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EVALUATION OF AIRPORT SURFACE DETECTION EQUIPMENT MODEL AN/MPN-7 (XW-1)

PART I

TECHNICAL EVALUATION

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PART I

TECHNICAL EVALUATION

SUMMARY

This is the first of two reports which describe the evaluation of an experimental airport surface detection equipment (ASDE) designated by the Department of the Air Force as Radar Set AN/MPN-7 (XW-1) Originally called Radar Set AN/CPS-8 (XW 1), this equipment was modified to provide information necessary to facilitate the movement of traffic on the surface of an airport during conditions of poor visibility

Part I of this report is concerned with the technical phase of the evaluation program Part II covers the operational tests conducted during the program

Azimuth errors of the equipment were less than one degree, and range errors were less than five feet The azimuth resolution varied from 35 to 70 feet at ranges of 1,000 to 5,000 feet The range resolution was 22 feet at a distance of 5,000 feet The performance was not greatly affected by precipitation except during exceedingly heavy rainfall

Recommendations are included for improvements in subsequent models

INTRODUCTION

A problem of airport traffic control under poor visibility conditions is to determine reliably the location of aircraft and vehicles on the surface of the airport in order to establish which runways and taxi strips are clear and available for use Since operations are now authorized in some locations under conditions in which visibility is restricted to one-half mile, it has become increasingly difficult for personnel in the control tower to exercise visual surveillance over the entire airport area This problem becomes acute at large airports, not only because the area which must be brought under surveillance is large but also because the accuracy of the controller's depth perception diminishes with distance These conditions result in errors in judgment and, consequently, in inadequate ground control

There have been proposed several possible solutions to the problem of providing the control tower personnel with more information regarding the movement of ground traffic during conditions of poor visibility These include the use on or alongside the runways and taxi strips of mechanical, electrical, or electronic devices to detect the passage of or to determine the location of an object near them Most of these solutions either present an extensive installation problem or lack means of providing continuous indications of the necessary information The most promising solution appears to be an accurate, high-resolution type of surveillance radar equipment which provides continuous information and is relatively simple to install

In order to determine the extent of assistance which radar equipment might render in improving the ground traffic control situation, the Air Navigation Development Board initiated a program under ANDB Project No 6 2 3 to evaluate ASDE, which was developed under ANDB Project No 5 1 The radar unit was obtained on a loan basis from the Rome Air Development Center of the Department of the Air Force After extensive modification by the Airborne Instruments Laboratory, it was moved in April 1951 to the Technical Development and Evaluation Center of the Civil Aeronautics Administration at Indianapolis, Indiana, for evaluation The trailer housing the equipment was installed at a site on the west side of Weir Cook Municipal Airport

The evaluation program was divided into two phases, a technical evaluation and an operational evaluation The technical phase was conducted by engineering personnel, and the results are contained in this report The results of the second phase of the evaluation program, which was conducted by traffic control specialists, are included in Part II of the report The evaluation

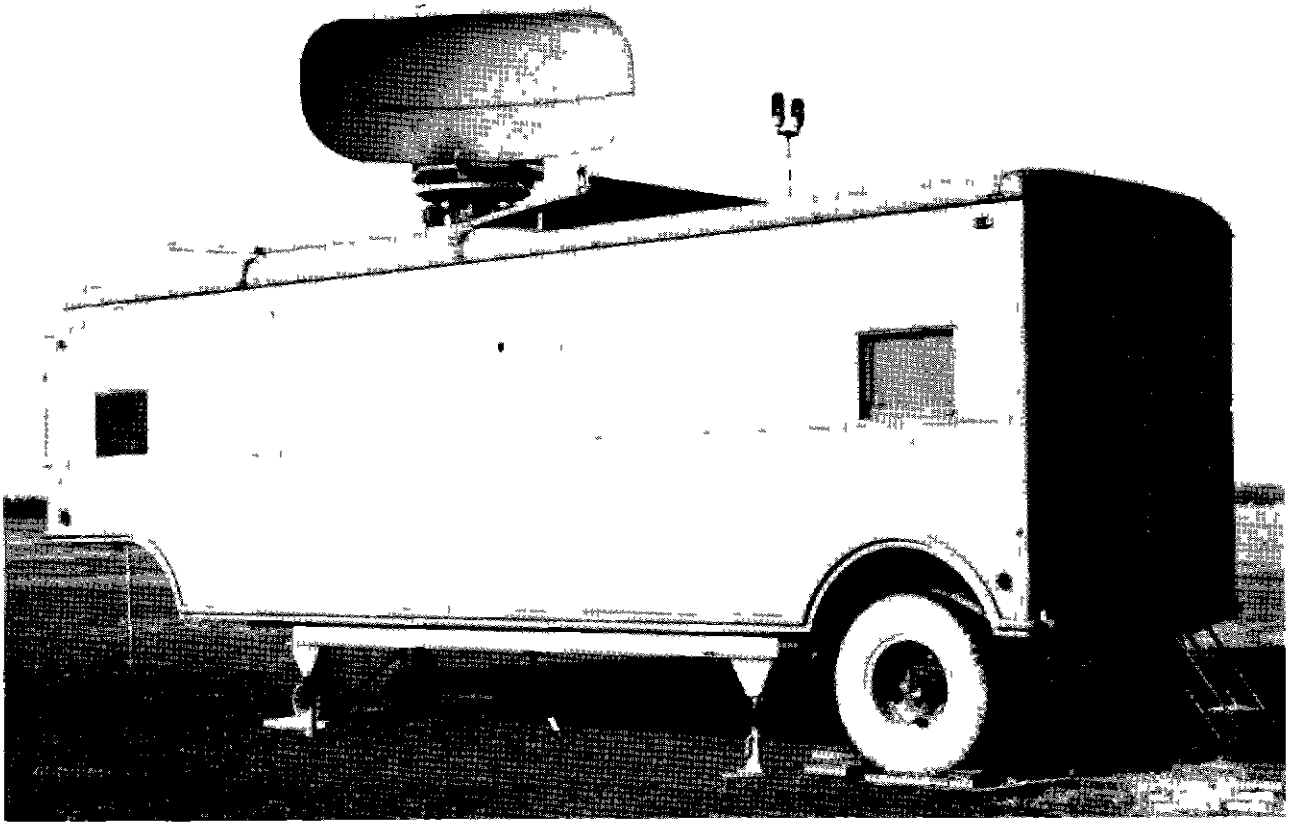


Fig 1 U S Air Force Type K-78 Trailer Housing ASDE

program was completed and the equipment returned to the Department of the Air Force in March 1952

DESCRIPTION

The equipment which was evaluated is a 1 25-centimeter (cm) search radar originally identified as Type AN/CPS-8 (XW-1), developed by Gilfillan Brothers, Incorporated, Los Angeles, California Modifications of the unit to improve performance characteristics were made by the Airborne Instruments Laboratory, Mineola New York, on Department of the Air Force Contract No AF-28 (099)-9, with funds supplied by ANDB under Project No 5 1 The radar set, new designated as AN/MPN-7 (XW-1), consists of the following basic parts a transmitter-receiver cabinet, two indicator cabinets, four rack-panel mounted power supplies, and a parabolic type antenna system The equipment is housed in a USAF Type K-78 trailer, which is shown in Fig 1

The transmitter is designed around a Type 3J31 K-band magnetron which in this installation supplies a peak power of 20 kilowatts at an average power of approximately 4 watts The modulator employs three Type 5D21 vacuum tubes connected in parallel and operates from a line type pulser which terminates in a Type 4C35 hydrogen thyratron

The receiver consists of the usual duplexer and associated switching tubes, a thermally tuned Type 2K50 reflex klystron local oscillator, a four-crystal mixer assembly, a distributed amplifier pre-amplifier, and a wide-band intermediate-frequency amplifier employing four triple stagger-tuned circuits

The two indicator display units house video amplifiers, power supplies, servo-system equipment, and deflection circuits They also house 12-inch diameter Type K1062 P2 cathode-ray tubes manufactured by Allen B DuMont Laboratories, Inc The transmitter, receiver, and indicator cabinets are shown in Fig 2 Fig 3 is a block diagram of the equipment Most of the power supplies, with the exception of those for tube filaments and the high voltages for the

Fig 2 Transmitter, Receiver, and Indicator Cabinets

magnetron and PPI tubes, are contained in racks at one end of the trailer Fig 4 shows the arrangement of this portion of the equipment

The antenna is a horn-fed truncated parabola, 7 1/2 feet long and 3 feet high, to which a spoiler plate has been added to provide a cosecant-squared pattern approximately 10° wide in the vertical plane The horizontal plane pattern of the antenna is 0 4° wide at the half-power points

The block occupancy system which is used in conjunction with the plan position indicator (PPI) to provide remote indication of targets within discrete areas consists of a hood adapter assembly, photocell amplifiers, power supplies, and a light type indicator display unit A hood adapter containing the Type 1P42 photoelectric cells is positioned over the cathode-ray tube, with each photocell monitoring an area 1/4-inch square The light from a target appearing within this area actuates the cell and produces a signal which is amplified and used to trigger a blocking oscillator The blocking oscillators generate pulses which operate relays controlling the warning lights

Other equipment furnished by the USAF for this program included a modified Type TSK-2SF spectrum analyzer, an MIT Model 5 synchroscope (A-scope), a Type TS-223/AP Test Set, a Model F-259 Dvorecord 35-millimeter (mm) camera, and a trigger generator variable from 5,000 to 20,000 pulses per second (pps)

TEST PROCEDURES

Accuracy Tests

Azimuth accuracy tests were conducted by comparing theodolite and radar measurements of azimuth angle between a fixed reference point and selected targets Angular measurements on 8- by 10-inch enlargements of PPI photographs were made to obtain radar azimuth data Both aircraft and corner reflectors were used as targets during the tests

In determining the range accuracy, the range mark delay control was adjusted so that the first range mark coincided with the return of a corner reflector at a measured distance of 2,000 feet The corner reflector was then moved so that its return coincided with the 4,000-foot range mark, the actual distance was measured to the radar antenna, and the error was determined These tests were repeated at various azimuths

Resolution Tests

Azimuth resolution at distances from 1,000 to 5,000 feet was established by measuring the angular separation required between two corner reflectors to produce two separate and distinct targets on the PPI Targets producing different amounts of return were compared for resolution characteristics at a range of 1,000 feet

Similar techniques were employed to determine range resolution, except that the radial separation between reflectors was measured The effect on range resolution of pulse widths from 0 015 to 0 08 microsecond was studied by means of photographs

Antenna Tests

The horizontal plane pattern of the antenna was determined with the antenna locked at a fixed azimuth A corner reflector was first placed at the point of maximum return and was then moved away from the center of the beam in increments of 0 05° In each position, the radar return was measured by observing the amplitude of the video output on an A-scope A wooden base 42 feet long, drilled at suitable intervals to support a pole holding a corner reflector, was used in these measurements to assure target stability All horizontal plane pattern

