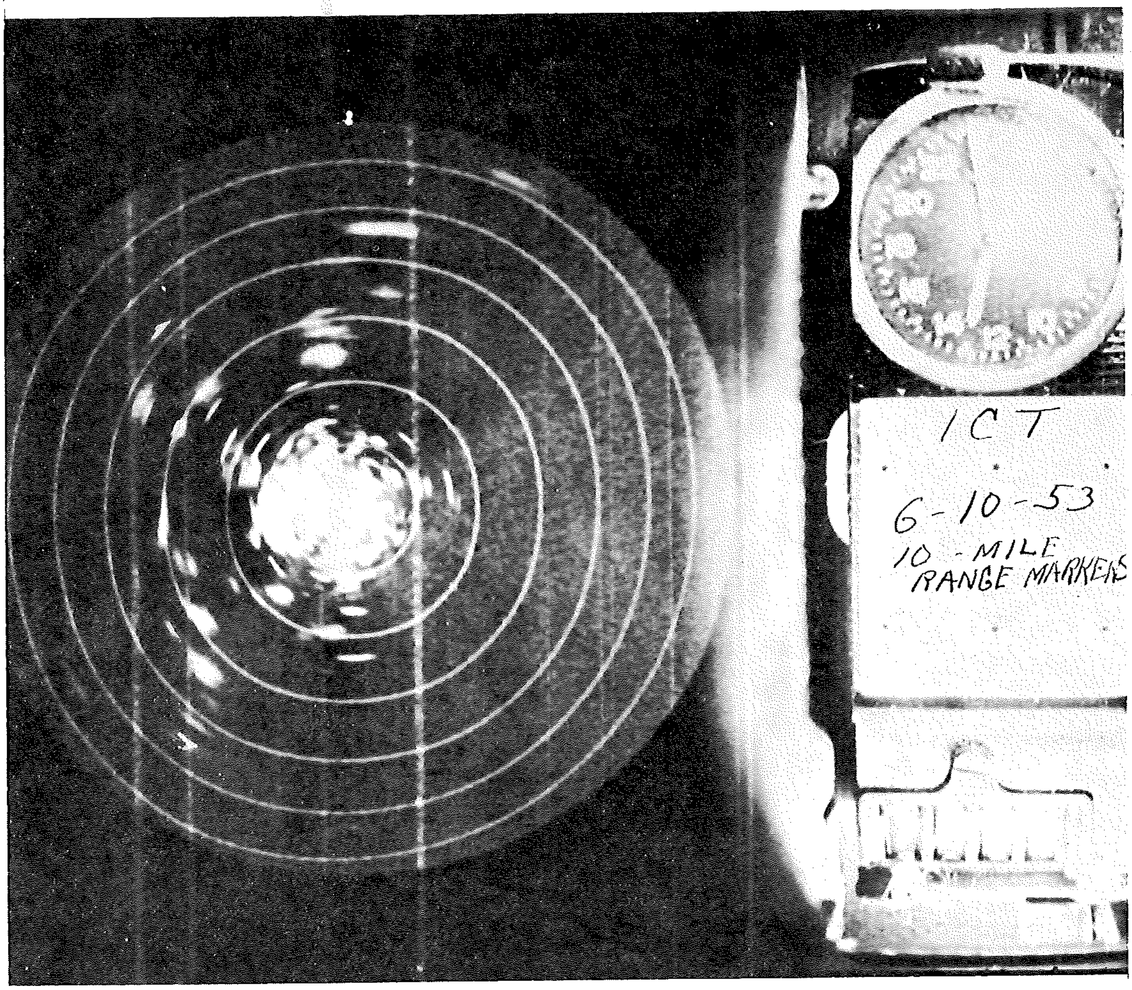

Fig. 8. Numerous Small Echoes.

These echoes are very small and too numerous and widely scattered to justify individual descriptions (see ¶ A15309). The echoes are located in the southwest and northwest quadrants and are scattered over an area extending from the station outward to an average distance of 54 statute miles. Code as: ICT 101258C RAREP6 SCTD MDT NO CHG MANY SML SCTD THRUT AREA XTNDG FM STN TO 54 MI RADIUS SW THRU W TO NNE MOVG FM SW/12.

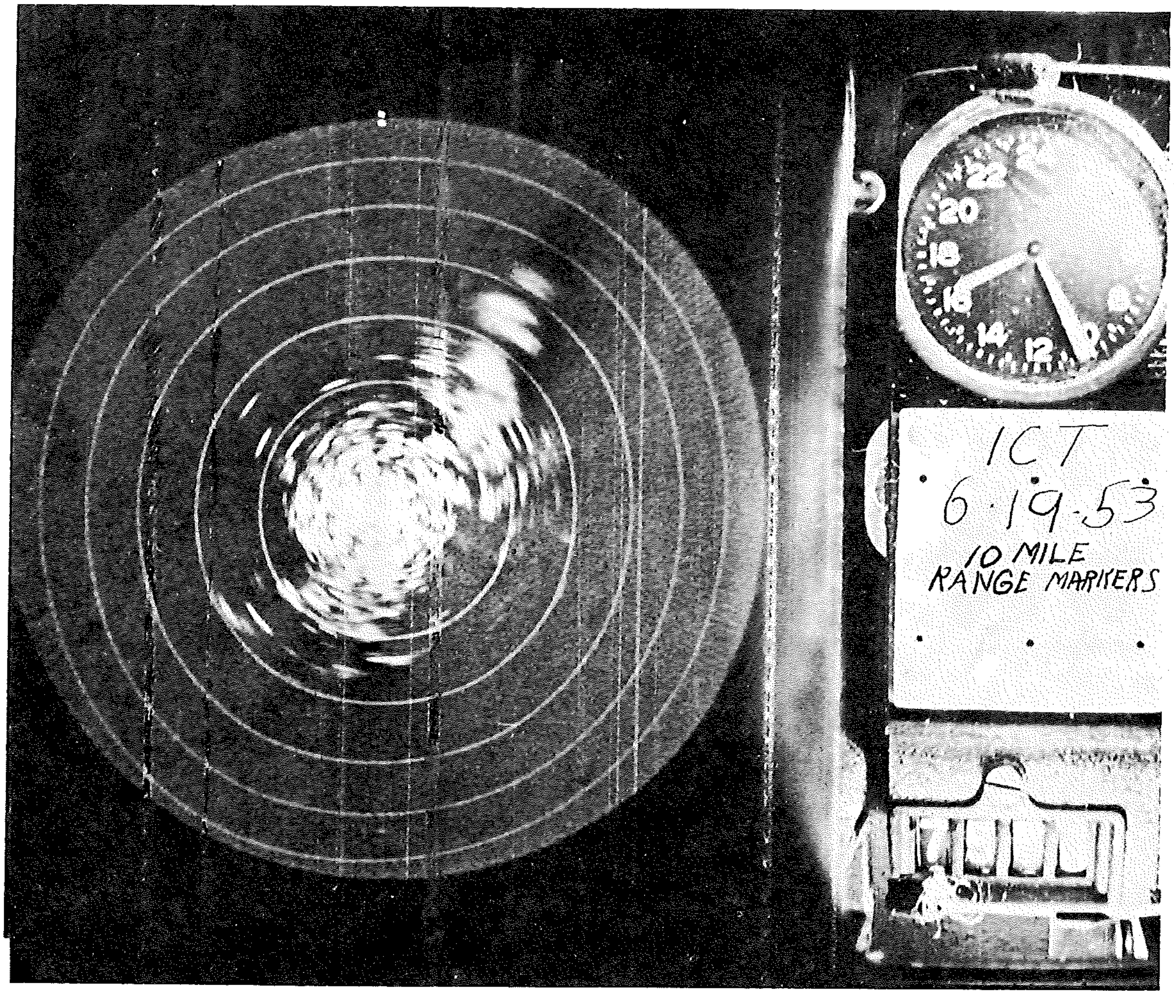

Fig. 9. Line of Scattered Echoes.

The most significant meteorological feature of a group of echoes should be retained, and, if possible, coded in one group. In this case, the larger echoes form a line of considerable importance to forecasters. The small scattered echoes may be added to the report as separate groups. Note that the ground clutter has increased owing to an increase of receiver gain; however, some precipitation echoes intermingle with the ground clutter (see Fig. 6). Code as: ICT 191626C RAREP7 LINE SCTD MDT NO CHG NNE/29 ORNTD SSW-NNE 40 LONG 12 WIDE MOVG FM NW/15 SCTD WK NO CHG E/29 DIAM 14 MOVG FM NW/15 SCTD MDT NO CHG N/28 ORNTD N-S 11 LONG 9 WIDE MOVG FM NW/15.