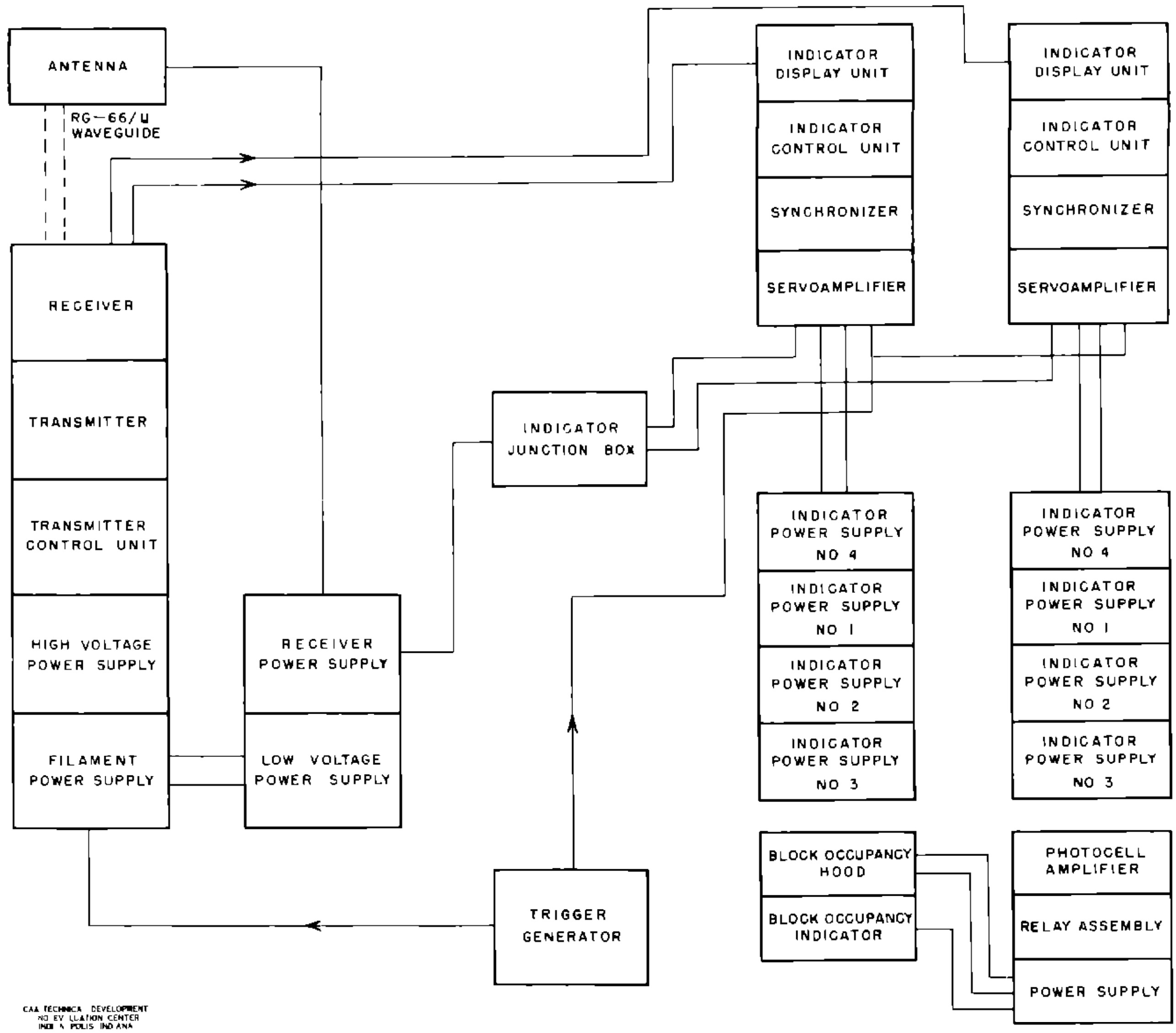


Fig 3 Block Diagram of Airport Surface Detection Equipment (ASDE)

measurements were made at a range of 4,000 feet to assure operation in the Fraunhofer region

To investigate the vertical plane pattern of the antenna, the angle of the top of the main lobe with respect to ground was first established This was accomplished by observing the altitude at which landing aircraft became visible on the PPI This process indicated that the top of the lobe was essentially parallel to the ground when antenna tilt was set at zero The shortest range at which a target could be seen on the indicator was then determined to obtain the angle of coverage The tests were conducted with the antenna mounted on a CPN-18 tower

Photographs of the PPI, taken with a Dvorecord Model F-259 35-mm camera, were used to compare radar coverage obtained with the antenna mounted on the trailer and on a CPN-18 tower 30 feet in height Similar photographs were employed to examine the extremes of coverage obtained when the antenna was tilted ± 2 0° from a horizontal position

Servosystem Tests

Measurements of servosystem lag and of the extent of fluctuation in servo-error voltages were made from enlarged photographs of oscilloscopic traces To determine the magnitude of the maximum error voltage, a Model 512 Tektronix cathode-ray oscilloscope was connected to the input of the servoamplifier The antenna drive motors were switched on and off rapidly while the

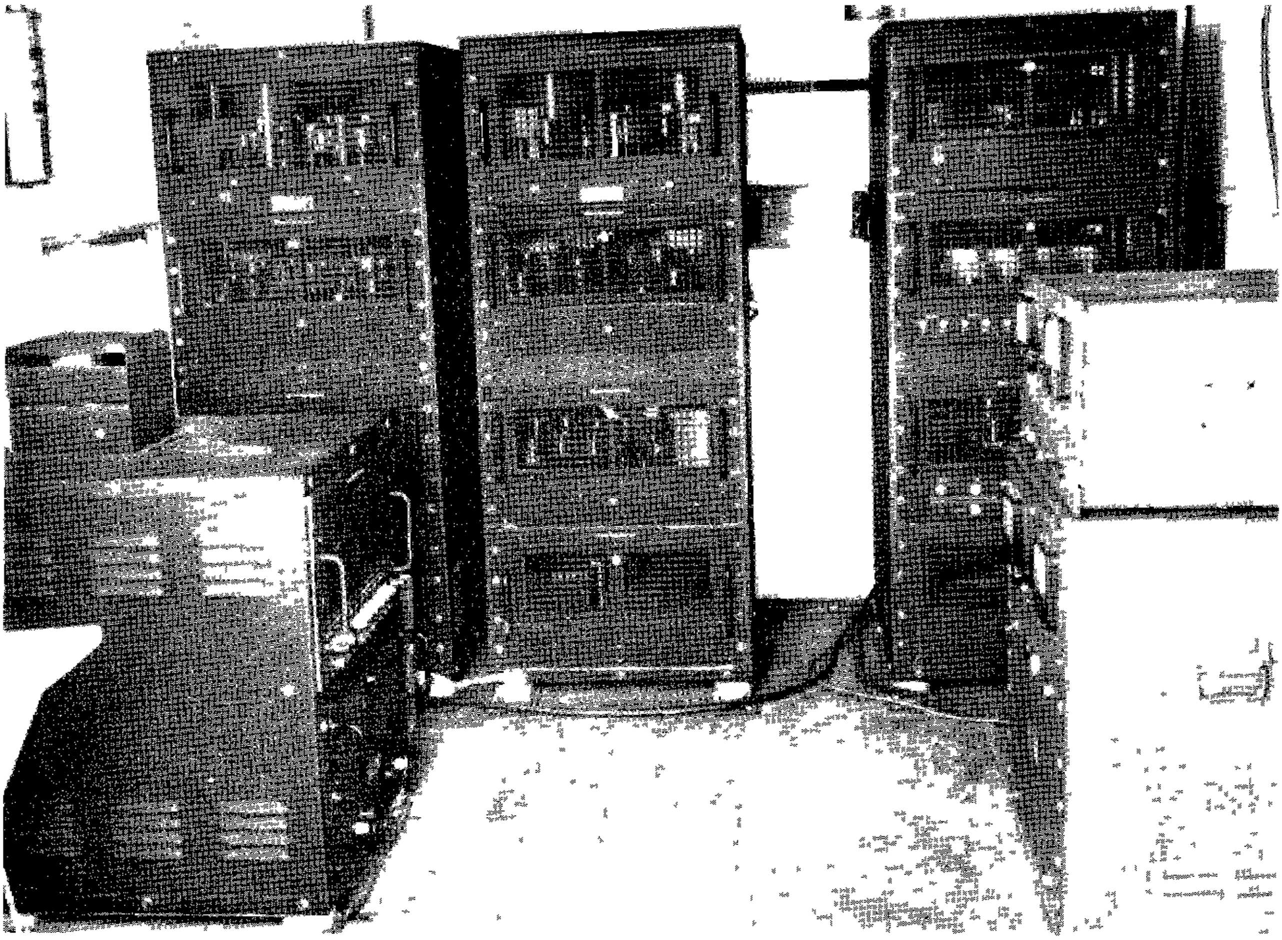


Fig 4 Power Supply Racks

maximum and minimum amplitudes of the error voltage were being observed The resulting oscilloscopic traces superimposed on a calibrating voltage signal were then photographed with a Model F-284 Fairchild polaroid camera The same photographic and oscilloscopic techniques were used in examining servosystem lag and error voltage fluctuations under various conditions of amplifier adjustment After it became apparent that no further reduction in error voltage fluctuation could be achieved with the existing equipment, electrical damping was introduced in the servosystem by incorporating a twin-tee network into the servoamplifier circuits After this modification, further tests were conducted

Block Occupancy System

The block occupancy system was prepared for testing by inserting photocells in the hood adapter assembly to cover a portion of one of the runways Aircraft were then taxied through the area under surveillance, and the operation of the warning indicators was observed

Precipitation Tests

The effects of rain, snow, and fog on radar operation were studied by direct observation and with the aid of photographs of the PPI under weather conditions suitable for such tests

Radar Area Tests

The radar area of targets was measured from photographs of the PPI Vehicles were stationed at ranges of 500, 1000, 2500, and 4000 feet with headings providing front, rear, and broadside views from the position of the radar equipment The negatives of the five exposures made at each of these headings and ranges were projected to a distance sufficient to provide the magnification necessary for precise determination of the area of each target

During the tests, the sharpest focus of the sweep was maintained at a point of the indicator representing a range of 3,000 feet

The following types of vehicles were employed as targets

TYPE OF VEHICLE	DESCRIPTION
Douglas C-54	Large-size 4-engine aircraft
Douglas DC-3	Medium-size twin-engine aircraft
Beechcraft C-45	Small-size twin-engine aircraft
Piper Clipper	Four-place personal aircraft
Cessna 140	Two-place personal aircraft
Jeep Fire Truck	Small-size utility vehicle

TEST RESULTS

Accuracy Tests

The azimuth accuracy of the equipment measured with a Douglas DC-3 airplane as a target produced the results shown in Table I

To prevent the factors encountered in the aforementioned tests from influencing measurements of radar accuracy, the tests were repeated using a corner reflector as a target and using range scales selected to utilize only the center of the PPI This series of tests produced the results shown in Table II

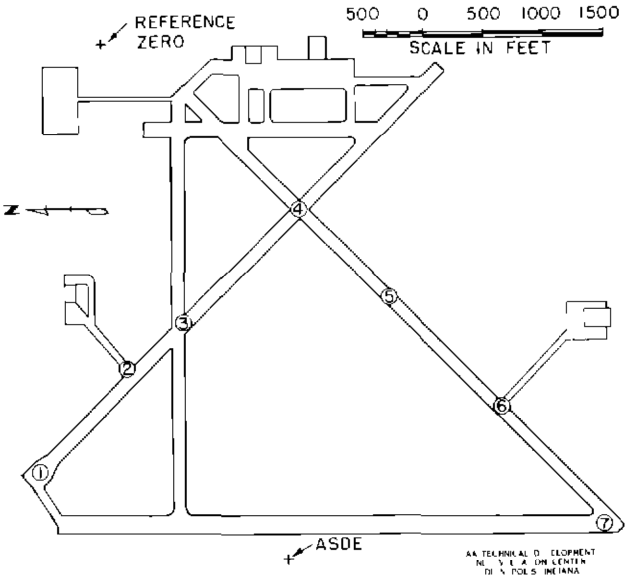


Fig 5 Approximate Location of Targets in Range Accuracy Tests

TABLE I

AZIMUTH ACCURACY TESTS

Position*	Theodolite Bearing (degrees)	Radar Bearing (degrees)	Error** (degrees)
1	311 15	313 30	+2 15
2	340 92	341 90	+0 98
3	356 85	357 60	+0 75
4	26 40	26 70	+0 30
5	40 35	40 00	-0 35
6	71 51	71 80	+0 30
7	102 14	102 90	+0 76

*Position numbers refer to the location of the target on the airport See Fig 5

**While the information shown in Table I indicates the azimuth accuracy obtained under normal operating conditions, it is believed that other factors contributed to the excessive errors found in certain test positions For example, in some cases the targets were close to the edges of the PPI, and measurements were thus affected by the nonlinearity of the sweep It also proved difficult to select a reference for precise theodolite measurements on a target such as the DC-3 airplane when the attitude of the craft, with respect to the theodolite operator, changed from one position to another

TABLE II

AZIMUTH ACCURACY TESTS

Position*	Theodolite Bearing (degrees)	Radar Bearing (degrees)	Error (degrees)
1	311 25	311 30	+0 05
2	342 00	342 50	+0 50
3	355 65	355 70	+0 05
4	22 00	21 50	-0 50
5	36 45	36 00	-0 45
6	71 40	70 80	-0 63
7	100 00	100 20	+0 20

*Position numbers refer to target location See Fig 5

TABLE III

RANGE ACCURACY TESTS

Range (feet)	Position*	Azimuth Angle From Zero Reference (degrees)	Error** (feet)
2000	1	0	0
2000	2	48 5	0
2000	3	77 5	0
2000	4	129 0	0
2000	5	155 5	+5
4000	6	53 5	0
4000	7	91 25	0

*Position numbers refer to the location of the target on the airport See map, Fig 6

**Zero error was recorded if the target return lay within the range mark which was equivalent to 10 feet in width

TABLE IV

AZIMUTH RESOLUTION TESTS

Range (feet)	Separation Required to Resolve Two Targets	
	*Low Gain (feet)	**High Gain (feet)
1000	35	35
2000	36	40
3000	40	44
4000	49	59
5000	65	70

*Low Gain — Minimum usable receiver gain level

**High Gain — 12 db above minimum signal level

Tables I and II show data obtained with a pulse repetition frequency (prf) of 5,000 pps, a pulse width of 0 02 microsecond and an antenna rotational rate of 60 revolutions per minute (rpm)

The results of the range accuracy tests of the ASDE are shown in Table III

TABLE V

AZIMUTH RESOLUTION TESTS

Range (feet)	Separation Required to Resolve Two Targets	
	Target Near Edge of PPI (feet)	Target Near Center of PPI (feet)
1000	36	30
5000	65	49

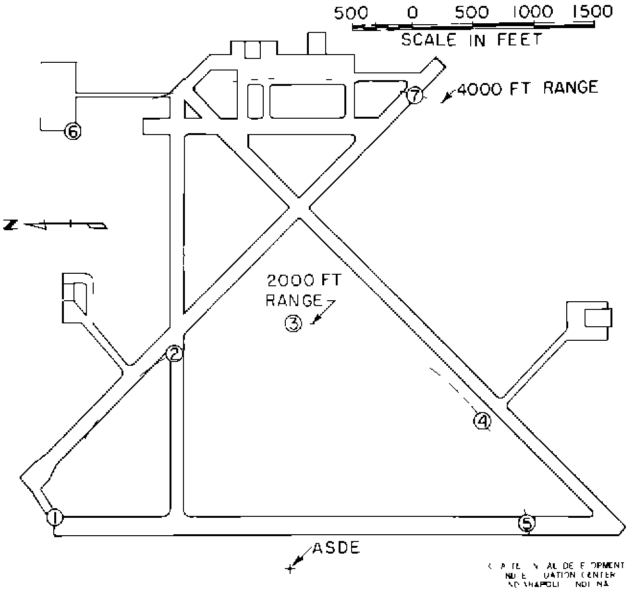


Fig 6 Approximate Location of Targets in Range Accuracy Tests

Resolution Tests

A series of tests to determine the over-all azimuth resolution of the equipment under normal operating conditions produced the average characteristics shown in Table IV

Some of the tests were later repeated to avoid the introduction of errors caused by nonlinearity of sweep and to ascertain the extent of improvement in azimuth resolution characteristics which could be obtained by moving the targets away from the edges of the PPI The separation required to obtain resolution between two targets varies considerably with the position of the targets on the cathode-ray tube, as shown by data displayed in Table V To study resolution characteristics further targets providing less return than standard corner reflectors were examined Table VI shows the separation required to secure resolution from several such targets

TABLE VI

AZIMUTH RESOLUTION TESTS

Range (feet)	Type of Target	Conditions	Separation Required to Resolve Two Targets (feet)
1000	Corner reflector	Normal orientation	30
	Corner reflector	Back of reflector toward radar	26
	Men		21
	Sedan delivery trucks	Broadside to radar (Measured bumper to bumper)	29
450	Men		12

TABLE VII

RANGE RESOLUTION TESTS

Range (feet)	Separation Required to Resolve Two Targets	
	*Low Gain (feet)	**High Gain (feet)
1000	20	20
2000	22	21
3000	23	22
4000	24	24
5000	22	22

*Low Gain — Minimum usable receiver gain level

**High Gain — 12 db above minimum signal level

TABLE VIII

RANGE RESOLUTION AS A FUNCTION OF PULSE WIDTH

Range 2000 Feet

Pulse Width (microseconds)	Separation Required to Resolve Two Targets (feet)
0 08	27 5
0 06	25 0
0 04	23 5
0 03	22 75
0 02	20 0
0 015	14 5
0 01	No return

Range resolution of the equipment is shown in Table VII

Tables IV, V, VI, and VII show data obtained with a prf of 5,000 pps, a pulse width of 0 02 microsecond, and an antenna rotational rate of 60 rpm

A variation in prf from 4,000 to 10,000 pps caused no noticeable change in resolution characteristics

The use of various pulse widths produced the changes in range resolution shown in Table VIII

As a result of the comparatively small differences in range resolution produced by changes in pulse width, the intermediate-frequency bandwidth of the receiver was examined A curve of the magnitude of a continuous wave signal applied to the first detector for a constant output voltage at the second detector plotted against frequency is shown in Fig 7 The bandwidth of the intermediate-frequency amplifier is 55 megacycles at 6 decibels (db) down

Antenna Tests

The horizontal plane pattern of the antenna system measured 0 4° wide at the half-power points Pattern measurements are shown in Table IX

The field intensity of the minor lobes was too low to be detected in this manner A target may be seen on the PPI through an

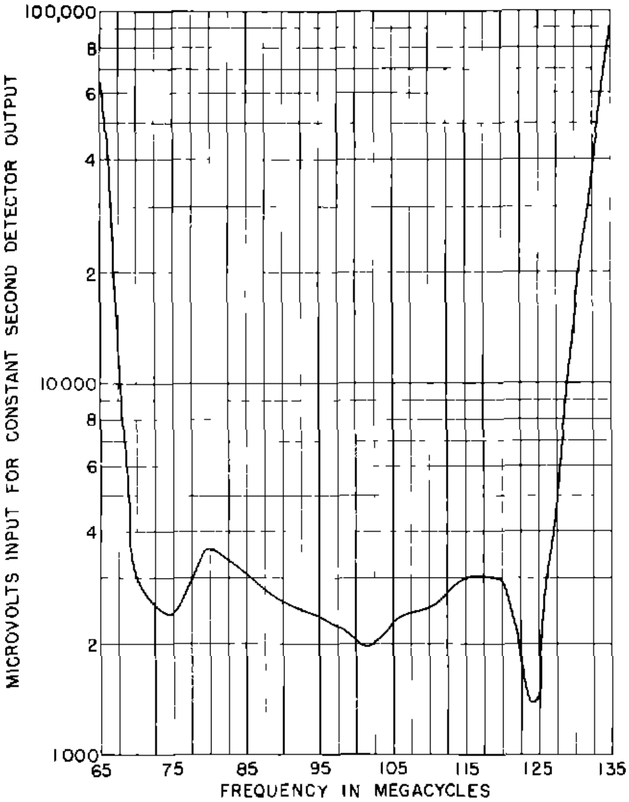


Fig 7 Receiver Intermediate Frequency Bandwidth

angle of 0 77°, or 54 feet at a range of 4,000 feet, if the radar return is not sufficient to saturate the receiver When the return is great enough to produce receiver saturation, a target is visible through 0 9°, or 63 feet at the same range

Measurements of the vertical plane field pattern revealed a beam width of approximately 10°, however, areas of low return were found to exist between angles of 2°44' and 3°21' and between 4°31' and 5°23' below the horizontal

Radar coverage of the airport at Indianapolis was improved considerably by moving the antenna from the top of the trailer to a CPN-18 tower 30 feet high The extra height at this location was required because the elevation at the center of the airport is eight feet higher than the site at which the radar unit was located Later tests with the trailer positioned near the center of the field demonstrated that some additional antenna height is necessary to provide complete radar coverage when the terrain is uneven The relative amount of field painted in with the two antenna heights is shown in Figs 8A and 8B Fig 9 shows the general appearance of the equipment when the antenna is mounted on the CPN-18 tower

Incorporated in the antenna system are provisions for changing the tilt ± 2 0° from a horizontal position At the maximum downward tilt an area within a radius of 1,000 feet is covered, while at the maximum upward tilt only objects of considerable height, such as trees or buildings, are visible Intermediate positions of antenna tilt will permit coverage of most types of terrain with an antenna elevation of 30 feet, if a direct line of sight from the antenna to the target exists

Radar coverage obtained with the equipment at Wold-Chamberlain Airport, Minneapolis, Minnesota, is shown in Fig 10 In this installation, the antenna was mounted on a tower near the center of the field

TABLE IX

HORIZONTAL FIELD PATTERN MEASUREMENTS ASDE ANTENNA (TWO-WAY)

Angle From Center of Beam (degrees)	Relative Amplitude of Return on A-Scope (decibels)
0 00	0.0
+0 05	-1 9
+0 10	-3.0
+0 15	-5 0
+0 20	-6.0
+0 25	-7 9
+0 30	-10 4
+0 35	-13 9

Servosystem Tests

Measurements obtained from a photograph of the oscillogram, Fig 11A, indicated that the maximum error voltage, developed under transient conditions, was 61 0 volts root mean square (rms) With the antenna rotating and with conventional servoamplifier gain adjustment procedures, maximum and minimum amplitudes of error voltage were found to be 8 0 and 5 8 volts rms, respectively These potentials represent a maximum and a minimum lag in the system of 7°32' and 5°27', or a fluctuation of 2°5'