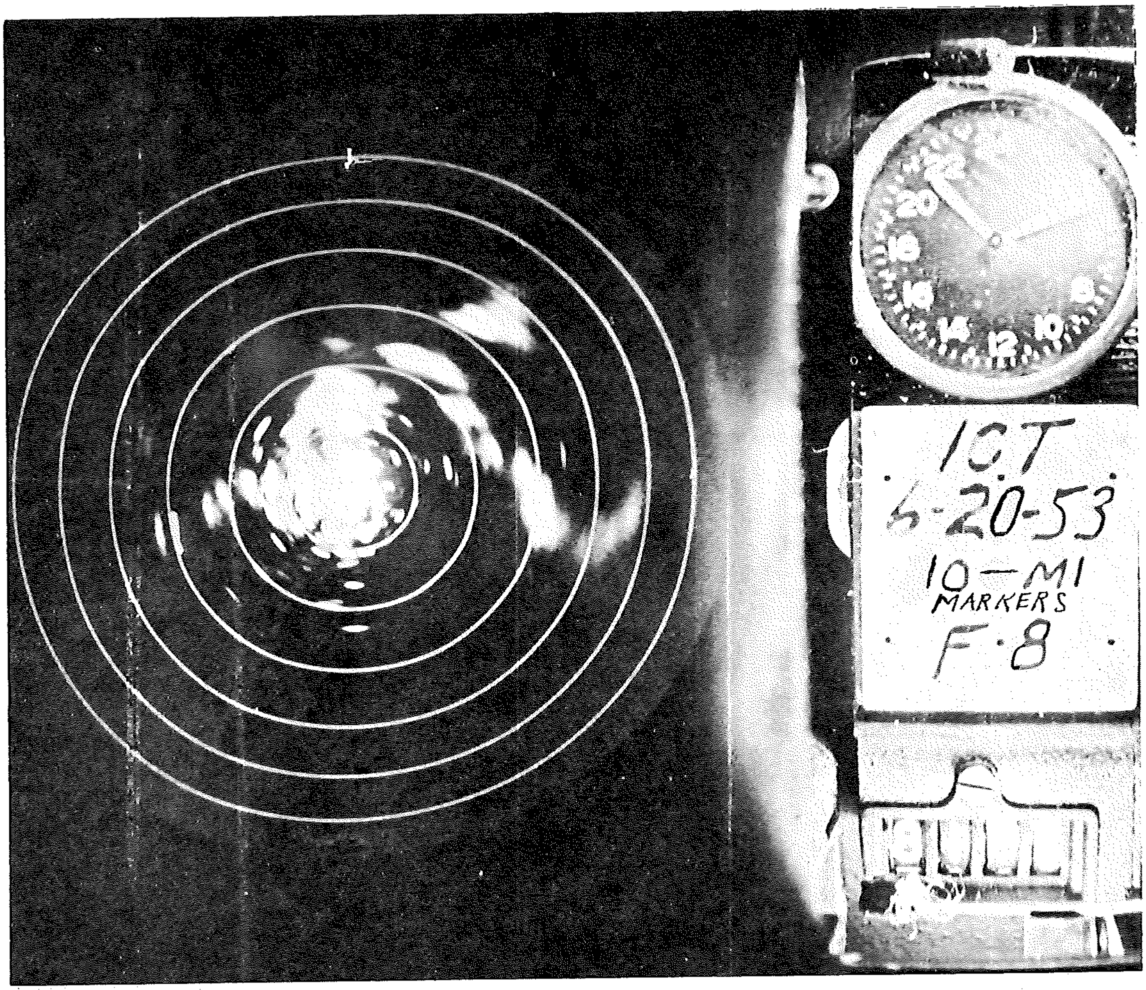

Fig. 10. Squall Line Echoes.

Echoes similar to these often accompany squall line activity. Several very small echoes have not been described in the report because they are relatively unimportant in a group of larger scattered echoes. Coded as: ICT 202111C RAREP9 SLD MDT INCRG SLOLY N/17 DIAM 15 MOVG FM N/18 LINE SCTD MDT INCRG SLOLY ENE/26 VCNTY EL DORADO ORNTD NW-SE 46 LONG 6 WIDE MOVG FM N/18 HGT 300 SLD MDT NO CHG NE/39 DIAM 11 MOVG FM N/18 SLD LINE WK DCRG SLOLY E/49 ORNTD SW-NE 15 LONG 8 WIDE MOVG FM N/18 LINE SCTD MDT NO CHG W/10 ORNTD SW-NE 15 LONG 3 WIDE MOVG FM N/18 SCTD WK NO CHG WSW/35 DIAM 3 MOVG FM N/18.

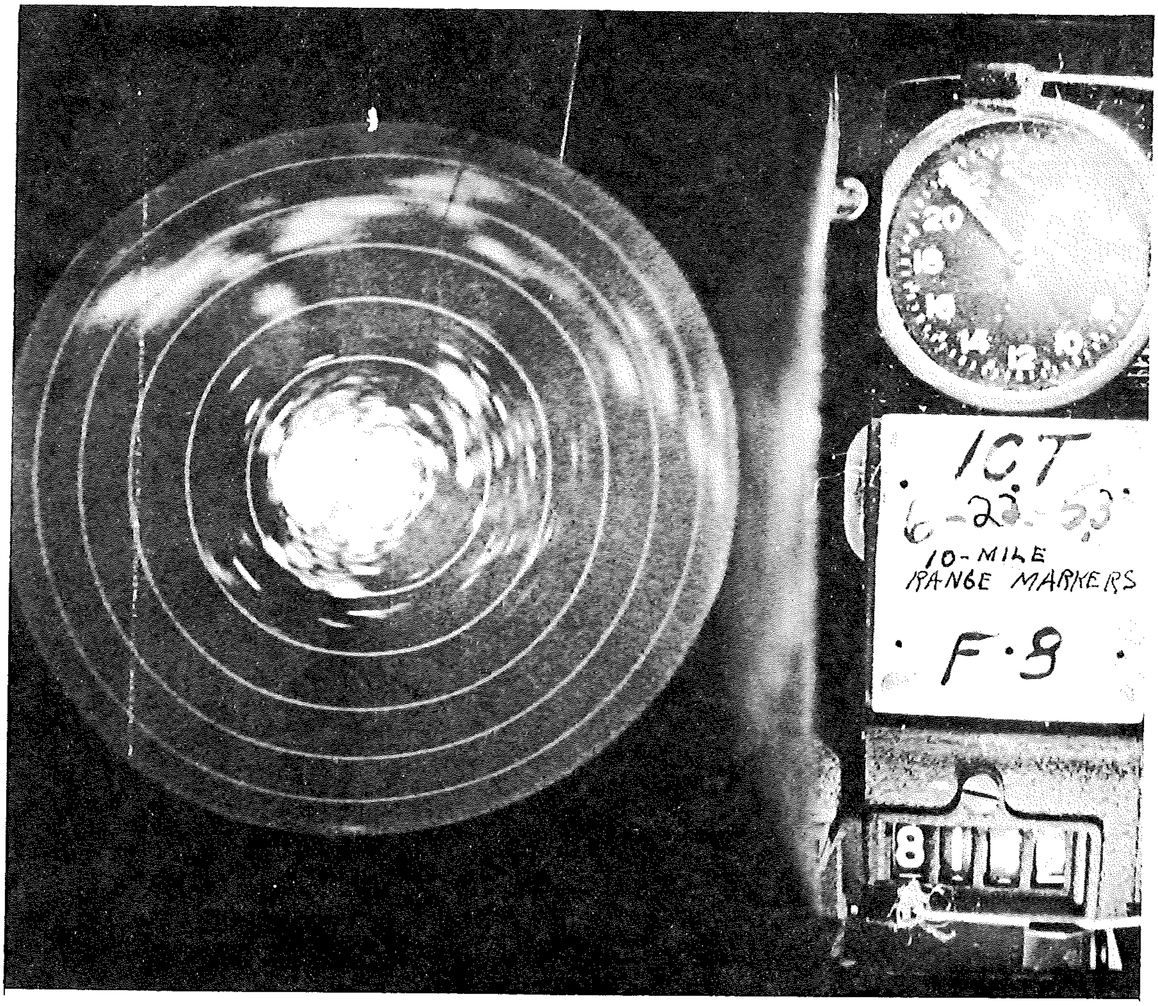

Fig. 11. Frontal Echoes.
A front with weak to moderate precipitation echoes is approaching the station from the north. The receiver gain has been increased to bring in the frontal echoes resulting in an increase in the amount of ground clutter (see Fig. 9). Two ellipses are used to describe the main portion of the front. Code as: ICT 220154C RAREP2 LINE SCTD MDT NO CHG NNW 52 ORNTD WSW-ENE 102 LONG 16 WIDE MOVG FM NW/25 LINE SCTD WK INCRG SLOLY NE 58 ORNTD NW-SE 85 LONG 13 WIDE STNRY SLD WK INCRG SLOLY NW/39 DIAM 6 MOVG FM N/25 SCTD WK DCRG E/25 ORNTD NNW-SSE 53 LONG 11 WIDE STNRY.