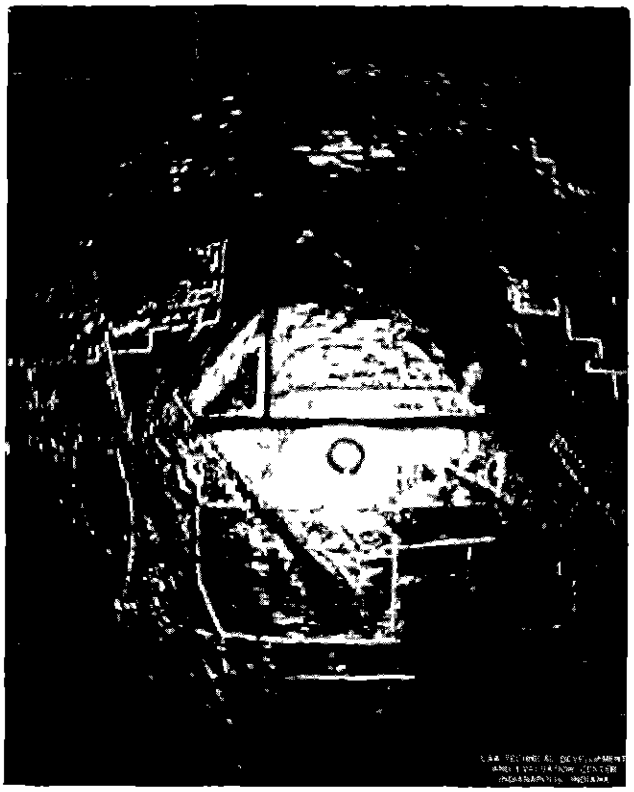


Fig 8A Radar Coverage of Weir Cook Airport, Indianapolis, Indiana Antenna Mounted on Trailer (12-Inch Cathode-Ray Tube)

Fig 8B Radar Coverage of Weir Cook Airport, Indianapolis, Indiana Antenna Mounted on CPN-18 Tower (12-Inch Cathode-Ray Tube)

Fig 11B shows the oscillographic trace from which these values were determined

When an oscilloscope was used as a guide in adjusting the servoamplifiers, a maximum error voltage of 3 21 volts rms (corresponding to a lag of 3°01') and a minimum voltage of 2 23 volts rms (representing a lag of 2°06') were noted The fluctuation was thus reduced to a value of 0°55' The oscillogram from which these measurements were made is shown in Fig 11C

Although a reduction in maximum servosystem lag from 7°32' to 3°01' was accompanied by a reduction in fluctuation from 2°05' to 0°55', it was believed that steps should be taken to minimize lag further It was determined that no additional improvement could be realized in the present equipment, since a further increase in servoamplifier gain produced oscillation, or hunting An oscillographic trace of error voltage during oscillation is shown in Fig 11D

One modification of the equipment to effect electrical damping consisted of inserting a twin-tee network tuned to the frequency of the servosystem, 60 cycles per

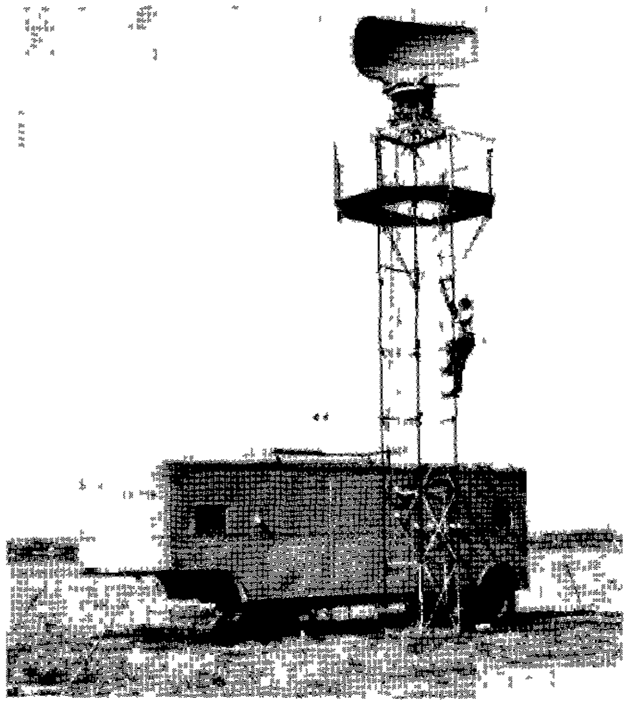


Fig 9 ASDE Antenna Mounted on CPN-18 Tower

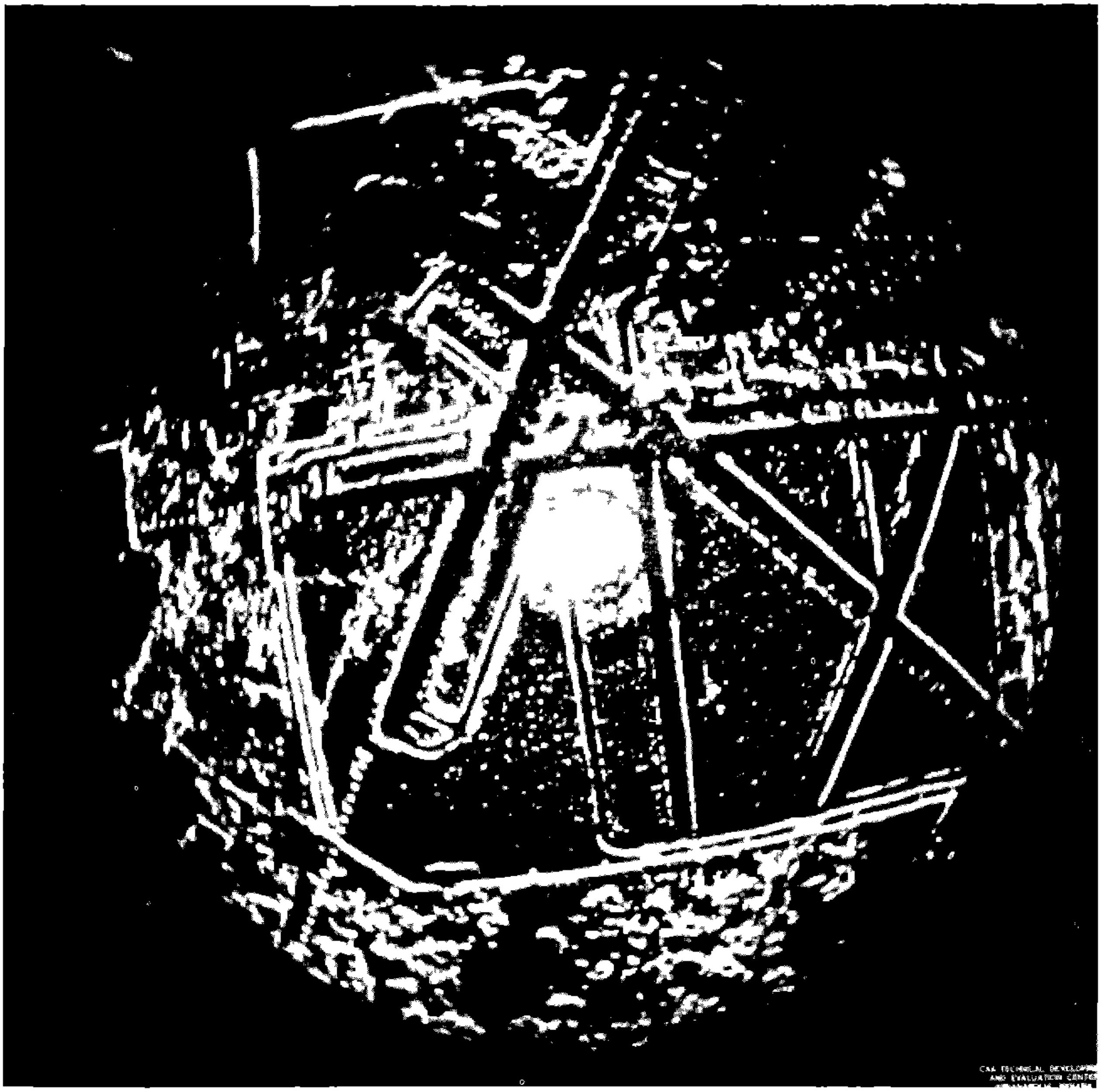
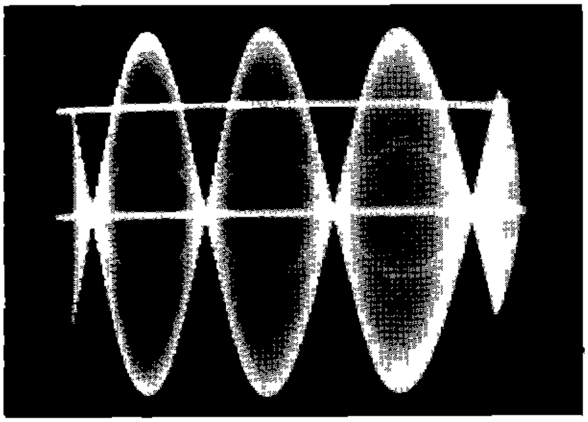


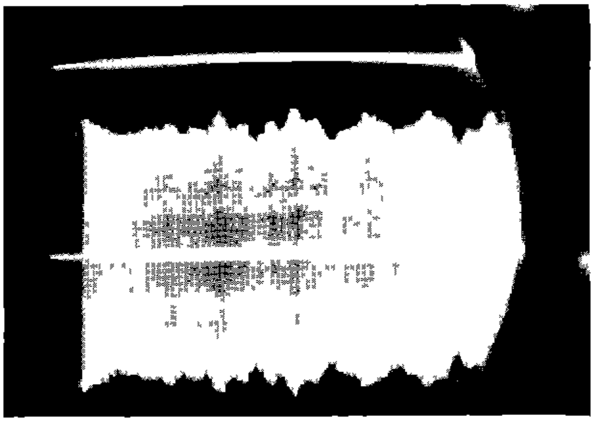
Fig 10 Radar Coverage of Wold-Chamberlin Airport, Minneapolis, Minnesota Antenna Mounted on CPN-18 Tower Near Center of Field (12-Inch Cathode-Ray Tube)

second, into the grid circuit of the first amplifier stage To compensate for the insertion loss, a two-stage preamplifier was connected ahead of the existing equipment The performance of the servosystem was somewhat improved in this manner, but the increased thyratron firing rate caused excessive current to flow in the PPI deflection yoke drive motors

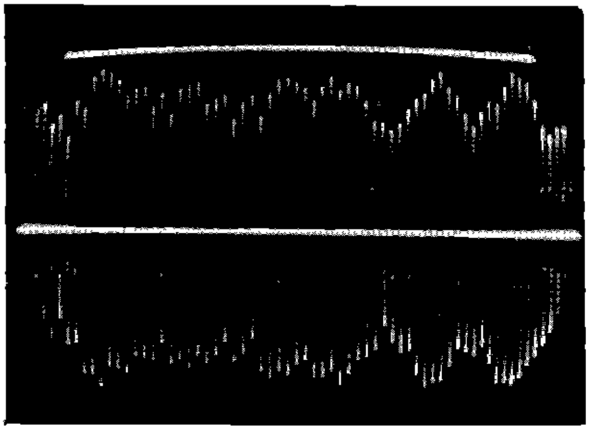
When the antenna rotational rate was increased from 30 to 60 rpm, a considerable increase in current flowing in the armatures of the deflection yoke drive motors was noted Under these conditions the current in the armatures was 1 4 amperes, a value in excess of the ratings of the windings, and remedial action was instituted A variable resistor of approximately 50 ohms at a rating of 50 watts and a 0- to 3-ampere meter were wired in series with the armature With the equipment in operation, the resistor was adjusted until minimum



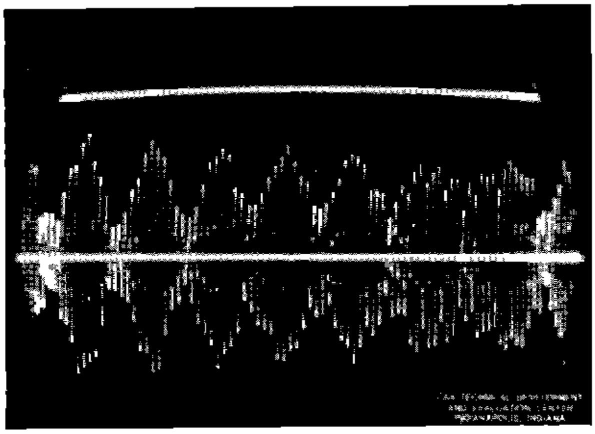
(A) Oscillogram of Maximum Error Voltage



(B) Oscillogram of Error Voltage With Conventional Servoamplifier Gain Adjustment



(C) Oscillogram of Error Voltage With Optimum Servoamplifier Gain Adjustment



(D) Oscillogram of Error Voltage When Servosystem Is in Oscillation

Fig 11 Oscillograms of Servo Error Voltage

current consistent with proper servosystem tracking was reached A current of approximately 0 5 ampere was found to be adequate for satisfactory operation At this level, the armatures of the deflection yoke drive motors run well within their ratings with no excessive heating

Even after the several modifications had been completed, erratic servo following (known as servo-jumping) was observed when sweep off-centering was employed This phenomenon was traced to poor regulation of the off-centering voltages

Block Occupancy System Tests

The block occupancy system is difficult to evaluate quantitatively Within certain limits of intensity of the PPI and with careful adjustment of photocell amplifier gain, the block system relays are actuated and indicator lights are turned on when a target appears immediately under a photocell However, adjustment of the system is quite elaborate Since the photocells view an area of 1/4 by 1/4 inch, an expanded range scale must be used to provide an area of specular return (e g , runways) of sufficient width so that the system is not triggered by grassy areas during the scan PPI intensity must be adjusted closely so that the block system is just ready to fire and will do so when a target appears in the area The photocells must be carefully positioned and the gain of the photocell amplifiers must be adjusted meticulously so that the same intensity of target illumination will trigger each photocell successively Malfunctioning occurred when the intensity of the target on the PPI was reduced or when servo-jumping introduced unwanted targets into the area covered

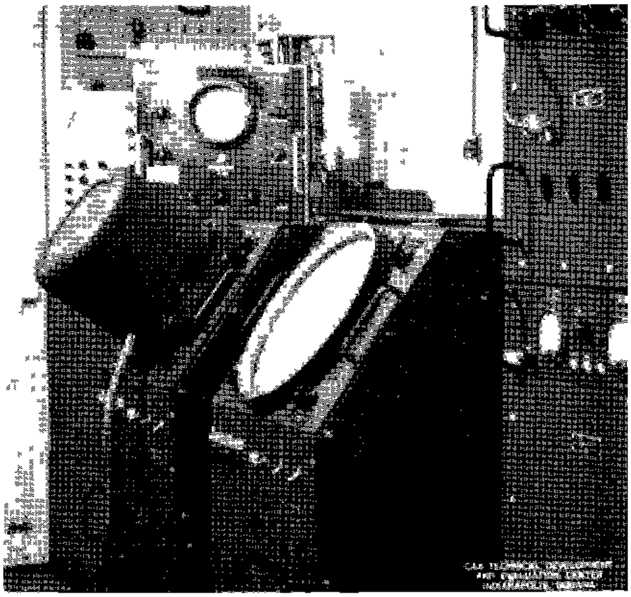


Fig 12 Block Occupancy Hood in Position on Indicator Cabinet

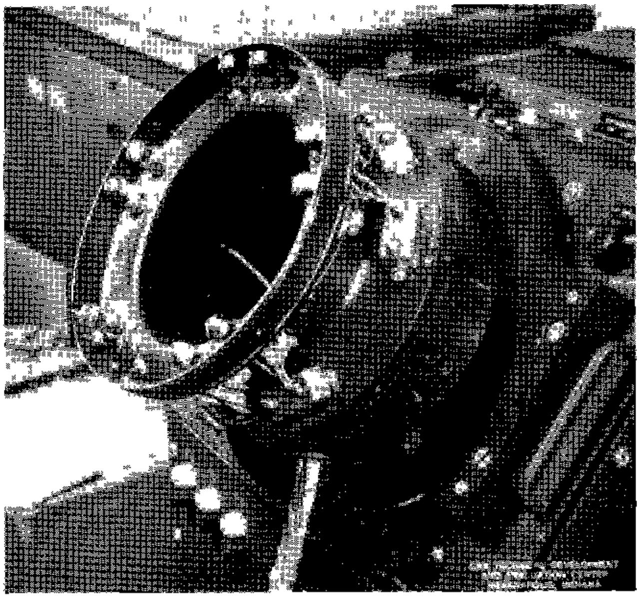


Fig 13 Block Occupancy Hood Assembly

by the photocells Sustained operation of the present system required excessive maintenance

Since failure of components or loss of power gives the same indication as an unoccupied block, the system does not provide fail-safe operation A view of the block occupancy hood in position on an indicator cabinet is shown in Fig 12, and a close-up view of the hood assembly is displayed in Fig 13

Precipitation Tests

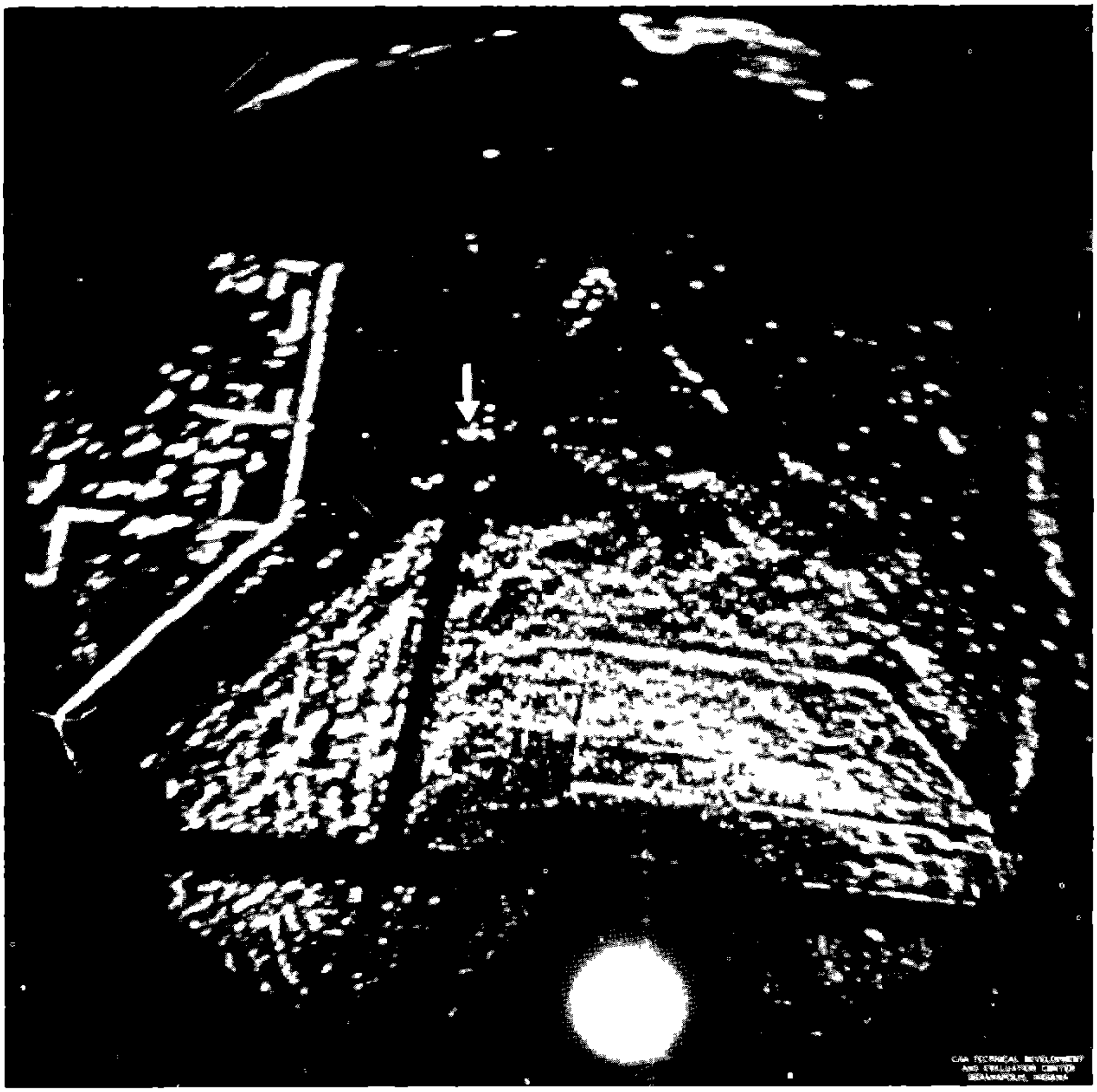
Photographs of the PPI taken during various intensities of rainfall are reproduced unretouched in Figs 14 to 16 inclusive Beginning with Fig 14, when the precipitation was 0 08 inch per hour and classified by the U S Weather Bureau as light rainfall, little effect on radar operation could be detected The Lockheed Constellation (indicated by the arrow in the photograph) can be seen plainly although visibility was less than one mile With moderate rainfall (0 25 inch per hour) rain clutter is apparent in the immediate vicinity of the radar unit, as shown in Fig 15 Visibility had decreased to little more than one-half mile, but the Douglas DC-3 can be seen quite clearly Fig 16 shows precipitation that had increased to 0 4 inch per hour, which is classified as heavy rainfall The Douglas DC-3, holding the same position as in Fig 15, is barely discernible Visibility was less than one-half mile at that time

Fog was encountered several times during the tests but the radar performance was not affected

Snowfall does not appreciably affect the operation of the equipment from the desired target viewpoint Fig 17 is an unretouched reproduction of a PPI photograph taken during moderate snowfall when visibility was approximately one-half mile A Boeing 247-D airplane is shown on the near runway Snowfall was very heavy when the photograph displayed as Fig 18 was taken, and visibility was under one-quarter of a mile The target on the runway in the upper right portion of the picture is a panel truck

Snow covering the ground presents an operational problem If it has not been removed from the runways, specular return is given by the entire field, then, only buildings, trees, fences, and similar targets can be seen on the radar screen If the snow has been scraped and piled along the runways, but not to heights sufficient to screen targets, operations can be conducted with normal precision A combination of these two conditions is shown in Fig 19 Runways 090 and 36 had not been cleared, while part of the snow had been moved from Runways 13 and 22

During the tests at Minneapolis, it was noted that the returns from wet and dry snow were different Whenever a wet snow was falling the picture deteriorated from the ground return viewpoint, although aircraft and truck targets continued to give good returns It was also noted that the snowbanks