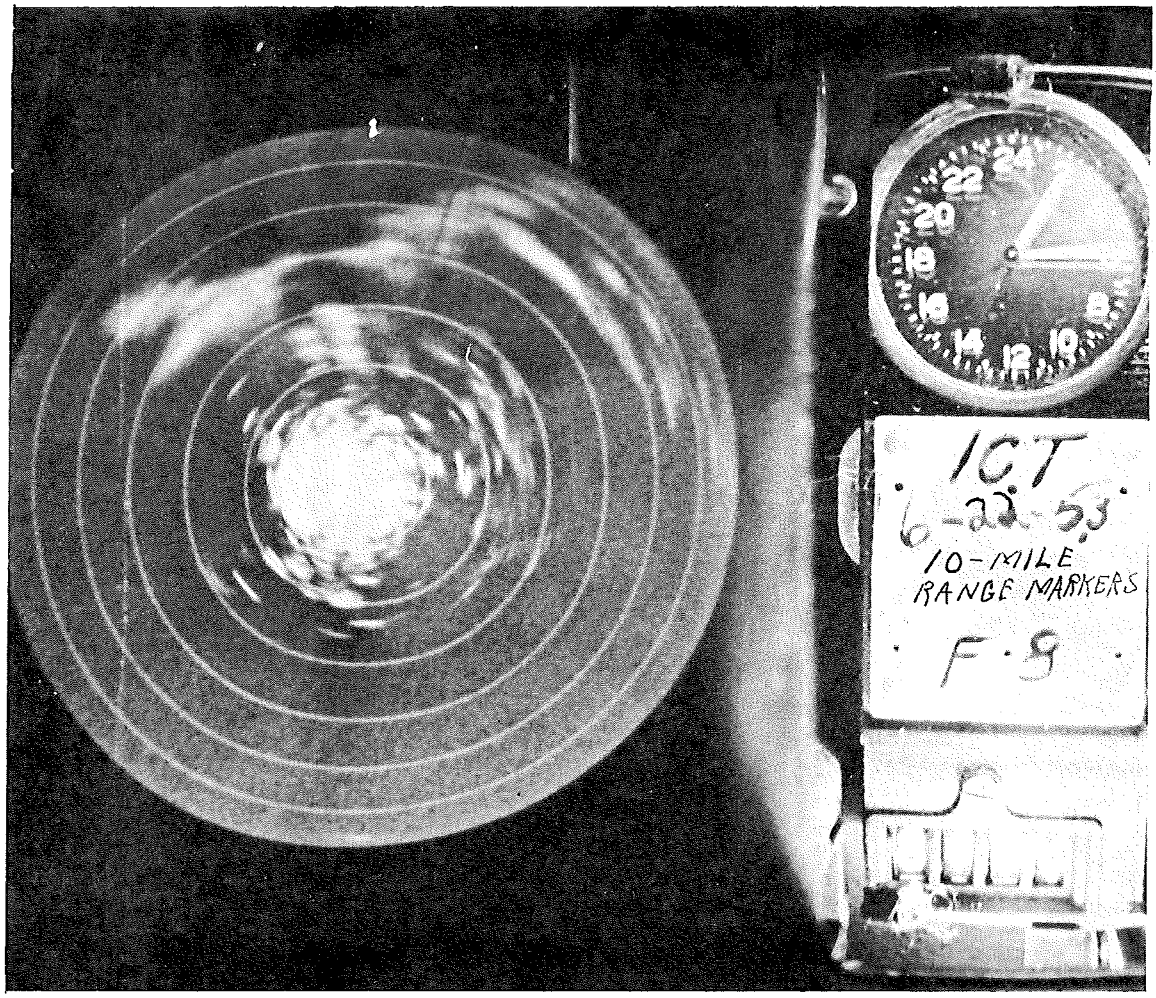

Fig. 11A. Frontal Echoes.

A portion of the front northwest of the station has advanced with a speed greater than 30 miles per hour. Therefore a special observation is required (see ¶ A15120(3)(b)). The section of the front northeast of the station appears to be weakening and to be moving from the southwest. A small wave may be forming on the front. Code as: ICT 220214C RAREP3 LINE SCTD MDT NO CHG N/46 ORNTD WSW-ENE 108 LONG 18 WIDE MOVG FM NW/32 HGT 220 LINE SCTD MDT DCRG NE/63 ORNTD NW-SE 82 LONG 13 WIDE MOVG FM SW/8 SCTD MDT INCRG N/29 DIAM 13 MOVG FM NW/25 HGT 200 SCTD WK NO CHG ENE/24 ORNTD NNW-SSE 40 LONG 10 WIDE NO MOVMT (Remarks) PTN FRONT NW STN MOVG RPDLY.

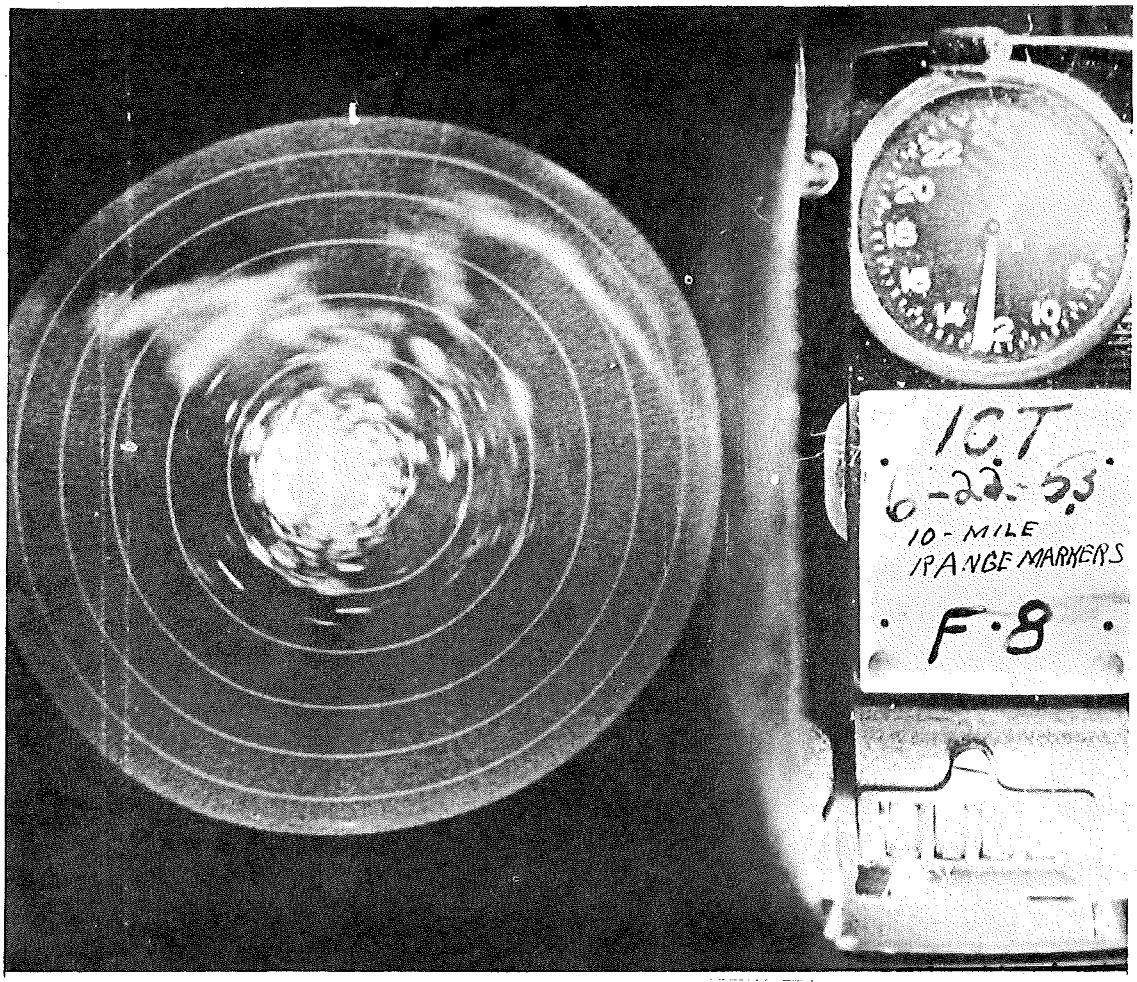

Fig. 11B. Frontal Echoes.
The fast moving sector of the front, also shown in Fig. 11 and 11A, has moved close to the station and the apparent wave to the north-northeast has become very sharp. The northern portion of the wave is weakening and moving out of range. The S-shaped front may be coded as: ICT 220231C RAREP4 LINE SCTD MDT INCRG N/22 HUTCHINSON TO NEWTON TO EL DORADO ORNTD WNW-ESE 110 LONG 24 WIDE MOVG FM NNW/25 HGT 240 SLD LINE WK DCRG NNE/41 ORNTD N-S 14 LONG 8 WIDE MOVG FM NW/25 SLD LINE MDT DCRG NE/60 ORNTD NW-SE 94 LONG 6 WIDE MOVG FM W/18.

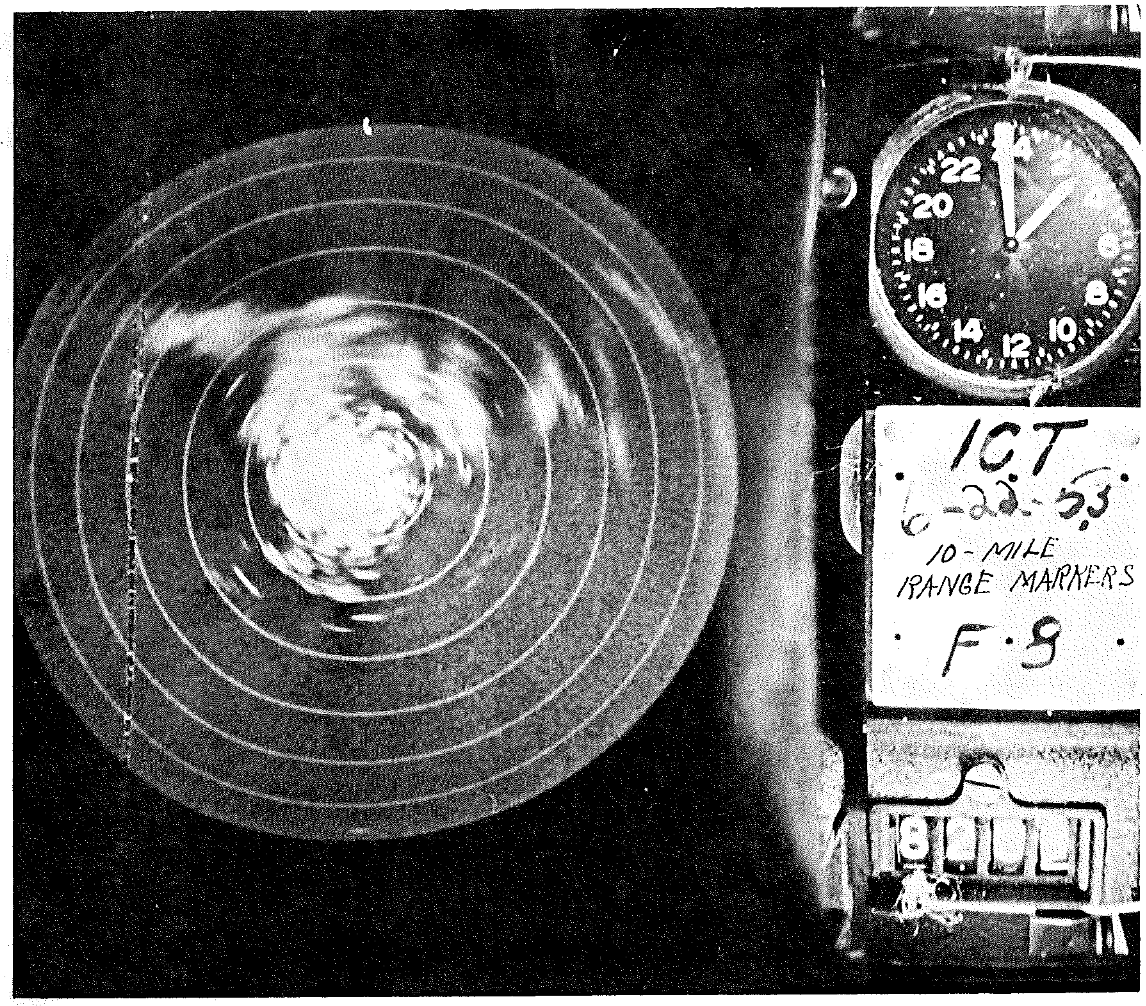

Fig. 11C. Frontal Echoes.
This observation was taken approximately one-half hour after the observation in Fig. 11B. The apparent wave has nearly disappeared from the scope. The heavy portion of the front may be described as one broad ellipse in order to preserve the frontal picture in the report. Code as: ICT 220258C RAREP5 LINE SCTD STG NO CHG N/20 ORNTD E-W 100 LONG 23 WIDE MOVG FM NW/25 LINE SCTD WK DCRG ENE/47 ORNTD N-S 25 LONG 3 WIDE MOVG FM NW/45 LINE SCTD WK DCRG NE/66 ORNTD NW-SE 42 LONG 3 WIDE MOVG FM NW/45.

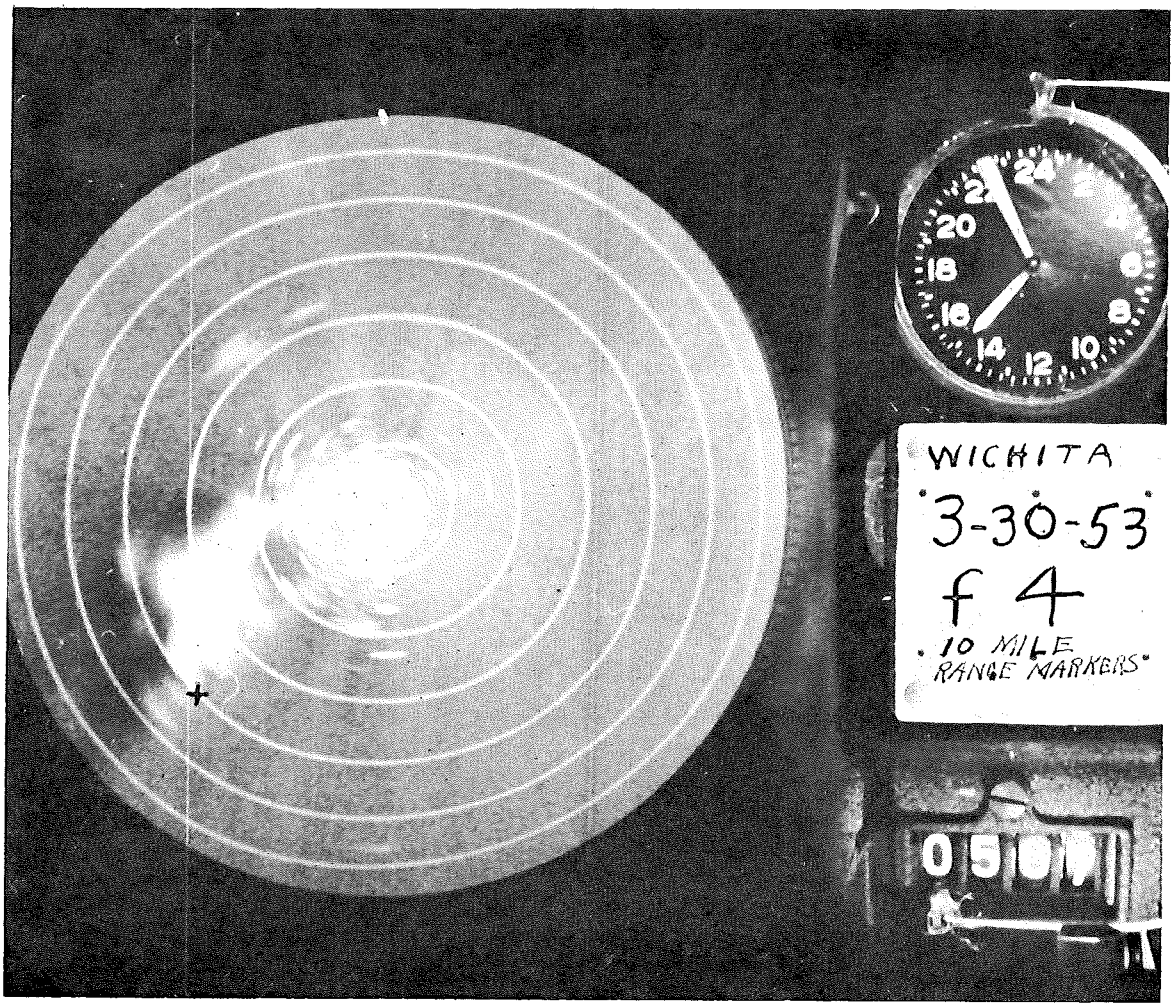

Fig. 12. Echo Accompanying a Tornado

Telephone calls verified the occurrence of a tornado at point "X" in connection with this thunderstorm. Warnings were given to areas in the path of the storm (see ¶ 2.1 and 7.1). RAREPS should be transmitted as "remarks" appended to special aviation weather operations in addition to their regular distribution (see ¶ A15611). Code as:ICT 301456C RAREP8 SLD STG NO CHG SW/34 OVR ANNESS DIAM 42 MOVG FM SW/25 HGT 300 SCTD WK DCRG NW/38 ORNTD SW-NE 23 LONG 5 WIDE MOVMT UNKN TORNADO LCTD SW/46 VCNTY HARPER 1445C.