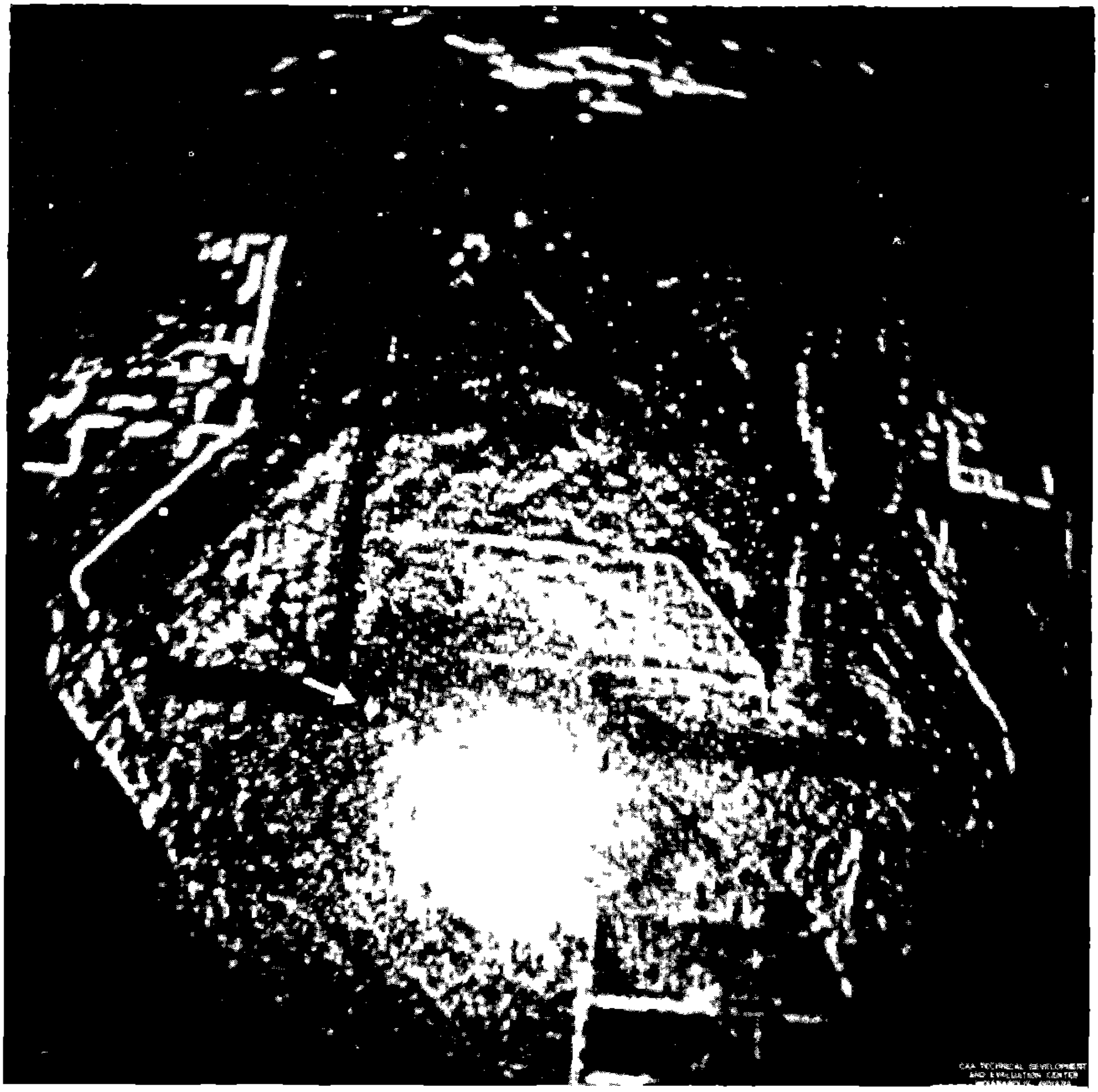
Legend
Light Rainfall 0 08 Inch Per Hour With Heavy Fog
Visibility Under One Mile
A Lockheed Constellation Is Shown by the Arrow

Fig 14 PPI Photograph Radar Area Tests (12-Inch Cathode-Ray Tube)

containing crumbly snow and in the shade produced more return than the wet, packed snow located in the sun This, perhaps, can be explained from the target size and type-of-return viewpoint However, no study was conducted on these observations

Radar Area Tests

The relative sizes of the various vehicles, as seen on the radar, are shown in Table X The irregularity of sweep focus precludes the possibility of quantitative measurements of area at the various ranges and permits only a comparison of the relative sizes of targets at the same distance Fig 20 shows the several targets as they appeared on the PPI in a forward view at a range of 1,000 feet

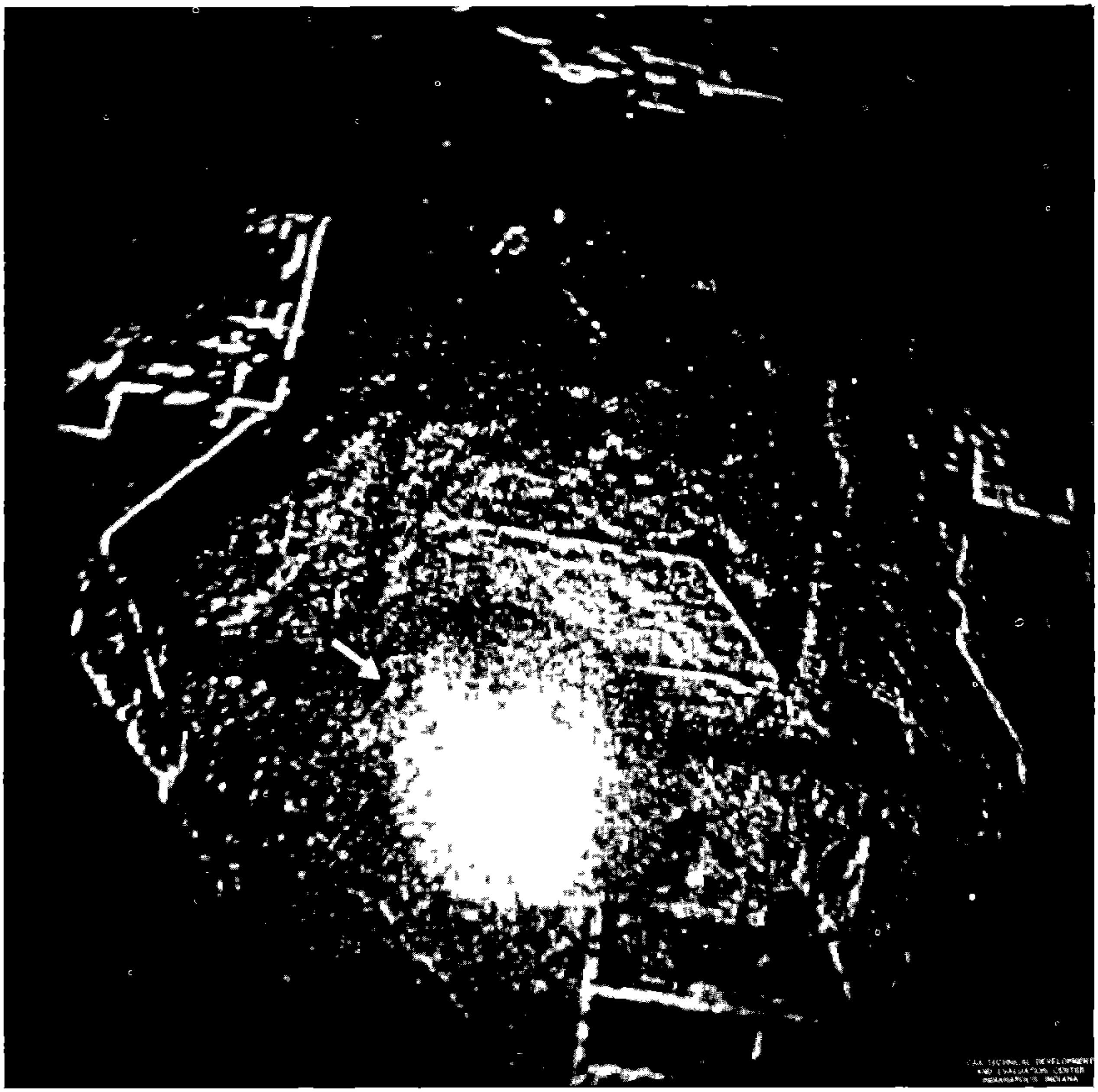


Legend
Moderate Rainfall 0 25 Inch Per Hour
Visibility Little More Than One-Half Mile
A Douglas DC-3 Is Shown by the Arrow

Fig 15 PPI Photograph Radar Area Tests (12-Inch Cathode-Ray Tube)

CONCLUSIONS

It is concluded that the equipment provides a satisfactory means for locating aircraft and other vehicles on an airport under weather conditions encountered during the tests, provided the reliability and stability are improved and the transmitted power output is increased The optimum frequency, pulse width, receiver bandwidth, and antenna rotational speed were not completely determined because the necessary flexibility was not provided in this model It appears that additional performance may be gained in



Legend
Heavy Rainfall 0 4 Inch Per Hour
Visibility Less Than One-Half Mile
A Douglas DC-3 Is Shown by the Arrow

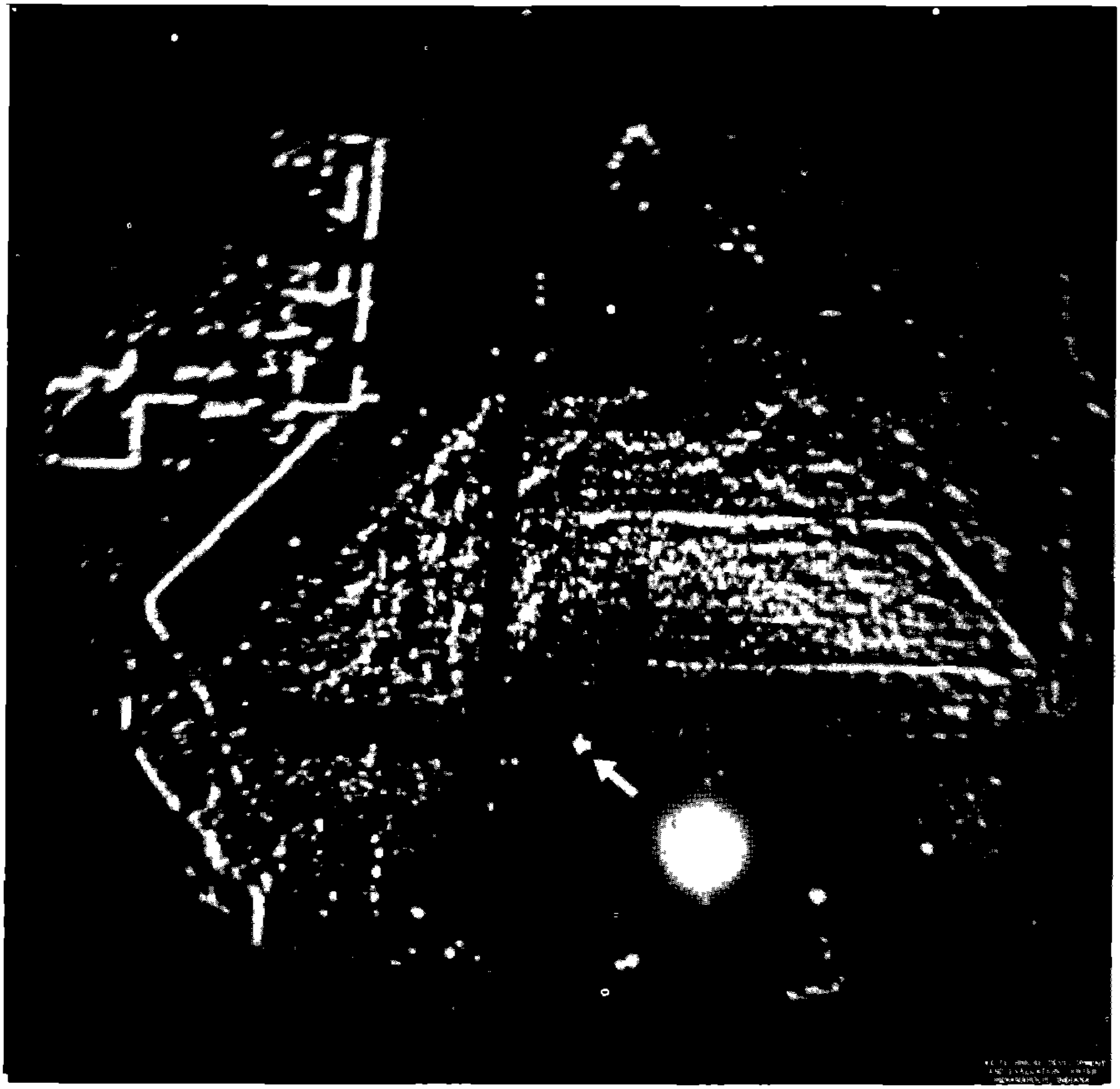
Fig 16 PPI Photograph Radar Area Tests (12-Inch Cathode-Ray Tube)