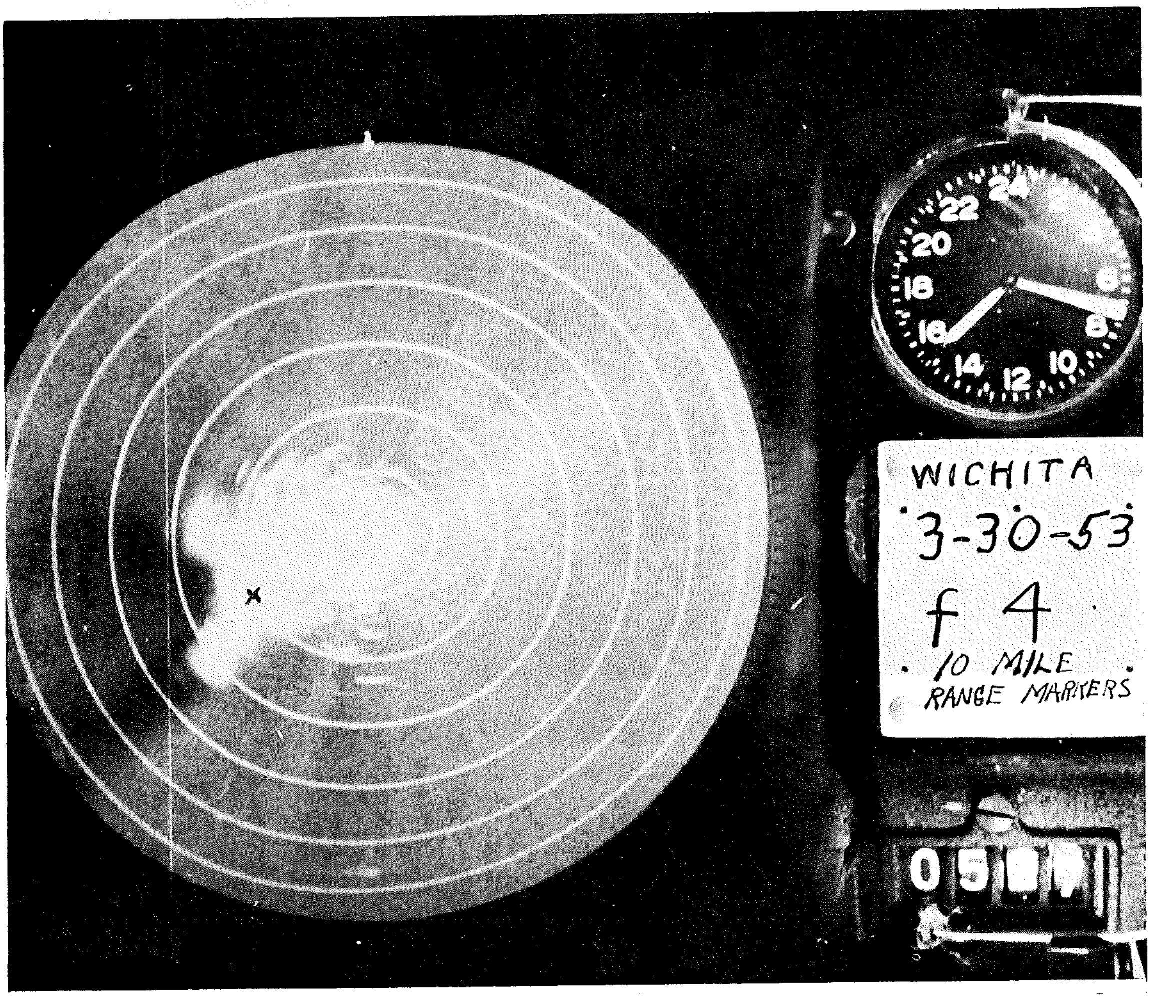

Fig. 12A. Echo Accompanying a Tornado.
As in Fig. 12. A telephone call located a tornado at point "X". Since more than one tornado may accompany a large area of thunderstorms, this may not be the same tornado as was reported in Fig. 12. In general, warnings should be given for the areas in the path of the thunderstorm, as the movement of a tornado funnel may be erratic. This report may be coded as: ICT 301518C RAREP9 SLD STG NO CHG WSW/21 DIAM 34 MOVG FM SW/25 TORNADO LCTD WSW/23 1515C.

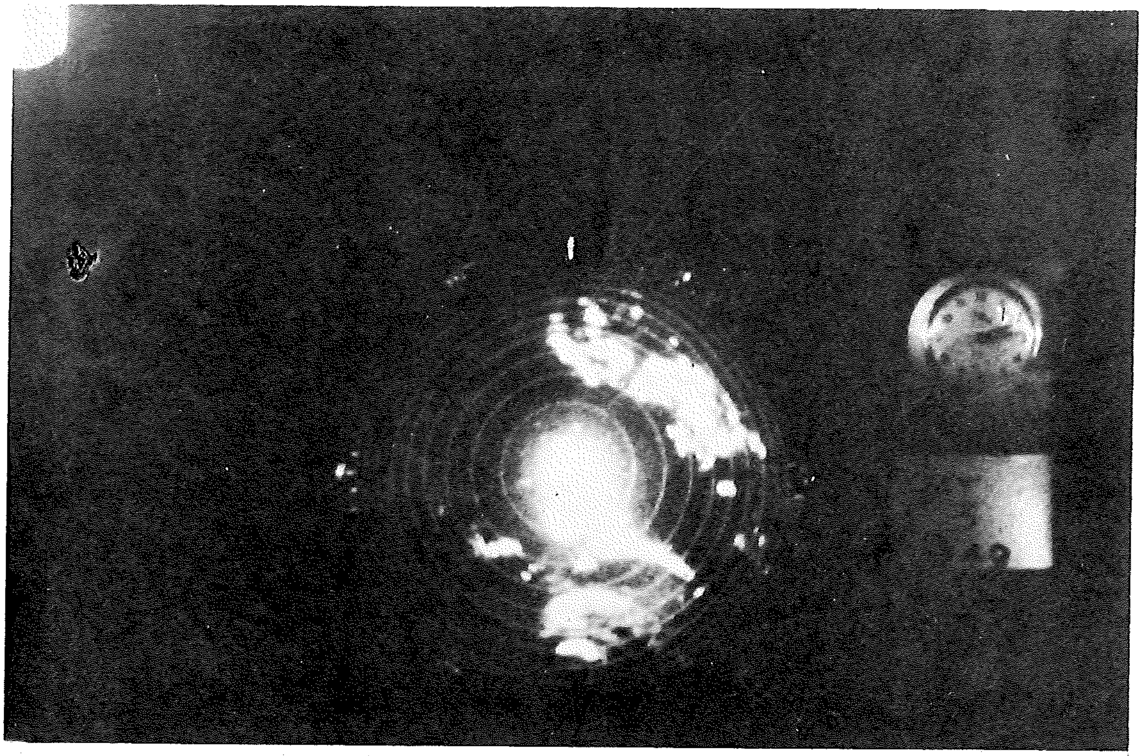

Fig. 13. Spiral Precipitation Bands.
These echoes are from precipitation bands associated with a hurricane approaching Freeport, Texas. These range markers are 20 statute miles apart. The spiral bands are located in the lower half of the scope, with the "eye" rather indefinite but apparently located near the bottom edge (see ¶ A15307.4). A general description of the storm and the location of the center should be given in aviation weather observations (see ¶ A15611). The report might be coded as: FREEPORT 031414C RAREP5 LINE SCTD STG NO CHG NE/90 ORNTD NW-SE 220 LONG 60 WIDE MOVG FM SSW/20 SLD SPRL BND STG NO CHG AZRAN 17/65 15/70 14/120 20 WIDE SLD SPRL BND STG NO CHG AZRAN 19/110 17/90 16/140 40 WIDE SLD SPRL BND STG NO CHG AZRAN 18/140 17/145 18 WIDE BNDS MOVG FM SSW/20 CNTR VCNTY 160 MI S.

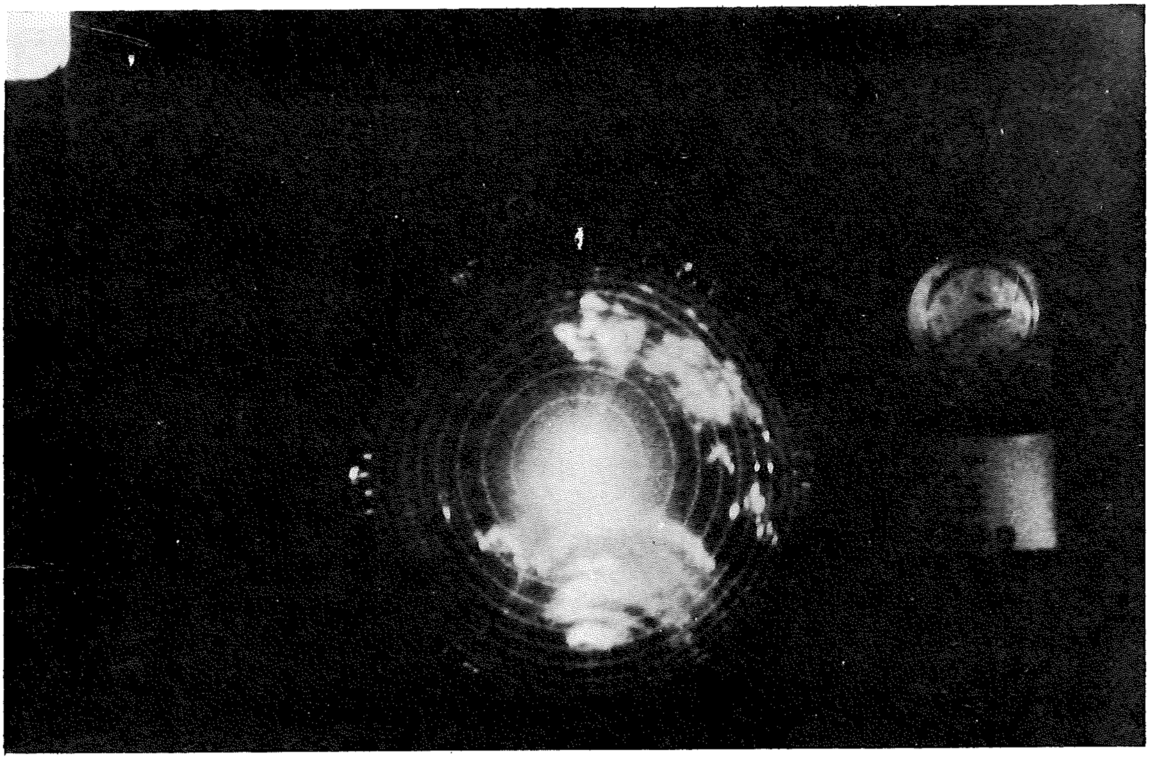

Fig. 13A. Spiral Precipitation Bands.