adjusting some of these equipment characteristics, however, this would require a new development model with the necessary flexibility

In regard to some of the equipment characteristics, the following conclusions can be drawn

1 Antenna design

a The design beam width of the antenna field pattern in the horizontal plane of 0 4° between half-power points was attained



Legend
Moderate Snowfall
Visibility One-Half Mile
A Boeing 247-D Is Shown by Arrow

Fig 17 PPI Photograph Radar Area Tests (12-Inch Cathode-Ray Tube)

b Areas of low radar return indicate that a cosecant-squared distribution of energy in the vertical plane pattern of the antenna was not obtained

c An increase in the height of the antenna results in a considerable improvement in the uniformity of coverage of the area under surveillance

d An increase in antenna rotational speed from 30 to 60 rpm did not result in deterioration of radar presentation Since it was possible to operate the antenna system at only two rotational rates, sufficient flexibility was not provided to ascertain the

TABLE X

RADAR RETURNS FROM SPECIFIC TARGETS

Type of Vehicle	Attitude* of Vehicle	Relative Area of Targets in Arbitrary Units at Several Distances			
		500 feet	1000 feet	2500 feet	4000 feet
Douglas C-54	Forward (F)	470	532	352	405
	Rear (R)	658	683	236	622
	Broadside (B)	554	692	410	642
Douglas DC-3	F	283	371	332	299
	R	394	437	358	382
	B	295	392	303	351
Beechcraft C-45	F	251	227	159	---
	R	246	225	196	102
	B	241	209	188	107
Cessna 140	F	178	238	176	211
	R	197	217	164	220
	B	167	185	188	198
Piper Clipper	F	171	169	149	169
	R	165	167	144	128
	B	163	155	141	142
Jeep Fire Truck	F	87	144	104	---
	R	79	176	125	114
	B	90	152	103	142

*Attitude of vehicle with respect to radar unit

minimum speed necessary for traffic control purposes However, the highest speed available was preferred by traffic controllers because of the more frequent position information provided

2 With the present antenna design, an increase in transmitter power is required in order to obtain more detailed presentation of areas beyond a range of 3,000 feet

3 Display

a A cathode-ray tube employing a metalized backing on the fluorescent material gave improved results with regard to brightness and persistence

b Definition was impaired by inability to obtain uniform focus over the entire face of the PPI tube

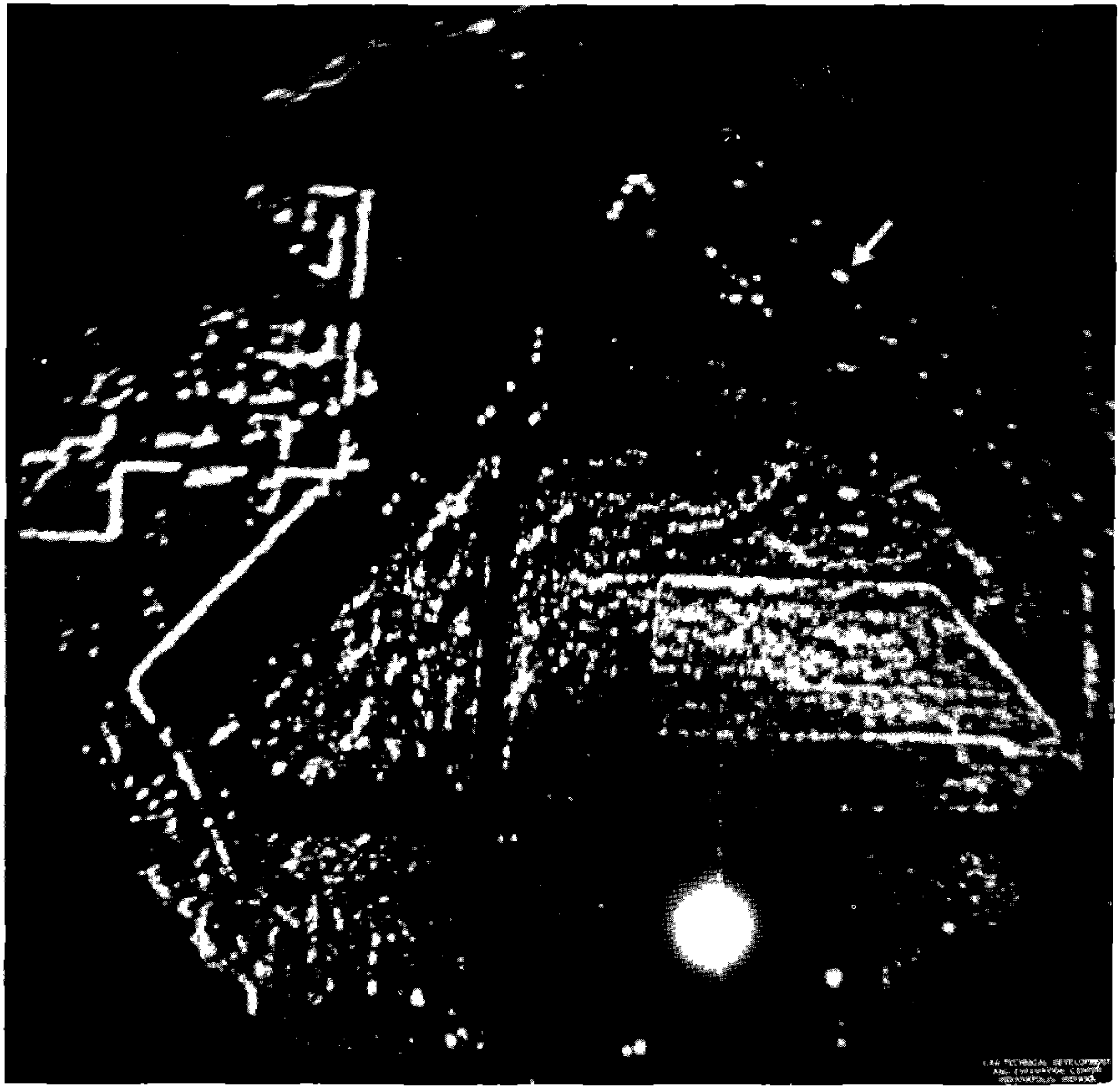
c Nonlinearity of sweep circuits resulted in distortion of the presentation

d The original servosystem did not permit satisfactory operation of the indicator at antenna rotational speeds of 60 rpm

4 The block occupancy system in its present form provides a remote indication of targets within discrete areas on the PPI display The system is not fail-safe, adjustment is difficult, and an inordinate amount of equipment would be required to cover large areas Because of the lack of sufficient stability of the present display, a complete evaluation of the block occupancy system was not possible During these tests, there was considerable doubt on the part of the observers and operating personnel concerning the necessity for a display system of this type

5 Snow, fog, and light-to-moderate rainfall do not seriously impair the performance of the equipment Extremely heavy rainfall tends to obscure targets on the indicator, but this effect can be minimized to some extent, depending upon the skill and experience of the operator

6 The resolution appears to be satisfactory for all present expected operating conditions However, with regard to the separation of objects in close relationship, such as aircraft parked on ramps and located



Legend
Heavy Snowfall
Visibility Less Than One-Quarter Mile
Panel Truck Is Shown by Arrow

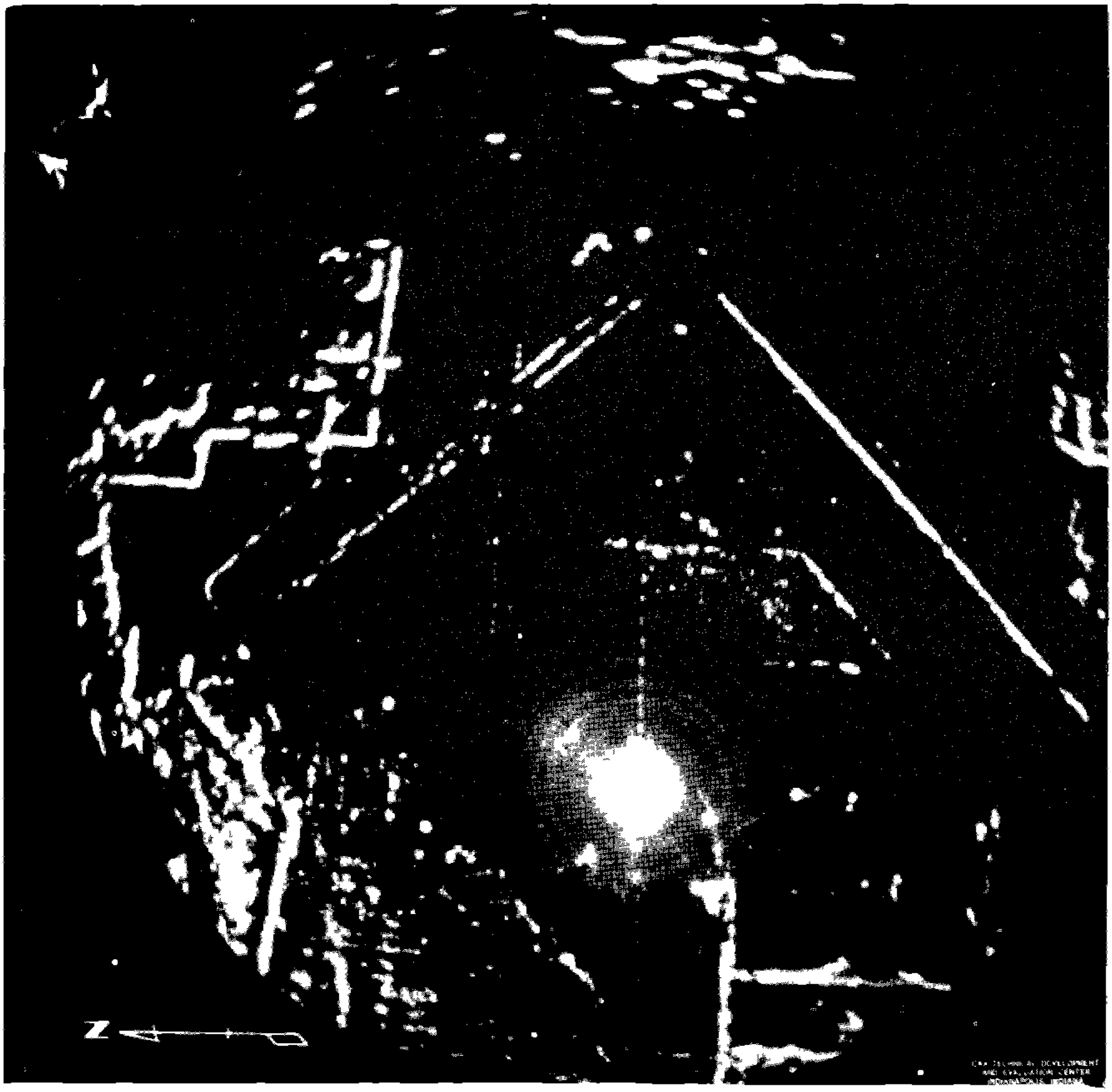
Fig 18 PPI Photograph Radar Area Tests (12-Inch Cathode-Ray Tube)

near buildings, the equipment lacks the required resolution characteristics

7 The reliability of the present model requires considerable improvement before continuous operation can be recommended

RECOMMENDATIONS

Should the construction of a second model of the ASDE be contemplated, it is recommended that the following features be