The hurricane bands are not as distinct as in Fig. 13, owing to a coverage of light precipitation between the bands. A slight reduction of the receiver gain may improve the definition of the bands in such cases (see ¶ 3.3). It was verified that all the precipitation occurring in connection with this storm was confined to the northeast quadrant of the hurricane, as shown by the precipitation bands in these photographs. Report coded as: FREEPORT 031440C RAREP6 LINE SCTD STG DCRG SLOLY NE/100 ORNTD NW-SE 285 LONG 70 WIDE MOVG FM SSW/20 SLD SPRL BND STG NO CHG AZRAN 13/130 16/40 22/75 20 WIDE SLD SPRL BND STG NO CHG AZRAN 17/70 20/70 10 WIDE SLD SPRL BND STG NO CHG AZRAN 16/150 17/85 20/110 30 WIDE SLD SPRL BND STG NO CHG AZRAN 17/130 20/110 15 WIDE SLD SPRL BND STG NO CHG AZRAN 17/140 18/140 20 WIDE BNDS MOVG FM SSW/20 CNTR VCNTY 150 MI S LGT PCPN AT STN AND BTN SPRL BNDS.

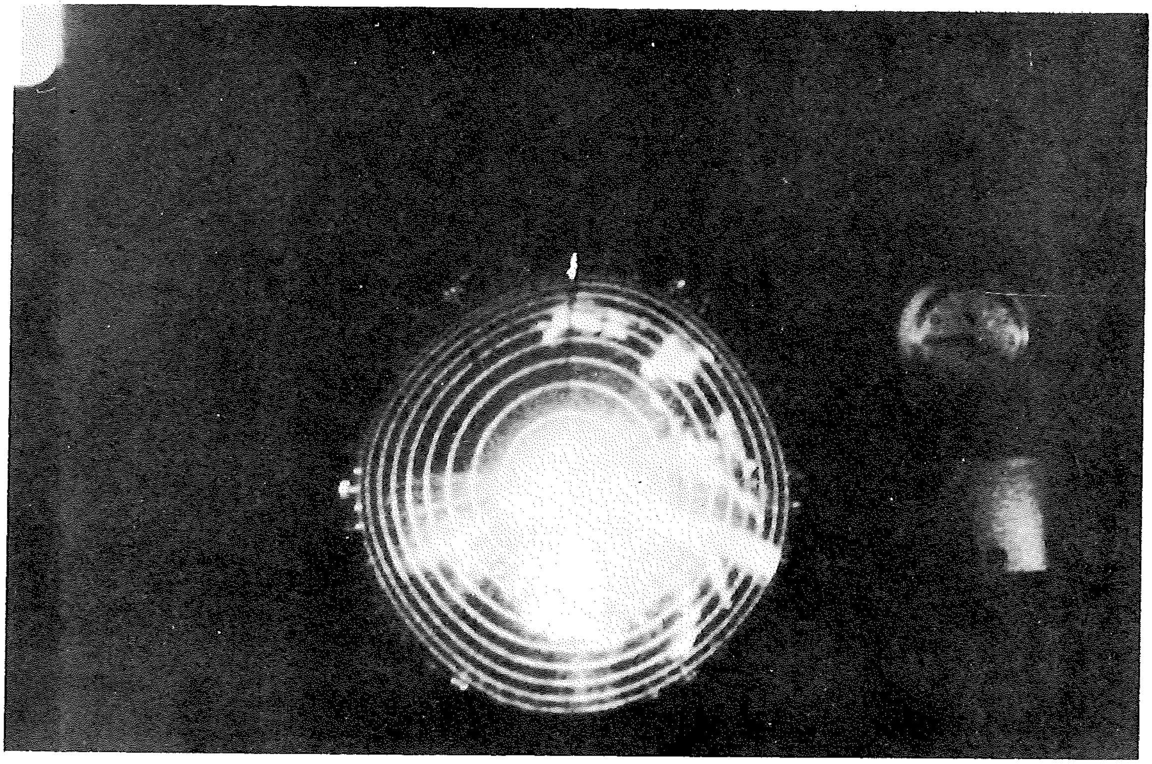

Fig. 13B. Spiral Precipitation Bands.

Moderate rain at the station and between the bands of heavy precipitation in the hurricane area obscures the central portion of the spiral bands. The radar station was closed down a few minutes after this observation was taken owing to dangerously strong winds. The individual spiral bands cannot be described in this case. However, a general description is possible. It is coded as: FREEPORT 031545C RAREP9 STG INDFT SPRL BNDS OF HURCN FILL SE QUAD FM STN TO ABT 170 MI CNTRD ABT 130 MI S OF STN MOVG FM S/20 LINE SCTD MDT DCRG SLOLY NNE/120 ORNTD NW-SE 150 LONG 45 WIDE MOVG FM S/20 HVY R STG WND AT STN OBSNS DSCONTD TIL HURCN CNDS IPV.

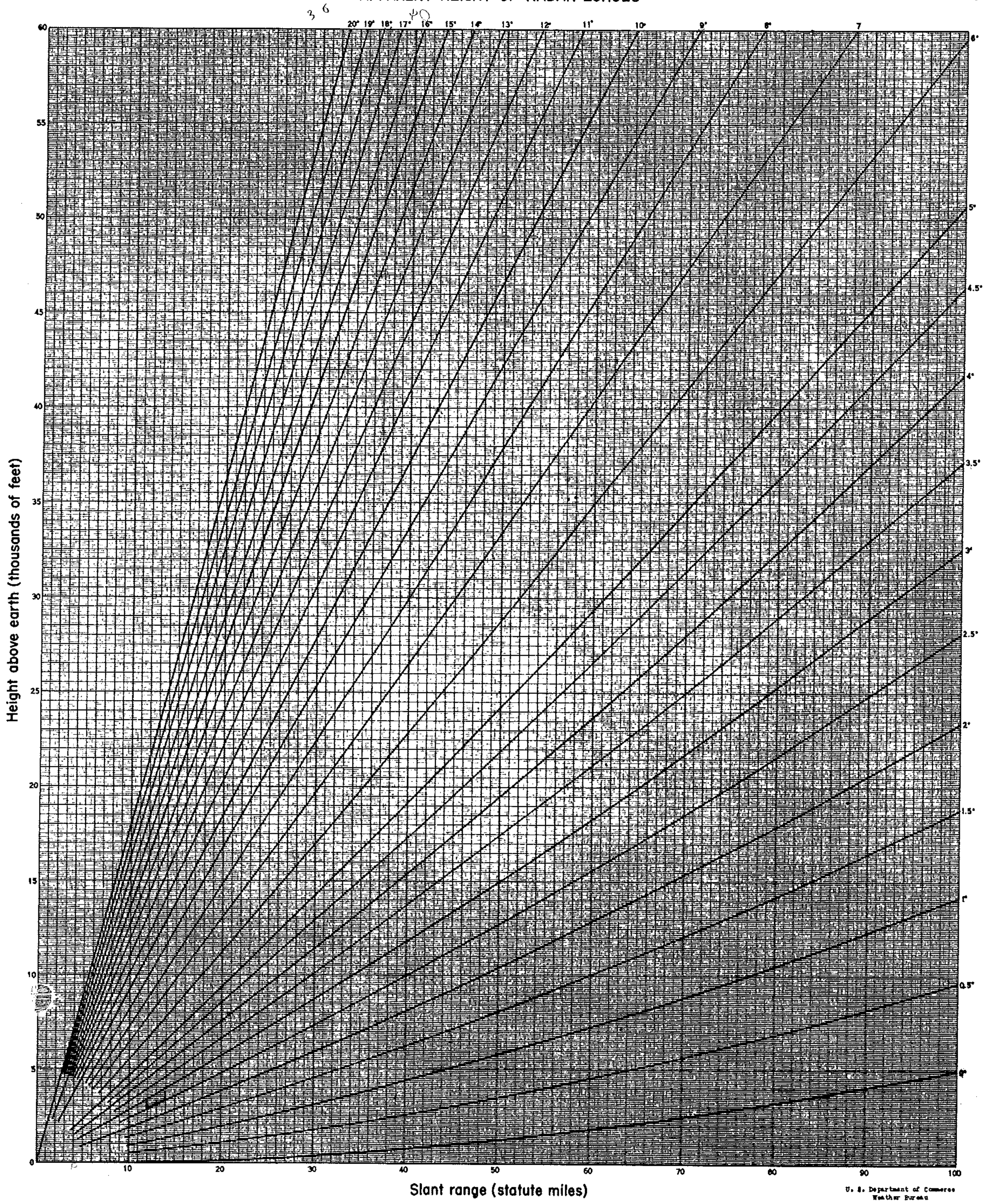

Fig. 14. Height Computation Chart.
The height of the echo above the level of the station is found at the intersection of the curve representing the elevation angle and the ordinate representing the slant range. The height of the 0° curve above the baseline indicates the curvature of the earth. This value is not subtracted from the height of the echo.