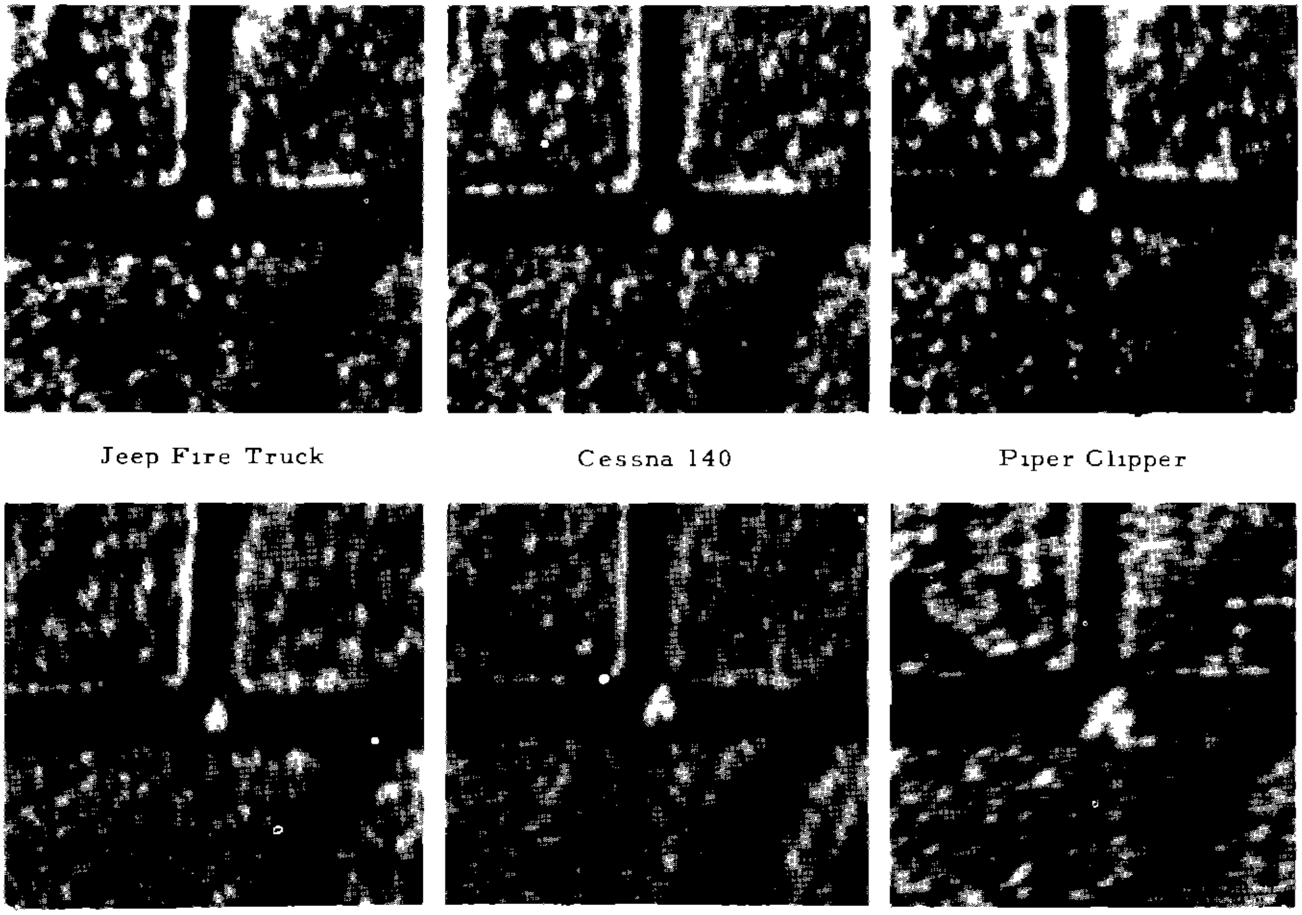
Legend
Three-Inch Snow on Ground
Runways 22 and 13 Partially Cleared

Fig 19 PPI Photograph Radar Area Tests (12-Inch Cathode-Ray Tube)

included in order that a more exhaustive testing program may be conducted

1 Antenna
  a An easily varied rotational rate
  b Tilt adjustable from the operating position
  c Pressurized waveguide to eliminate condensation and icing
  d An improved design to obtain more uniform coverage
  e An investigation of circular polarization with a view to minimizing the effects of heavy rainfall

2 Transmitter
  a Additional power to improve coverage
  b Automatic frequency control



Jeep Fire Truck — Cessna 140 — Piper Clipper

Beechcraft C-45 — Douglas DC-3 — Douglas C-54

Fig 20 PPI Photographs Radar Area Tests (Approximately Actual Size)

c A more flexible method of varying pulse width

d Test point metering

3 Receiver

a A method of changing intermediate frequency bandwidth to accommodate various pulse widths

4 Indicators

a A cathode-ray tube with a flat face and a minimum diameter of 16 inches

b A cathode-ray tube with metalized backing on the fluorescent coating to provide a brighter display

5 Power Supplies

a Improved regulation

6 Test Equipment

a A more reliable spectrum analyzer

b Power measuring equipment

c Improved photographic equipment

APPENDIX I

MAINTENANCE LOG

Date	Running Time (hours)	Symptoms	Cause	Remedial Action
5-25-51	7	No video on PPI No 1	Failure of 6Y6 in video power supply burned out two 600-ohm, 5-watt plate current limiting resistors (R-1607, R-1608)	Replaced tube resistors
6-1-51	19	No sweep on PPI No 2	Fault in plug (P-1902) connecting trigger generator to synchronizer	Plug repaired
6-4-51	34	Sweep on PPI No 2 failed	Failure of 6AC7 (V-1907) in sweep circuit	Tube replaced
6-15-51	52	Dvorecord camera did not advance film after exposure	Nonregulated sweep off-centering voltage used to operate camera dropped to a potential of 19 5 volts which is insufficient to actuate the solenoid	A 24-volt "Nobatron" power supply with good regulation installed to operate the camera
8-7-51	87	On PPI No 1 the sweep did not follow antenna rotation	Failure of servoamplifier due to open primary in thyratron grid transformer (T-2504)	Transformer replaced, but servosystem remained inoperative
8-8-51	87	Fuse blown on servoamplifier for PPI No 1, no sweep rotation (continuation of difficulty previously noted)	Shorted armature winding on deflection yoke drive motor	Armature rewound
8-10-51	90	High voltage for transmitter could not be brought up to proper level	Breakdown of Micarta terminal board on high voltage power supply chassis	Replacement terminal board constructed of Lucite
8-23-51	90	Fuse blown on servoamplifier for PPI No 2, no sweep rotation	Shorted armature winding on deflection yoke drive motor	Armature rewound
9-5-51	92	Fuse blown on servoamplifier for PPI No 2, no sweep rotation	Shorted armature winding on deflection yoke drive motor	Armature rewound and attempt made to cool motors with forced air
9-12-51	95	Video signal and receiver tuning indication intermittent	Failure of + 300 volts from receiver power supply because of poor connection in plug (P-702)	Plug repaired

MAINTENANCE LOG (continued)

Date	Running Time (hours)	Symptoms	Cause	Remedial Action
9-18-51	98	Receiver mixer crystal current varied with antenna rotation	Faulty connection between waveguide and base of rotating joint after placing antenna on CPN-18 tower	A section of flexible waveguide inserted at this point stabilized crystal current
9-24-51	100	No rf return, receiver crystal current zero	Failure of -1,000-volt dc "keep-alive" voltage to "transmit-received" (TR)	Transformer (T-705) and selenium rectifier (CR-701) replaced
10-1-51	100	Spectrum analyzer inoperative	Western Electric 169618 klystron local oscillator failed	Unable to secure replacement tube which would oscillate at the proper frequency
10-2-51	101	No target return	Condensation of moisture in waveguide	Section cleared and all waveguide joints treated with moisture-proofing compound
10-3-51	105	Misfiring of modulator as indicated by visual inspection of pulsing thyratron	Trigger generator intermittent at higher pulse repetition rates	12AT7(V-3) in trigger generator replaced
10-4-51	110	No sweep on PPI No 2	Two 68,000-ohm cathode resistors (R-1910, R-1911), or 12AU7 (V-1903) in the synchronizer chassis burned out	Resistors replaced
10-4-51	110	No video on PPI No 1	Two 600-ohm, 5-watt plate current limiting resistors (R-1607, R-1608) burned out	600-ohm resistors of 10-watts rating used in replacement
10-8-51	120	Fuse blown on servoamplifier for PPI No 2, no sweep rotation	Burned out armature winding on deflection yoke drive motor	Armature rewound and a 50-ohm, 50-watt resistor added in series to reduce armature current
10-25-51	130	Intensity control on PPI No 1 intermittent	Leads to 4,700-ohm resistor (R-623) in cathode circuit of cathode-ray tube broken	Leads to resistor replaced
11-5-51	140	8-ampere fuse (F-901) in transmitter control unit blown	Cannon plug (J1001) on power cable shorted	Replacement plug could not be located so cable was wired direct

MAINTENANCE LOG (continued)

Date	Running Time (hours)	Symptoms	Cause	Remedial Action
11-15-51	148	8-ampere fuse (F-901) in transmitter control unit blown	Arcing (arc-over) in wiring of low voltage power supply, insulation inadequate	The low voltage power supply rewired
12-6-51	164	Intermittent spoking observed on PPI displays	Arc-over at high voltage sliding contacts in transmitter chassis	High voltage contacts cleaned and adjusted
12-6-51	169	No video or receiver tuning indication.	Plug on interconnecting cable at receiver power supply faulty	Plug repaired
12-17-51	180	No targets visible on either PPI	Moisture accumulated behind antenna horn cover	Horn cleaned and cover replaced

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