RADAR WEATHER OBSERVATIONS, LAND STATION

Station WICHITA, KAN. Type of Radar APS-2F Month and Year JUNE 1953

Date	Time C S.T.	RAREP No.	Description of Return: Character	Intensity	Tendency	Position of Echo: Distance	Direction	Orientation	Location	Length	Width or diameter	Movement: Direction	Speed (mph)	Height 100's ft. (MSL)	Remarks (Enter data not transmitted in parentheses)	Operational status	Initials
04	1005															PPINE	DW
04	1305															PPINE	DW
04	1605															PPINE	FW
04	1645	1	LINE SCTD	MDT	INCRG	100	NNW	NE-SW	BEAVER TO MANCHESTER	75	15				(camera on 1645 C)		FW
04	1728	2	LINE SCTD	MDT	NO CHG	80	NW	NE-SW	HODSON TO GYPSUM	80	15	NW	20				FW
—			SLD	MDT	NO CHG	50	N		NR MARION		5	NW	20				FW
04	1825	3	SLD	MDT	NO CHG	80	NW		NR CHASE		6	NW	20				FW
—			SLD LINE	MDT	DCRG	120	NW	E-W	RUSSELL TO WESTFALL	40	5	UNK					FW
04	1907	4													(camera off 1907 C)	PPINE	FW
04	2030	5	LINE SCTD	MDT	INCRG	60	WNW	NW-SE	SLYVIA TO ARLINGTON	18	8				(camera on 2028 C)		FW
04	2125	6	SLD	MDT	NO CHG	75	NW		NR FALUN		8	SW	30				FW
04	2150	7	SLD LINE	STG	NO CHG	120	SW	NW-SE	NR CURTIS	15	4						FW
04	2225	8	SLD LINE	STG	NO CHG	100	SW	NW-SE	NR WAYNOKA	20	7	NE	25		(camera off 2230 C)		FW
04	2306	9	SLD LINE	STG	NO CHG	70	SW	NW-SE		20	8	NE	60				EZ
04	2335	10	SLD LINE	STG	NO CHG	45	SW	NNW-SSE	20 W ARGONIA	20	10	NE	50	480			EZ
05	0008	1	SLD LINE	STG	NO CHG	20	SW	NW-SE		20	7	NE	50				EZ
05	0107	2	LINE SCTD	MDT	DCRG	30	S	N-S		120	50	NE	35				EZ
05	0212	3	SLD LINE	MDT	NO CHG	50	SE	N-S		100	10	UNK		260	(camera on 0214 C)		EZ
—			SLD LINE	MDT	INCRG	30	W	N-S		120	15	UNK		250			EZ
05	0350	4	SCTD	MDT	INCRG SLOLY		COMPLETE	CIRCLE	AROUND ICT	RADIUS	70	MI	FROM		STATION		EZ
05	0432	5	SLD LINE	MDT	NO CHG	35	SE	NE-SW		80	20	UNK		280			EZ
05	0505	6	SLD LINE	MDT	DCRG	50	SSE	NE-SW		70	20	NW	20				EZ
05	0532	7	LINE SCTD	WK	DCRG RPDLY	60	SSE	NE-SW		100	30	UNK			(camera off 0531 C)		EZ
05	0605	8														PPINE	DW
05	0755	9	LINE SCTD	WK	DCRG	80	NW	NNE-SSW	N GREATBEND TO NE PRATT	50	6	UNK					DW
—			SLD LINE	WK	DCRG	85	SE	NE-SW	E COFFEYVILLE	20	5	UNK					DW
05	0835	10														PPINE	DW
05	1130	11	SLD LINE	WK	UNK	90	SE	NE-SW	NR BARTLESVILLE	20	5	UNK					DW
05	1200	12														PPINE	DW
05	1405															PPINE	FW
05	1554	13	SLD	STG	UNK	50	S		NR BRAMAN		20	SW	10	320	(camera on 1554 C)		FW

Direction to 16 points of the compass.
Distance to the nearest statute mile.

Length and width to nearest statute mile.

Fig. 15. Recording form for radar weather observations.

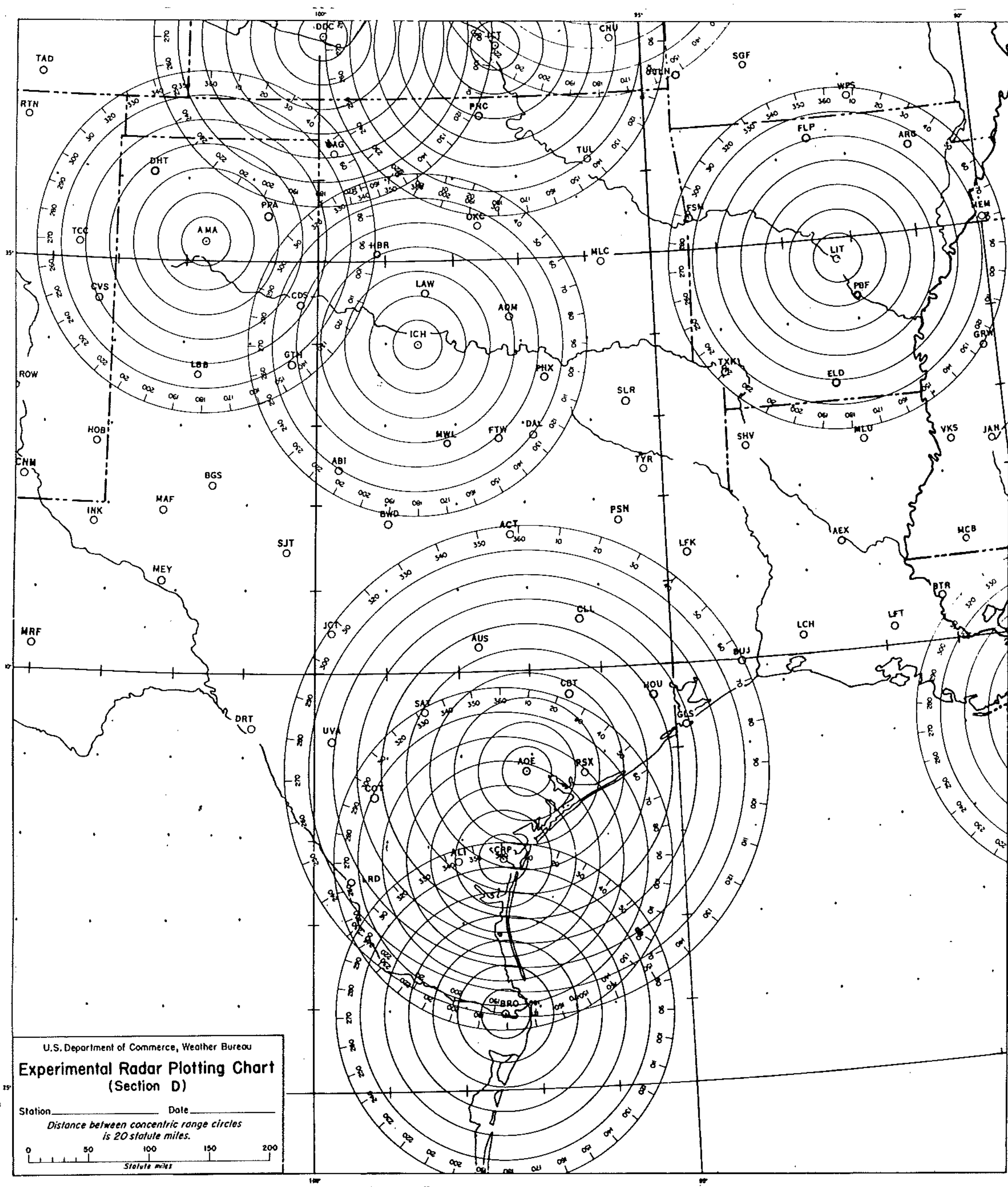

Fig. 16. Radar Plotting Chart.
Similar charts have been prepared for other sections to facilitate the plotting of radar reports.

☆U. S. GOVERNMENT PRINTING OFFICE: 1953 O—273498

Climatic Analysis

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON

February 24, 1961

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO

FILE: 610.3

MEMORANDUM

0-4.25

MEMO

TO : All Radar Stations
All Continental Regional Administrative Offices (for information), RADU

FROM : Chief, O&SF Division

SUBJECT : Use of Radar During the Severe Local Storm Season

(Use of Radar During the Severe Local Storm Season)

Each year, the use of radar in storm-warning and short-range forecasting becomes increasingly important. With the advent of the severe local storm season, it is suggested that each station have some type of radar observation training program prior to the spring season. The broad objective of this program should be to increase effectiveness and make the best use of radar during the severe weather and thunderstorm season. Although the issuance of severe local forecasts and warnings should be an integral part of any training program, this memorandum is primarily concerned with the detection and appearance of severe storms on radarscopes and their subsequent recording on WB Form 610-3 and film. Suggestions for training on hurricanes will not be included in this memorandum, but will be covered at a later date. The following items and articles are suggested for review and discussion:

1. Synoptic situations associated with severe weather. A very good resume of these parameters may be found in Forecasting Guide No. 1, "Forecasting Tornadoes and Severe Thunderstorms."

2. Weather Surveillance Radar Manual; especially Chapters 3 and 4.

3. Training Film Strips Nos. 1, 4, 5, 6, and 7.

4. Review of local severe weather warning procedures.

5. Memorandum 0-5.34, "Skill in the Utilization of Weather Radar," dated July 22, 1959.

6. Texas A&M Report, "The Use of Radar in Severe Storm Detection, Hydrology and Climatology," Myron G. H. Ligda, October 1956. (available at most radar stations)

WASHINGTON, D. C.
2-24-61

7. Any other material related to the detection of severe local storms by radar that are available in the station library.

8. Ralph Donaldson's Report, "Radar Methods for Identification of Severe Storms." (Listed in Progress Report No. 4, page 8).

Item (6) contains the distinctive characteristics most frequently observed to occur with hooked echoes. Recent studies have shown that identification of the hooked echo feature is easier and frequently better defined at about 20,000 feet rather than near the ground. Further, in many cases, the hooked echo will be obscured by light rain at full radar sensitivity. Therefore, the attenuator control, in the case of the WSR-57, or the receiver gain control in the case of the WSR-1, 3, or 4 should be used to reduce the radar sensitivity so that the weaker echoes are not distinguishable. Of equal importance is the evolution of the hooked echo. Continuous manning of the radar is mandatory in order to observe the often short-lived appearance of this particular feature. It is worthy of note that although the presence of a hooked echo is an important indication of severe local weather, other parameters are equally important.

In addition, to features discussed in items (5) a number of significant research results should be evaluated by all stations. Recent articles indicate a method for objective determination of storm severity by utilizing the WSR-57 attenuator controls and the Rainfall Rate-Echo Intensity Chart. Echo heights with respect to the tropopause and the echo intensity at 20-30,000 feet are considered to be important criteria for severe local storm identification. The intensity criteria contained in the echo intensity graph were developed, in part, to provide assistance in severe local storm identification. Research results have shown that echoes falling within the "Strong" category are very often associated with hail greater than 1/2 inch at the ground, and echoes in the "Very Strong" category are very often associated with tornadoes. Although there may be some climatic differences, and some tornadoes may occur in association with "Moderate" echoes, radar operators should consider that echo intensity is an excellent criterion of storm severity, particularly when an intensity maximum of Strong or Very Strong occurs at middle levels of the echo (20,000-30,000 feet). These criteria may be used only when echoes are less than 100 miles distant. Beam dimensions, refraction of the beam and earth curvature combine to create sufficient uncertainty of the reliability of data beyond 100 miles.

Incidentally, RADU is conducting on a national scale a study to evaluate the extent that tropopause penetration can be used to identify severe local storms. Once again, recent research has indicated that echoes penetrating the tropopause by 5,000 feet or more should be regarded as potential producers of large hail, with an increasing threat of a tornado as echo tops grow higher.

Although the operational requirements of the radar should always have top priority, every effort should be made to photograph data on severe storms. This should include PPI and RHI photographs at different antenna elevations and attenuator settings. If time and operational needs will permit, reflectivity profiles should be made.

The above echo severity criteria may also be used by WSR-1, 3, and 4 radars, but in a less precise manner. Although suitable observations are difficult to obtain, diligent operators may do fairly well. To observe either of the two criteria, i.e., maximum echo height, and height and intensity of the strongest portion of the echo, the antenna should be positioned in the azimuth of the storm being investigated, then scanned vertically. By decreasing receiver gain until the echo reaches a threshold level, the height of the echo maximum may be observed on the RHI or A scope. By trial and error, operators will have to learn the significance of receiver gain settings, with proper consideration of the range to the target. Maximum echo height may be determined in the usual manner.

If the Radar Unit of this division can be of any assistance in the formulation of the radar observation training program, please feel free to request it of us.

A. K. Showalter

UNITED STATES DEPARTMENT OF COMMERCE
WEATHER BUREAU
WASHINGTON
January 6, 1959

FILE: 610.3 x467

IN REPLY, PLEASE ADDRESS
CHIEF, U. S. WEATHER BUREAU
WASHINGTON 25, D. C.
AND REFER TO
0-6

MAL 5-59

MULTIPLE ADDRESS LETTER NO. 5-59

TO: Selected Stations

FROM: Chief of Bureau

SUBJECT: Use of Radar Film for Hydrologic or Climatological Purposes

(Use of Radar Film for Hydrologic or Climatological Purposes)

WASHINGTON, D. C. 1-6-59

With increased use of radar as a weather detecting instrument has come a corresponding increase in the number of requests for radar data, especially for time-lapse film of the radarscope. Many of these requests have come from groups concerned with water resources development in areas where radar has been given a great deal of publicity. As our radar installations become more numerous, these inquiries can be expected to increase accordingly.

Almost without exception, people desiring this information lack an understanding of the limitations inherent in WSR-1 and 3 radar sets currently in operation. For this reason, it is felt that the capabilities and limitations of the radars and the time-lapse film should be enumerated. On this basis, field officials will be better able to answer requests for such data as monthly and annual isohyetal maps, storm studies, etc., based on radar time-lapse film.

It should be made clear that all of the limitations ascribed to the WSR-1 and 3 radars will not necessarily apply to the SP type in operation at Nantucket, Cape Hatteras and San Juan, or to the WSR-57 radar which is to be placed in operation at many stations within the next year and a half.

The following table lists, for comparison purposes, the major characteristics of Weather Bureau radar equipment:

CHARACTERISTICS OF WEATHER BUREAU RADAR EQUIPMENT

	WSR-1 and 3	SP	WSR-57
Wave Length	10 cm	10 cm	10 cm
Peak Power Output	60 KW	1000 KW	500 KW
Beam Width	4°	2°	1.8°
Antenna	6 Ft	8 Ft	12 Ft

Examination of these characteristics will indicate the more predominant differences between the several radar types, the primary one being in power output. The power received at the radar from a storm is directly proportional to power output, inversely proportional to the square of the range and directly proportional to the area of the antenna. Thus, for radars of equal power and wave length, one having a 12-foot antenna would detect four times more energy from a storm than one with a 6-foot antenna. On the basis of power output and antenna area of the three radar types, power received by the SP radar would be 30 times greater, and for the WSR-57, 33 times greater than that of the WSR-1 and 3. Low power and small antenna severely limit the range of detection of the WSR-1's and 3's for all but the heaviest precipitation. In other words, low power prevents the radar beam from penetrating areas of heavy precipitation. This makes it difficult to estimate the areal extent and intensity variations of precipitation.

Investigations have also shown that the WSR-1 and 3 cannot generally detect precipitation falling at rates lower than 0.10-inch per hour. It should also be pointed out that when a radar is operating at full gain, echoes from heavy precipitation will sometimes saturate the PPI scope, depending upon the range of detection. This upper limit of detection has not been clearly defined and will vary somewhat from radar to radar, depending upon its operating efficiency, power output, antenna size or dynamic range. (It is this dynamic range which determines the upper and lower limit of detectability.) When the receiver gain on the radar is lowered the more intense precipitation is indicated, but at the expense of not detecting the lower rates. The most ideal radar would be one that could present all intensities. Though the WSR-57 and SP radars will have much greater dynamic range than the WSR-1 and 3, they still are limited to a range of intensity of up to approximately 3-1/2 to 4 inches per hour.

It should be made clear to those requesting radar data that though our coverage is adequate in some areas (with the lower-powered radars) for severe storm detection, overlapping coverage satisfactory for hydrologic analysis on a large scale is not yet available and won't be until the WSR-57 network is complete. The hydrologic range of the WSR-1 and 3 radar is only about 60 miles, beyond which the relationship between the radar echo and measured precipitation becomes increasingly obscure. This range will be extended to 130-150 miles with the SP and WSR-57 sets.

Other factors which affect all radars regardless of power, etc., can influence the determination of precipitation distribution. These include refraction of the radar beam, anomalous propagation (AP), and the quality of the time-lapse film itself.

Under certain atmospheric conditions, the radar beam may be refracted either upward or downward. If upward, the beam is lost in space and may overshoot storms normally detected. If bent downward, all of the energy may be lost in a very short range, thus limiting the range of detection. Certain atmospheric conditions cause the beam to be trapped or ducted in a layer close to the ground, thus presenting ground echoes on the face of the scope to distances far beyond the normal ground clutter of the radar. Frequently these anomalous propagation echoes have occurred simultaneously with the appearance of precipitation echoes over the same area. It would be difficult, if not impossible, in this case for even an experienced analyst to separate false echoes from precipitation. An inexperienced analyst would not even recognize the echoes derived from anomalous propagation, whereas a person familiar with radar could compensate to some extent for the presence of such phenomena.

Another factor limiting analysis of time-lapse radar film is the quality of the film itself. There are times when malfunctioning of the camera or radar equipment, incorrect exposure, inadequate data card information, or interruptions in the filmed sequence will preclude the use of the film for determining precipitation distribution, even for short-duration storms.

Despite efforts to exercise some control over these factors by the RADU, such difficulties will have to be overcome before the film will be completely adequate for climatological analysis. However, studies of specific storms may be undertaken by competent analysts familiar with the vagaries of radar storm detection.

In spite of the numerous limitations listed above, the WSR-1 and 3 radars are very useful. They still perform admirably under many circumstances, and especially so in the detection of severe thunder and hail storms, tornadoes, and for alerting river forecasters to the possibility of flash floods.

It is believed that all concerned with the use of radar should be cognizant of the operating characteristics of the radars in use. Only with such understanding can field officials properly evaluate the usefulness of the radar time-lapse film when requested for specific storm studies.

Until the time when our network of WSR-57 radars is established and the time-lapse film program is stabilized, it is deemed necessary to restrict the distribution of radar film copies to those agencies which fully understand the limitations of the radar and the quality of radar film data. The time-lapse film may still be useful for specific storm studies providing the quality is good. In these instances, it may be used to supplement "bucket surveys", flash flood situations, and other cases where knowledge of the precipitation distribution is required. However, the use of available time-lapse radar film for the determination of long-period rainfall or climatological averages should definitely be discouraged at this time.

Copies of this Multiple Address Letter may be used in replying to requests for radar film or radar studies.

F. W. Reichelderfer

USCOMM-WB-DC